SIS NL'S 89

missing

Aug Analog: "Its the Real world"

ASIC

Feb ~~ASIC Surpases $ 7.4 Billion in 1998~~

GAAS

Mar ~~ISCC Features Advanced in~~
GAAS IC

Dec GAAS IC Growth tempered By Industry slowdown and consolidations

DSP

may the invisible DSP IC market: Gate array cell-based custom, and silicon compiler designs.

PMT

Feb preliminary Result on 1988 Analog market share

1C Feb ~~ASIC Surpass $ 7.4 Billion in 1988~~

May Our time our choice our Anguish our decision

May PMT EXEC Memo: Do ASIC Manufacturers need their own Sematech

Aug The PLD Evolution

~~Component Group~~

~~Missing 8 14 newsletters~~

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OK "Worldwide SIC Outlook:

~~1st~~ Qtr 89

Corporate Research

May DQ's Electronic Industry Forecast

Dataquest
a company of
The Dun & Bradstreet Corporation

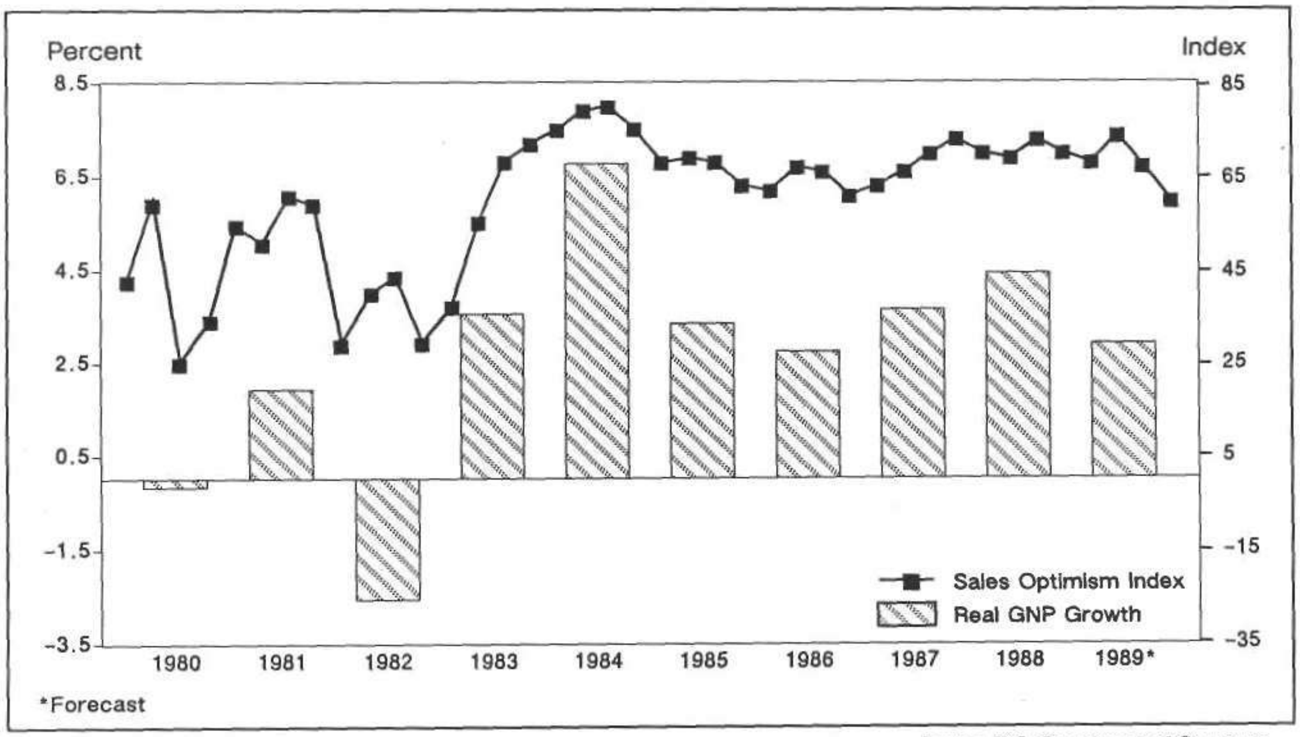
Research Newsletter

ECONOMIC OUTLOOK: . . . AFTER THE SOFT LANDING

SUMMARY

Economic indicators are sending mixed signals about the possibility of a recession in the short-term future. The Dun & Bradstreet Corporation's survey results indicate that the current economic lethargy probably will continue during the coming months, although a contraction is not likely in the near term. Compared with prerecession periods earlier this decade, business executives' expectations about future business conditions remain relatively positive. Furthermore, inflation and inventory overhang, two important precursors of recession, are relatively stable and minimal. Real gross national product (GNP) growth in 1989 is shaping up to be between 2.0 and 2.5 percent and is expected to remain in this range in the early months of the new year (see Figure 1).

FIGURE 1
Business Expectations and the Economy



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Source: U.S. Department of Commerce
The Dun & Bradstreet Corporation

0005767

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Although the growth of the economy has slowed significantly since the first quarter of 1988, a descent into a recession has been avoided thus far. This slowing without reason characterizes the soft-landing scenario of economic growth that we have read and heard about so much recently. It is difficult to infer from recent macroeconomic data whether the slowdown will develop into a recession or reverse itself in the near future. Using survey techniques to ask decision makers directly about conditions in their businesses helps to resolve this uncertainty. Although many government economic indicators show a muddled picture of the economy, survey data gathered by Dataquest's parent company, Dun & Bradstreet (D&B), clearly indicate that the soft-landing situation probably will be sustained through the next several months.

RECENT ECONOMIC DATA ARE AMBIGUOUS

One of the important, albeit murky, macroeconomic gauges that measure industrial activity is the value of new orders for manufactured goods. This indicator is useful because it is highly predictive of investment expenditures, the most volatile component of GNP. Through May 1989, new orders had been averaging 8 to 10 percent ahead of levels for the same period in 1988. In June, new orders were only 3.1 percent ahead of 1988 levels, but orders rebounded in August to 4.5 percent ahead of year-ago levels. This upturn would be considered a good omen, except that new orders for nondefense capital goods, considered an especially vital component of total new orders, fell 15.3 percent in August and September and rose only 1.2 percent in October, which is the latest reported month.

Similarly, future consumer spending growth has been difficult to discern from recent personal consumption expenditure data. As with new orders, recent growth rates have rebounded from a summer slowdown. But a substantial part of this rebound resulted from increased sales of automobiles as a result of vigorous price-incentive programs from car manufacturers—certainly not a sign of sustainable growth.

Meanwhile, employment growth has slowed substantially. The economy generated an average of 250,000 new jobs each month during the first half of this year. Since July, average monthly job growth has dropped below 150,000. Furthermore, the unemployment rate edged up by one-tenth of a percentage point in November to 5.4 percent, the highest level since January, and factory jobs fell for the eighth straight month. On the positive side, inflation and interest rates have been edging downward in recent months, transitory fluctuations notwithstanding. In short, it is ambiguous whether the economy is entering a period of accelerating or decelerating growth.

More conclusive evidence can be found in recent Dun & Bradstreet Business Expectation Survey results. These results indicate that although a period of economic weakness is anticipated, it is not pronounced enough to indicate that a recession is imminent.

BUSINESS EXPECTATION SURVEY RESULTS

The Dun & Bradstreet Business Expectation Survey is a random survey of 1,500 executives in the manufacturing, wholesaling, and retailing sectors. (The survey sample will be expanded to 3,000 executives beginning with first quarter 1990 data and will add additional service-sector coverage.) These executives are asked if they expect sales, profits, selling prices, and employment and inventory levels to increase, decrease, or remain the same in the upcoming quarter. From these results, a sales optimism index is compiled.

D&B's optimism index is a valuable leading indicator of economic activity, because it quantifies business executives' expectations of future business conditions. This survey's strength is that it is composed mostly of small and medium-size businesses, which account for more than 97 percent of all businesses. If business executives are feeling relatively uncertain about future business conditions, most investment plans probably will be curtailed. For purposes of forecasting future economic activity, the root causes of this uncertainty matter comparatively little—only the resulting behavioral changes are relevant.

The optimism index for expected sales reached 60 points for the fourth quarter of 1989—down from 74 points for the second quarter. The current index level is noteworthy for two reasons. First, despite the slow decrease, the overall level of optimism remains high. Second, the magnitude of the decline is significantly smaller than the declines typically associated with a recession. These observations are illustrated in Figure 1. So, the recent 14-point decline indicates that economic growth probably will remain positive, although sluggish. The economy is not likely to crash-land into a full-blown recession.

Comparing these results with the two previous recession years of 1980 and 1982 gives credence to this analysis. In 1980, the sales optimism index fell from 61 to 26 between the second and third quarters, acutely portending the contraction that followed. Similarly, the index fell from 59 to 30 between the fourth quarter of 1981 and the first quarter of 1982, again providing some early warning of the coming recession.

THAT WAS THEN; THIS IS NOW

Two precursors of recessions are unexpected changes in inflation (and resulting unexpected changes in interest rates) and excess inventories that trigger sharp production cutbacks. The D&B Business Expectation Survey optimism index for selling-price increases has declined in each of the last two quarters, falling from 46 points in the second quarter to 34 points in the fourth. This decrease corroborates recent economic statistics that show inflation rates abating (or at least not accelerating). Furthermore, current expectations for selling-price increases pale by comparison with levels in the 70- to 80-point range seen between 1980 and 1982.

Current inventory accumulation survey results reveal a similar picture. The inventory expectations index dropped 10 points over the past two quarters. Diminished inventory accumulation likely will slow economic growth in the near term, but it also probably will diminish the chances of a contraction-inducing inventory overhang.

THE OUTLOOK: SLOW GROWTH TO CONTINUE

Real GNP growth averaged more than 3 percent in the first half of this year, with the second quarter markedly slower than the first. Dataquest believes that this weakness will continue through the remainder of 1989, with the economy expanding at a 2.0 to 2.5 percent annual rate. We believe that declining inventory accumulations in the fourth quarter will be a major factor in this continued weakness in growth. In addition, a slowdown of income growth also will hamper consumer spending through the Christmas season.

Terrance A. Birkholz

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Research Newsletter

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1989
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We will provide electronics industry forecasts twice a year. In the second quarter, we will present updated information for the previous year. Also, we will include forecast data for the current year and five years in the future. The fourth quarter newsletter will update these forecasts.

SUMMARY

Overall electronic equipment sales softened in 1989 and will continue to slow for the remainder of the year. In light of this, we expect the semiconductor industry to experience a minirecession from the third quarter of 1989 through the first quarter of 1990. The electronics equipment manufacturers, in the current lull, are competing aggressively with heavy discounts of their products and strong emphasis on customer service and support. Some of the bright spots in the industry are in the workstation, facsimile machine, voice-messaging, ink jet and page printers, and optical disk markets.

WORLDWIDE ECONOMIC OUTLOOK

The Dun & Bradstreet Corporation, Dataquest's parent company, reports that the U.S. economy grew faster between 1986 and 1988 than originally determined but has slowed rapidly in 1989. Although no recession is expected, the economy for 1989 through 1990 is projected to be softer than in 1988. Real gross national product (GNP) growth is projected to be 3.0 percent and 2.7 percent, respectively, for 1989 and 1990, versus 4.4 percent in 1988. Capital spending remained strong throughout the first half of 1989. Lower interest rates should keep this sector healthy. However, a flat dollar will make exploiting new export markets more difficult in 1990. Government purchases are soft and falling because of cutbacks in defense spending. This trend accelerated this year. It will most likely continue in 1990, given the probable austerity of the fiscal 1990 budget.

Dataquest Incorporated, 1290 Ridder Park Drive, San Jose, CA 95131-2398 / (408) 437-8000 / Telex 171973 / Fax (408) 437-0292

In Japan, economic growth picked up strongly in the first quarter of 1989, after slowing during the fourth quarter of 1988. The GNP growth for 1989 is estimated to be slightly less than 5 percent, because investment and consumer spending may grow more slowly this year. In the period 1985 to 1988, the yen rose dramatically. At the beginning of 1989, the yen declined against the strong dollar. The Japanese inflation rate is still relatively low but edged up this year. The increase is partly because of the new sales tax, and partly because wholesale prices have risen as the weaker yen and firmer oil prices pushed up import prices.

Meanwhile, the countries of the European Community continue working to eliminate all internal trade barriers by 1992. The major European economies are forecast to have gross domestic product (GDP) growth on par with or slightly above the United States in 1989 and 1990. In France, GDP growth picked up in the first quarter of 1989, having slowed in the fourth quarter of 1988. Investment and exports again will provide the main boost to growth this year. West Germany has inflation fears, prompted by the fall of the deutsche mark, increasing consumer prices, higher oil prices, and large wage increases. The United Kingdom is plagued by extremely high interest rates, approximately 14 percent, and inflation is also still high at 8 percent.

The Asia/Pacific countries are expected to have continuing high GNP growth rates, ranging from 6.2 percent to 9.7 percent through 1990. Problems facing this market in the short term are wage hikes, domestic unrest, currency appreciation, and international trade tensions.

SEMICONDUCTORS

We have lowered slightly our forecast for worldwide semiconductor industry growth in 1989, from 12.3 percent to 11 percent. We are seeing increases in semiconductor inventories at both the vendor and user levels, sharp decreases in 1Mb DRAM prices, and a definite slowing of semiconductor order rates. The situation will begin to improve in the second quarter of 1990. By the fourth quarter of 1990, shipments will be moderately strong. In 1990, we will see a growth of 1.5 percent worldwide.

In the long term, we believe that the industry will experience moderate growth in 1991 and strong growth in 1992 and 1993. The peak year of the growth cycle will occur in 1993 (see Table 1). This forecast is based on the peaking of volume shipments of 4Mb DRAMS, the availability of 8-inch wafers for volume production, historical cyclical trends, and the 1992 effect.

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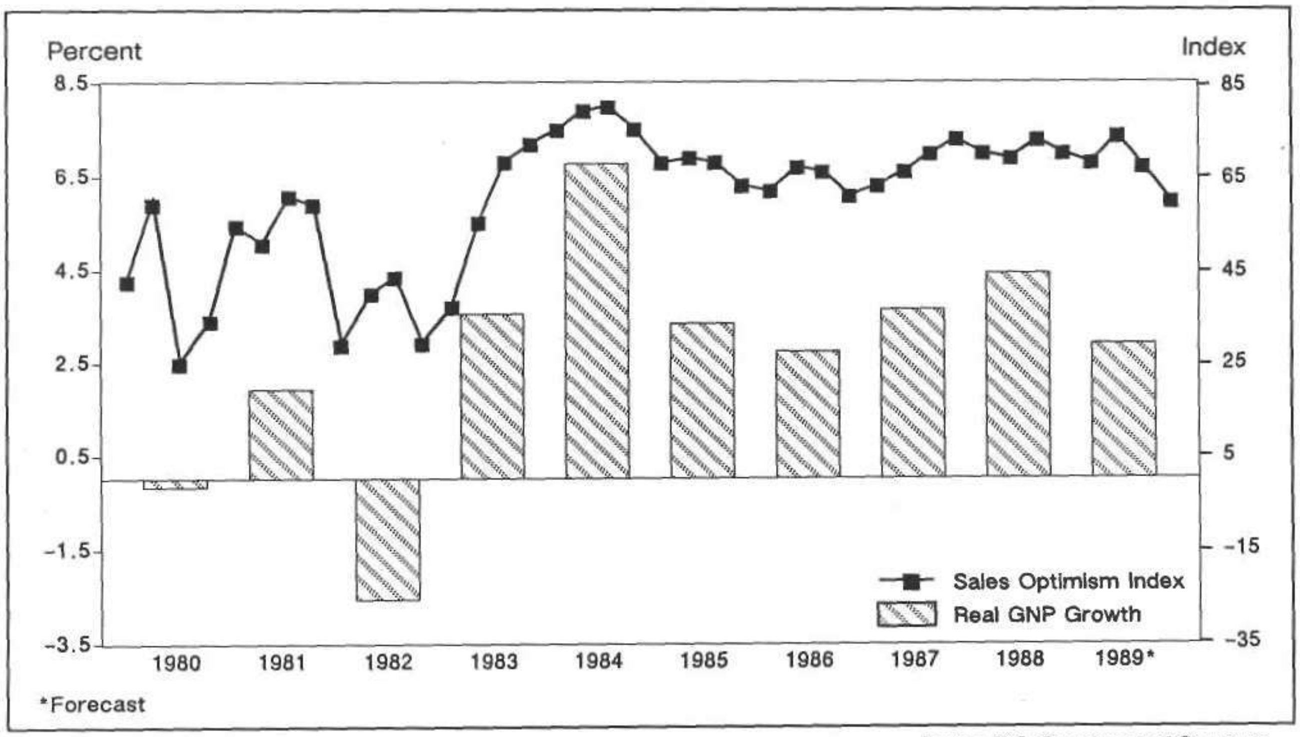

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Total	$56.4	$57.2	$104.3	16.6%

Source: Dataquest
November 1989

Asia/Pacific, with its fast growing economy and aggressive capital spending, will continue to be the fastest growing region through 1994. Europe will be the second fastest growing region. Europe is already reaping the benefits from the 1992 effect, as both electronic equipment and semiconductor manufacturers move their manufacturing plants to Europe. We believe that some of the semiconductor shipments that previously would have been consumed in North America or Japan will be consumed in Europe in the future.

COMPUTER INDUSTRY

Business Computers

The 1989 business computer markets have performed as Dataquest forecast earlier this year. A soft market increased competition, which led to lower hardware prices. See Table 2 for a five-year forecast of the business computer market.

Table 2

Business Computers
Estimated Worldwide Revenue
(Billions of Dollars)

	1989	1990	1993	CAGR 1989-1993
Corporate Resource	$29.6	$30.6	$36.1	5.1%
Business Unit	10.3	12.3	17.0	13.3%
Large Department	9.5	10.1	12.5	7.1%
Small Department	7.4	7.6	8.6	3.8%
Work Group	9.0	9.6	11.5	6.3%
Total	$65.8	$70.2	$85.7	6.8%

Source: Dataquest
November 1989

IBM renewed extremely aggressive discounting on large-scale processors, at least in accounts where it is vying against Amdahl. Additionally, IBM's aggressive AS/400 pricing and its encouragement of leasing continues to drive down the average selling price of business unit systems at an unusually steep rate. In the midrange systems environment, both Digital Equipment Corporation and Wang Laboratories have been involved in heavy discounting. Interestingly, while the major vendors have been pricing their systems aggressively, other vendors have been offering competitive financing and service.

Many traditional large department systems vendors have had problems. Some have shown poor financial performance and loss of market share. These vendors include such major participants as Data General Corporation, Digital, Prime Computer, Unisys, and Wang.

On a lighter note, sales of on-line transaction processing (OLTP) applications remain strong. These applications account for 48 percent of the worldwide business systems revenue. Sales are predicted to capture 60 percent of the market by 1993.

Technical Computers

The 1989 forecast for technical computers has been revised slightly for certain products. Table 3 shows the Dataquest forecast for five years for the technical computer market, which includes the workstation market discussed below. We do not expect Cray to sell as many supercomputers as predicted. The marketing of the Y-MP series before its availability led to cancellation of X-MP orders. Consequently, there was a period of time when Cray did not deliver either Y-MP or X-MP systems.

Table 3

Technical Computers
Estimated Worldwide Revenue
(Billions of Dollars)

	1989	1990	1993	CAGR 1989-1993
Corporate Resource	$ 6.6	$ 7.5	$ 9.9	10.7%
Business Unit	4.0	4.6	6.7	13.8%
Large Department	2.1	2.0	1.9	(2.5%)
Small Department	2.0	2.0	2.2	2.4%
Work Group	0.9	1.0	1.0	2.7%
Single-User Enhanced	6.8	9.3	18.7	28.8%
Total	$22.4	$26.4	$40.4	15.9%

Source: Dataquest
November 1989

IBM sold more vector facilities than expected. We believe that IBM's interest in this market is due to its potential; these machines account for 20 percent of the technical computers. IBM also needs to protect its high-end installations against replacement by Cray and Convex systems.

In May 1989, Cray Research Inc. split into two companies—Cray Research Inc. and Cray Computer Corporation. The latter is headed by Seymour Cray, the founder of the original company. This move will provide outside research and development funding for the new company. It also introduces another manufacturer of U.S. supercomputers.

Vendors of the traditional models—mainframes, superminicomputers, and minicomputers—are still under a great deal of stress. Mainframes at the very high end are losing market share to supercomputers or networked workstations. The low-end minicomputer market (16-bit) is declining, as its functionality is replaced by personal computers. Only old follow-on contracts for these products are being sold. On the other hand, use of traditional computers is increasing in the networked environment. Minicomputers and superminicomputers are being used in file server configurations. Mainframes act as database servers and network routers.

Workstations

Performance continues to increase at the high end of the workstation market, while price wars are being fought at the low end. Workstations implementing reduced-instruction-set computing (RISC) technology are forecast to overtake complex-instruction-set computing (CISC) by 1993. The systems using RISC will represent 61 percent of the total workstation revenue in 1993.

Most major workstation vendors announced a lower-priced system this year. As a result, competition is fierce in the entry-level workstation segment. In September 1989, Apollo Computer announced a low-end 68030 workstation, with prices beginning at approximately $4,000. This is the lowest-priced 68030 workstation available today, and it is also the first product announced by Apollo since its merger with Hewlett-Packard.

Digital Equipment is notifying the industry that it is committed to UNIX and RISC by announcing a family of RISC workstations. Digital is now the leader in performance/price ratio for RISC workstations, except for Data General.

In August 1989, Stardent was born with the merger of Ardent and Stellar. Stardent plans to have a unified product line with a single instruction set by early 1991.

Sun Microsystems, Inc., announced a $20 million loss for its fourth quarter of fiscal 1989, which ended in June. This is Sun's first stumble. Sun also revamped its product line. More emphasis is placed on Sun's SPARC products, while the 68xxx product family is positioned less aggressively. The SPARC family represents approximately 28 percent of 1989 fiscal year sales.

Personal Computers and Personal Computer Software

Dataquest estimates that worldwide PC shipment growth will continue at 9 to 10 percent for 1989 to 1990 (see Table 4). European growth will exceed that of the United States. So far this year, many vendors are showing increased sales over the same quarter last year.

Table 4

Personal Computers
Estimated Worldwide Revenue
(Billions of Dollars)

	1989	1990	1993	CAGR 1989-1993
Less than $10,000	$64.4	$75.6	$110.5	14.5%

Source: Dataquest
November 1989

The battery-powered true portable PC market continues to be the fastest growing segment of the market, fueled by recent introductions of lightweight, powerful notebook-size portables from Compaq, Grid, and Zenith Data Systems. Introduction of a laptop computer by Apple Computer, Inc., coupled with MS-DOS-based hand-held PC announcements from Atari, Inc., and Poqet also have excited this growth.

The MCA and EISA debate will continue, now with many more products available. We expect at least 11 vendors to introduce EISA machines and more than 16 vendors to show MCA clones at the fall Comdex show this year. Intel's 486-based machines will be news during the last quarter, with at least 10 vendors introducing 486 based systems. We expect all of these initial systems to be either EISA or MCA.

Most PC vendors enjoyed record sales in 1988; however, gross margins dropped because of extreme price cutting in the 80286 market. In 1989, many vendors are showing increased sales over the same quarter in 1988; however, profits are lower. We expect this margin issue to continue, as the channel continues to tighten. To successfully compete during 1990, vendors must find ways to differentiate their products from the competition. New technology has been the traditional vehicle for product differentiation. Although we will continue to see technological advances, success in the 1990s will be dictated by a vendor's ability to differentiate via effective marketing and service programs.

In PC software, growth rates are diminishing in the more mature market segments--such as spreadsheets, database, and word processing. Supplemental software--such as analyzers and utilities—is showing high growth. The Dataquest five-year forecast for PC software is shown in Table 5.

Table 5

Personal Computer Software
Estimated Worldwide Revenue
(Billions of Dollars)

	1989	1990	1993	CAGR 1989-1993
Productivity	$12.0	$14.5	$24.0	18.9%
Business	4.9	5.9	11.1	22.7%
Instructional	0.8	0.8	0.9	3.0%
System	8.1	10.1	19.0	23.8%
Entertainment	0.9	1.0	1.7	17.2%
Technical Engineering/Scientific	2.9	3.6	5.3	16.3%
Total	$29.6	$35.9	$62.0	20.3%

Source: Dataquest
November 1989

Applications of OS/2 that demonstrate clear ease of use and productivity advantages to the end user are becoming available quickly. Aldus PageMaker is an excellent example. The development of strategic applications is the driving force behind the adoption of OS/2 in large corporations, both in the United States and Europe.

The recent alliance of Apple and Microsoft, regarding computer typography, prepares the way for Apple's entrance into the lower-cost computer market. We expect a Macintosh priced at approximately $1,000 to be introduced next year.

The home PC market has grown significantly this year, fueled primarily by both increased computer literacy and decreased prices for more powerful systems. We expect this trend to accelerate. Dataquest survey results document a surprising increase in multimedia applications, especially in music applications.

UNIX Systems

Worldwide revenue for UNIX continues to grow strongly, especially in non-U.S. markets. From a negligible market share in 1986, growth increased dramatically and will continue to increase in 1989. See Table 6 for Dataquest's forecast for the UNIX market.

Table 6

UNIX Systems
Estimated Worldwide Revenue
(Billions of Dollars)

	1989	1990	1993	CAGR 1989-1993
Corporate Resource	$ 1.1	$ 1.6	$ 2.3	20.2%
Business Unit	2.1	2.7	4.1	18.2%
Large Department	2.6	3.2	5.0	17.8%
Small Department	4.5	6.3	7.5	13.6%
Work Group	6.0	6.8	8.8	10.0%
Single-User Enhanced	5.3	7.8	14.0	27.5%
Personal Computer	0.7	0.9	1.2	14.4%
Total	$22.3	$29.3	$42.9	17.8%

Source: Dataquest
November 1989

The Open Software Foundation is determining whether it will be able to incorporate Carnegie Mellon University's Mach into OSF/1. This incorporation would achieve the multiprocessing and increased security demanded by OSF members.

The talk from AT&T is about spinning out the UNIX Software Organization (USO) as an independent company. In order to become more profitable, USO decided to raise the UNIX licensing fees for System V, Release 4. The terms of the license fees make UNIX less expensive for PC users and low-end workstation manufacturers. However, many high-end workstation, mainframe, and supercomputer manufacturers facing fees that are 1 percent of the hardware costs will be angry.

The graphical user interface debate has heated up as Motif and Open Look proponents take sides. Motif currently has the edge in the number of companies who have chosen to implement it.

PERIPHERALS

Electronic Printers

The 1989 electronic printer markets have performed as Dataquest forecast last spring, showing an overall growth of 10 percent in terms of units and 12 percent for revenue. Page printers have overtaken serial printers in revenue and growth continues as forecast. Ink jet printers continue their high growth rates. Table 7 shows the Dataquest five-year forecast for electronic printer sales.

Table 7

Electronic Printers
Estimated Worldwide Revenue
(Billions of Dollars)

	1989	1990	1993	CAGR 1989-1993
Serial	$ 9.3	$9.8	$10.0	1.8%
Line	2.3	2.3	2.3	0
Page, Nonimpact	7.4	8.7	13.3	15.8%
Total	$19.0	$20.8	$25.6	7.7%

Source: Dataquest
November 1989

The new 24-wire dot matrix printers are gaining on the 9-wire ones, although not as quickly as expected. Lower-priced (approximately $500) 9-wire printers are showing higher growth rates than expected. The market for 24-wire printers appears to be affected by the sale of nonimpact printers, such as ink jet and low-end laser printers.

Hewlett-Packard Company's announcement of the LaserJet IIP on September 17, 1989, is a significant change to the low-end page printer market. Dataquest anticipated such a new class of 10 to 12kg page printers at approximately $1,500 at its conferences last year in Vienna and Tokyo and early this year in Monterey. The price of the IIP puts it squarely in competition with high-end dot matrix and ink jet printers, threatening the market niches those technologies had captured. Page printer revenue surpassed that for dot matrix printers in 1988 for the first time; HP's new entry will widen the gap further.

Networking, high resolution, and color are still the features to watch, as indicated last spring. Better distribution and software support strategies are still the most important marketing issues. Lower prices will force vendors to concentrate on niche markets, with higher volumes of lower-margin printers. Vendors using a two-tier distribution strategy are experiencing tremendous margin pressure from low-priced nonimpact printers that are making their way to the end user via single-tier distribution.

Sales of page printers will continue to surge in 1990, at the expense of all other technologies. Competitors will be hard pressed to match the IIP's price and performance ratio, but such matching will be the price of staying in the market. Many more significant announcements of low-end page printers are expected in the months ahead.

Computer Storage

Dataquest's forecast for the computer storage industry remains unchanged. Events since the spring have confirmed the forecast made then. The five-year Dataquest forecast for computer storage sales is shown in Table 8.

Table 8

Computer Storage
Estimated Worldwide Revenue
(Billions of Dollars)

	1989	1990	1993	CAGR 1989-1993
Rigid	$35.4	$39.8	$50.4	9.2%
Flexible	4.8	4.8	5.3	2.4%
Tape	6.9	7.6	8.0	3.8%
Optical	1.1	2.2	9.6	72.9%
Total	$48.2	$54.4	$73.3	11.0%

Source: Dataquest
November 1989

The overcapacity in the rigid disk drive markets has eased, as expected. It now appears that revenue for rigid disk drives will be within 4 percent of Dataquest's forecast for 1989. The recent introduction of a 320-megabyte, 3.5-inch disk drive from IBM has raised the ceiling for PC storage capacity. OEM pricing has stabilized. Disk arrays are coming to market.

In the flexible disk drive market, 20- to 40-megabyte drives are emerging. They have the potential to impact or replace the low-end tape market for data backup.

Optical drives continue to be the hottest portion of this market, with CD-ROMs leading the way. Although the U.S. government requested price bids for write-once, read many (WORM) drives, which are sorely needed to replace tons of paper files, no contracts have been awarded. The federal deficit situation must be clarified before purchases can be expected. Erasable optical drives are here, but, priced at approximately $6,000, they are too expensive for the bulk of the PC market.

Digital audio tape (DAT) is available but is still too expensive for the PC market. Although DAT can store up to 1.3 gigabytes, the data transfer rate is slow. These tapes may find a niche in the minicomputer market. The value of IBM's 3490 half-inch cartridge tape at $55,000 leaves the future unclear for the 3480, which is currently doing well. Reel-to-reel half-inch tape is finding a niche in the PC-to-mainframe data exchange area. Tape backups for PC in the 60-megabyte and 150-megabyte range will be the biggest sellers through 1990.

Display Terminals

Dataquest's forecast for display terminals continues to show growth in shipments for 1989, 5.1 percent over 1988, and a decline of 3.5 percent in revenue for the same period. These numbers compare to the growth between 1987 and 1988 of 3.1 percent in shipments and 1.1 percent in revenue. Display terminal sales as forecast by Dataquest are shown in Table 9.

Table 9

Display Terminals
Estimated U.S. Revenue
(Billions of Dollars)

	1989	1990	1993	CAGR 1989-1993
Minicomputer-Based	$0.90	$0.80	$0.40	(18.4%)
Non-IBM, Protocol-Specific	0.04	0.03	0.01	(29.3%)
IBM 3270-Compatible	1.20	1.10	0.60	(15.9%)
Nonhost-Specific	0.60	0.60	0.30	(15.9%)
Processing	0.20	0.30	1.10	53.1%
Total	$2.94	$2.83	$2.41	(4.8%)

Source: Dataquest
November 1989

Minicomputer-specific terminals are slightly ahead of plan for reaching the Dataquest forecast for 1989 of 942,000 units shipped. Digital remains the leader in this segment, with 126,200 units shipped during the first half of 1989, which represents 28.9 percent market share.

Unisys and Bull display terminals are well ahead of plan to reach our forecast for the year. Unisys remains the dominant leader, with 58.2 percent market share on shipments of 20,900 for the first half of 1989.

Sales of IBM 3270-type terminals are expected to improve during the second half of 1989 because of new product announcements by IBM. At midyear, the industry was behind forecast shipments on a volume of 336,100. IBM retains its strong leadership in this market, with 50.3 percent share. Memorex Telex is gaining strength, with a market share of 28.6 percent.

Host-independent/independent manufacturer terminals are slightly behind targeted midyear shipments when measured against the 1989 forecast. Shipments for the first half of the year were 530,800. Wyse Technology and its subsidiary, Link, continue to dominate this segment, with 50.4 percent market share.

Processing terminal shipments are well below expectation for the first half of 1989. This is partly the result of the lack of leadership in this segment. Dataquest now expects shipments for the year to be well below the original estimate of 102,000.

COMPUTER-INTEGRATED MANUFACTURING

The computer-integrated manufacturing (CIM) forecast remains unchanged based on the past six months' events. Computer and controller revenue will continue to slow as we originally predicted, as microprocessors and desktop computers become the primary hardware platforms.

Dataquest forecasts a higher rate of software growth for North American vendors. The market is less global in nature than the hardware or networking CIM segments. The more parochial software market is primarily due to language barriers between cultures. In addition, software development typically lags behind hardware development by several years.

The trend will be toward the purchasing of boxes, boards, and software from many different vendors versus users purchasing bundled solutions. This trend will allow a more customized product, because no one vendor's offering is the best solution for every customer. Table 10 displays Dataquest's five-year forecast for the CIM market.

Table 10

Computer-Integrated Manufacturing
Estimated Worldwide Revenue
(Billions of Dollars)

	1989	1990	1993	CAGR 1989-1993
Computer Products	$11.8	$12.8	$17.1	9.7%
Software	5.9	6.8	10.9	16.6%
Network and Data Collection	2.1	2.6	4.7	22.3%
Service	4.0	4.5	6.4	12.5%
Total	$23.8	$26.7	$39.1	13.2%

Source: Dataquest
November 1989

TELECOMMUNICATIONS

Mergers, acquisitions, and alliances continue to be widespread throughout the U.S. telecommunications industry. Customer demands for service and support require larger resources than small companies can muster. See Table 11 for Dataquest's five-year forecast for the telecommunications market.

Table 11

Telecommunications
Estimated U.S. Revenue
(Billions of Dollars)

	1989	1990	1993	CAGR 1989-1993
PBX	$ 3.6	$ 3.7	$ 3.8	1.4%
Data Communications Equipment	7.8	9.9	13.4	14.5%
Call-Processing Equipment	1.3	1.5	1.9	10.0%
Facsimile Machines	2.0	2.3	3.2	12.5%
Video Conferencing	0.1	0.1	0.2	32.1%
Public Equipment	8.0	8.4	10.5	7.1%
Public Services	135.0	141.1	159.7	4.3%
Cellular Radio Services	3.4	4.7	7.6	22.3%
Total	$161.2	$171.7	$200.3	5.0%

Source: Dataquest
November 1989

Size alone, of course, does not guarantee success. The sale of ROLM Corporation from IBM to Siemens has been completed. IBM exchanged ownership responsibilities for a marketing arrangement with Siemens for worldwide distribution of PBX equipment. However, the PBX market is flat and will remain so.

Vendors of data communications equipment are increasingly turning to international markets, especially Europe. Worldwide standards, such as Integrated Services Digital Network (ISDN) and Open System Interconnect (OSI), are making the telecommunications market truly international. We expect ISDN-related revenue for equipment and services of $742 million in 1989 to grow to $1.3 billion in 1990, reaching $3.3 billion by 1993.

Facsimile machine revenue exploded in 1988. Revenue for 1989 still will be strong, although sales will not increase as dramatically as initially estimated.

The voice-messaging systems market continues to be a hot growth area, with an increase in sales of more than 65 percent in 1988. Further growth of more than 40 percent is expected in 1989, totaling $734 million in revenue. Annual growth then will moderate, with the market topping $1 billion by 1993. Recent regulatory changes permit Regional Bell Operating Companies (RBOCs) to offer voice-messaging services, which will mean even larger systems in this booming market.

The Very Small Aperture Terminal (VSAT) market is growing rapidly after some false starts. Forecast 1989 revenue of $322 million is expected to grow at a 24.7 percent compound annual growth rate to $778 million in 1993, as widely dispersed corporate operations are tied together by these private network tools.

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Research Newsletter

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ARE LOW MANUFACTURING PRODUCTION COSTS REASON ENOUGH TO RELOCATE?

INTRODUCTION

Investing in a foreign country is neither a simple nor a trivial matter for a company. This newsletter assesses the hourly compensation costs for production workers in manufacturing industries for the United States and 23 foreign economies. Compensation in manufacturing is one piece of a critical decision-making puzzle for an organization to consider in moving offshore.

In 1988, for all 23 foreign economies included in this evaluation, the trade-weighted average cost level was 86 percent of U.S. costs (in U.S. dollars). Hourly compensation costs for the majority, but not all, of the countries reached new highs in 1988 relative to the United States.

THE BUREAU OF LABOR STATISTICS INFORMATION

The Bureau of Labor Statistics (BLS) has developed a methodology by which hourly compensation costs for production workers in 23 foreign countries can be compared with those in the United States. Although there is not an "apples to apples" relationship between compensation structures among the different countries, the BLS has applied trade weights to bring an acceptable level of consistency to the data. From 1975 through 1988, U.S. hourly compensation costs increased an average of 6.0 percent per year. In comparison, the 23 foreign economies increased an average of 9.6 percent for the same period. Figures 1 and 2 show costs in the electronic manufacturing industry for the United States, West Germany, Japan, and Korea.

Hourly compensation as defined by the Bureau of Labor Statistics is payments made directly to the worker before payroll deductions of any kind. This figure also includes any employer expenditures for legally required insurance programs and contractual and private benefit plans. Compensation is measured on an hours-worked basis. Hourly compensation is one of several costs considered when evaluating total compensation.

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Changes in hourly compensation costs measured in U.S. dollars for foreign countries also reflect fluctuations in the exchange rate to the U.S. dollar. As a result, for the 23 subject economies, hourly compensation costs increased from 64 percent of the U.S. cost level in 1975 to 73 percent in 1980, decreased to 57 percent in 1985, then increased sharply to 86 percent in 1988.

Europe

In Europe, for example, average hourly compensation costs rose from 82 percent of the U.S. level in 1975 to 102 percent in 1980, then fell to 62 percent by 1985, reflecting the <u>appreciation</u> of the dollar. In 1988, European hourly compensation costs rose to an all-time high of 105 percent, largely as a result of the <u>depreciation</u> of the dollar between 1985 and 1988.

Japan

Japan has sustained moderate hourly compensation costs relative to those in the United States. This trend has been supported by a strong Japanese currency exchange rate, which was stronger than those of the other economies covered. From 1975 to 1980, Japanese hourly compensation costs rose from 48 percent to 57 percent of U.S. costs. In 1985, costs declined to 50 percent and then climbed dramatically to 91 percent by 1988.

Korea and Taiwan

Korea and Taiwan, countries traditionally known for low hourly production costs, are experiencing a rise in costs. The increase is related to the exchange rate values of the Korean won and the Taiwan dollar, which are also climbing. Since 1980, Korea maintained hourly production costs at an average of 11 percent of U.S. costs. Between 1987 and 1988, costs increased from 13 to 18 percent, the largest jump for these countries in the 13-year time span analyzed here.

DATAQUEST ANALYSIS

Although low hourly production costs are attractive at face value, they must not be considered in a vacuum. Dataquest believes that it is imperative to investigate the details of foreign trade barriers before making a decision to relocate an operation offshore. Types of foreign trade barriers are the following:

- Import policies
- Standards, testing, labeling, and certification
- Government procurement
- Export subsidies

- Lack of intellectual property protection
- Service barriers
- Investment barriers
- Barriers that encompass more than one category listed above or that affect a single sector

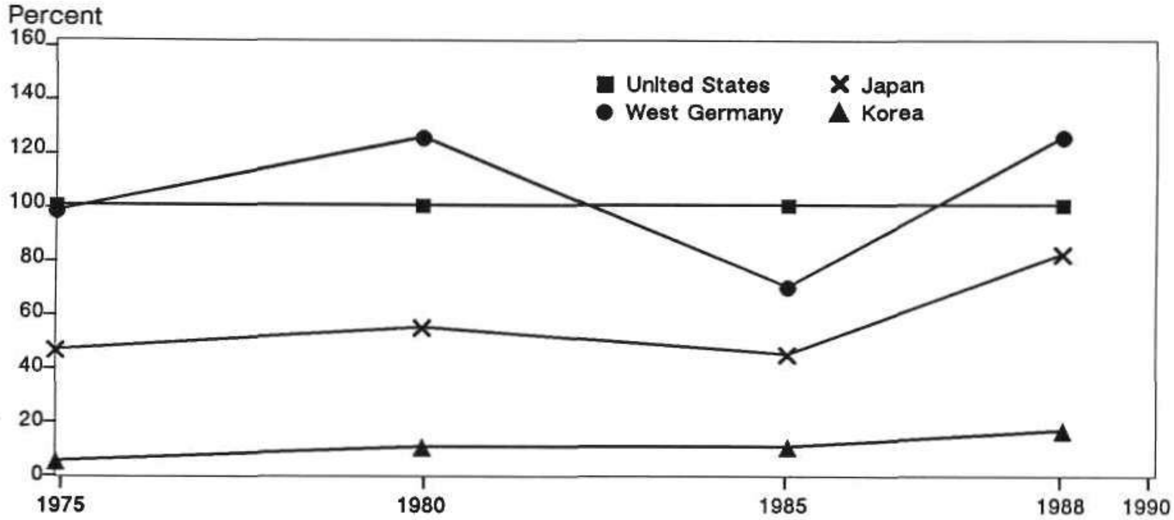
Companies giving serious thought to relocating business and/or manufacturing operations offshore must identify the strengths and weaknesses in a country's business and trade operations. Strong consideration must be given to the impact that language barriers will have on inter- and intracompany communications. Also, Dataquest believes that distance can cause unavoidable delays between the design and manufacturing phase for new products. The organization must determine its long-term objective. Is the move offshore being made to lower manufacturing costs or to become a part of the local market, i.e., manufacture in Europe to be in a better position to sell in Europe?

In moving operations to a foreign country, what may appear to be an inexpensive road may have costly pitfalls along the way.

Bernadette Cesena

Figure 1

Hourly Compensation Costs for Production Workers*
Electric and Electronic Equipment Manufacturing**
(Percentage)



*Index: U.S. = 100
**Standard Industrial Code 36

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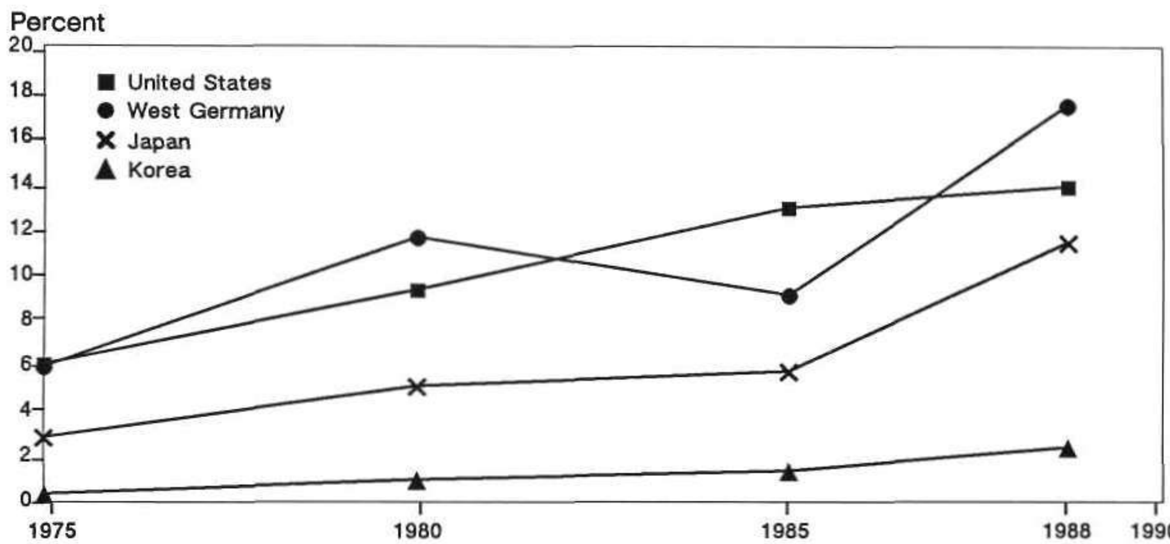
Source: Dataquest
November 1989

Figure 2

Hourly Compensation Costs for Production Workers
Electric and Electronic Equipment Manufacturing*
(U.S. Dollars)



*Standard Industrial Code 36

0005445-2

Source: Dataquest
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Research Newsletter

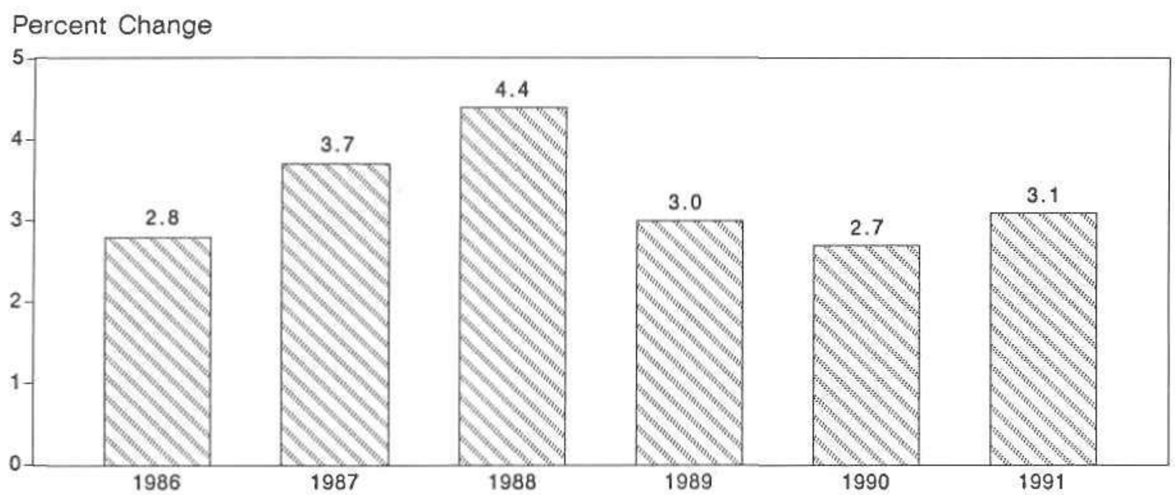
ECONOMIC OUTLOOK: THE ECONOMY HAS LANDED

SUMMARY

Real U.S. Gross National Product (GNP) growth is forecast to be 3.0 percent in 1989 and 2.7 percent in 1990 (see Figure 1). Quarterly growth is expected to decelerate through the end of this year and slowly pick up in the first quarter of 1990. Lower interest rates in 1990 should stimulate household expenditures on consumer durables and business investment in plant and equipment. As the investment climate improves, Dataquest expects electronic equipment production to follow suit, growing at a 6.4 percent pace in 1990, up from 6.1 percent this year.

Figure 1

Real GNP Growth



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Source: The Dun & Bradstreet Corporation

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BETTER SHAPE THAN WE THOUGHT

GNP data, recently revised by the U.S. Commerce Department, indicate that during the period between 1986 and the first quarter of 1989, the economy was almost $30 billion larger than previously reported. Most of this increase was in the balance of trade, and most of that was due to an improvement in exports. The revision reflects two things. The first is a broader definition of exports that now includes more financial and business services trade (e.g., accounting and consulting). The second thing the revision shows is that consumer and investment spending increased slightly and, significantly, inventories accumulated at a much slower pace.

Slower inventory growth reduces the probability of any significant downward correction in the remainder of the year. Because inventory corrections typically trigger recessions, the likelihood of a recession beginning any time soon is less than previously expected.

THE U.S. ECONOMY, NOW ARRIVING AT GATE...

The soft landing is a situation where economic growth decelerates but remains positive enough to avert a recession, although slow enough to bring about a reduction of inflation. Second-quarter real GNP grew at a 2.5 percent annual rate, well within the nonaccelerating-rate-of-inflation growth range. This rate was lower than the 3.0 percent growth in the second quarter of 1988. Recent price indexes also show that inflation has stabilized. Thus, both requirements of the soft landing have been met, at least for the time being. Now that we've landed, how long is this stopover going to last? What's the economy's next flight plan?

DEPARTING FOR...

The latest Dun & Bradstreet forecast calls for real U.S. GNP growth to slow further this year, at 2.4 percent and 2.0 percent rates in the third and fourth quarters, respectively, putting 1989 annual growth at 3.0 percent, down from 4.4 percent in 1988.

If recent interest rate decreases are sufficient to stimulate spending without touching off a flight from dollars—and the recent strength in the dollar indicates that this is indeed happening—then the economy's next takeoff is scheduled for the first quarter of 1990. We forecast real growth of 2.3 percent in the first quarter of 1990, accelerating to 3.1 percent in the second. Third- and fourth-quarter growth are expected to be 4.1 percent and 3.7 percent, respectively, which would place 1990 annual growth at 2.7 percent over 1989.

DEMAND COMPONENTS

Consumer Expenditures

The outlook is for a modest pickup in spending. Growth has been slowing each quarter since the beginning of 1988, yet consumer confidence in the economy remains relatively optimistic. Rising interest rates were responsible for this slowdown in 1988. More recently, however, weakening spending has been attributable to increases in personal tax payments resulting from deferrals of income from 1986 and 1987 into 1988 and to a spurt in food and energy prices earlier this year. In 1990, tax rates still will increase, but only slightly, and expected lower interest rates should ease consumers' debt burdens.

Investment Expenditures

Business investment spending should improve, but not dramatically. Capital spending remained strong throughout the first half of 1989 following a period of weakness in late 1988. As in the consumer sector, lower interest rates should help stimulate this sector. However, the rally in the dollar that began last spring, if it persists, will make exploiting new export markets more difficult in 1990. Also, sharply higher (domestic) automobile prices will inhibit growth in this important area.

Government Expenditures

Last year, inflation-adjusted government expenditures fell primarily because of cutbacks in defense spending. This trend has accelerated this year and is likely to continue in 1990, given the (credible?) threat of across-the-board budget cuts, if Gramm-Rudman-Hollings deficit reduction goals are not met. Spending by state and local governments will provide some (minimal) stimuli, but their own fiscal problems will limit any significant offset.

Foreign Trade

Growth in net exports (i.e., exports less imports) also will stall compared with recent years. In 1988, net exports contributed $41 billion to real GNP growth; a $25 billion contribution is forecast in 1989. In 1990, the contribution is expected to continue to fall to less than $1 billion. Because of the recent appreciation of the dollar, export growth, while still healthy, is not likely to match the strong performance of the past two years. Meanwhile, as the economy takes off, the demand for imports will grow also.

DATAQUEST CONCLUSIONS AND RECOMMENDATIONS

Dataquest expects growth of business fixed investment in equipment to decelerate through the end of this year. Starting in the first quarter of 1990, however, we expect the pace of capital equipment spending growth to accelerate through the end of the year.

The faster rate of capital spending should, in turn, translate into a faster pace of growth in electronic-equipment production. We forecast the value of North American electronic equipment production to grow 6.1 percent in 1989, down from 6.6 percent growth last year and to grow 6.4 percent in 1990.

Notably, wide swings in growth are being moderated by manufacturers' efforts to keep a tight reign on inventories. Indeed, because equipment inventories are appropriate for the current lull in equipment shipments and orders growth, electronics manufacturers are well poised to take advantage of the quicker pace of business expected during the first half of 1990.

Until that time, however, Dataquest urges the manufacturing community to be vigilant in its commitment to run a lean, nimble shop and compete on intangibles such as customer service and satisfaction. This commitment is the surest bet to catch the next wave and the attendant market share.

Terrance A. Birkholz

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Research *Newsletter*

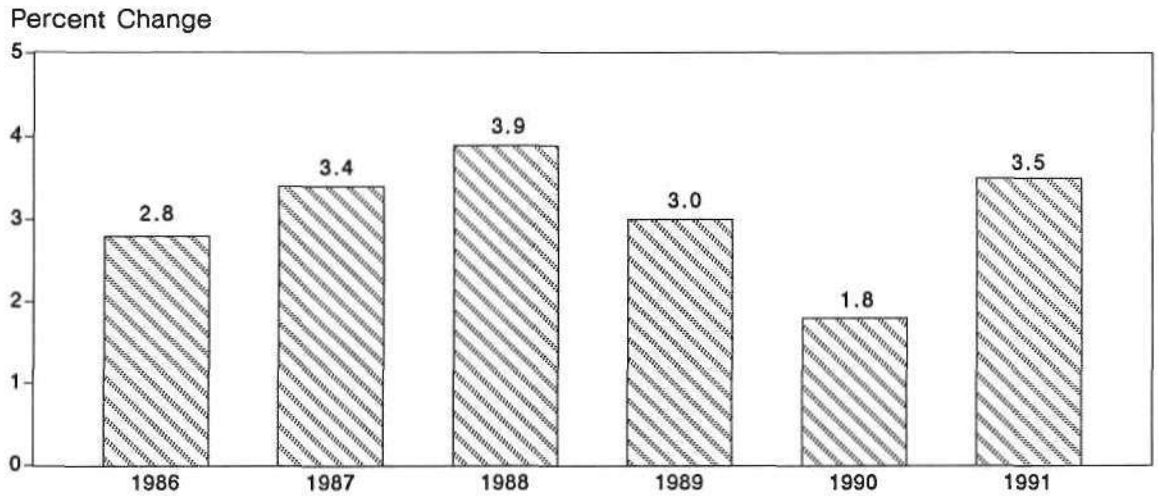
MIDYEAR ECONOMIC REVIEW AND OUTLOOK

SUMMARY

The U.S. economy has been growing continuously since November 1982--the longest U.S. economic peacetime expansion on record--and shows every sign of continuing well into its seventh year. Overall, no recession is foreseen, but an economic slowdown seems to be on the horizon. Real gross national product (GNP) growth in 1988 was 3.9 percent, an improvement from the 3.4 percent growth in 1987. A possible slowdown should result in growth rates of about 3.0 percent in 1989 and 1.8 percent in 1990, as shown in Figure 1. Beyond this, GNP growth is expected to accelerate to a 3.5 percent growth rate in 1991.

Figure 1

Real GNP Growth



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Source: Dun & Bradstreet Corporation

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Dataquest relies heavily on the economic analysis department of the Dun & Bradstreet Corporation, our parent company, to help us develop our economic forecast. A synopsis of D&B's economic outlook is discussed in this newsletter.

A SOFT LANDING IN OUR FUTURE?

Many economists are looking for evidence that the economy will experience a "soft landing" in the near term. This soft landing, which federal economic policy makers are trying to engineer, would involve a gradual slowing of economic growth without the onslaught of a recession. They believe that this policy would decelerate what appears to be recently quickening inflation, without endangering continuing economic growth.

To achieve a soft landing, the economy will have to slow from its strong 3.9 percent growth in 1988. Reduced job creation rates and consumer spending growth in the first half of 1989 indicate that a soft landing may be emerging. Inflation rates jumped upward earlier this year, creating anxiety among those who feared that the Federal Reserve Board would respond with higher interest rates. In retrospect, however, this recent acceleration in inflation is seen as transitory, the result of increases in oil and food prices. Thus, the deceleration-of-inflation component of the soft landing also appears intact.

Nonetheless, the export and investment sectors of the economy should remain relatively strong. Capital spending should continue growing at a healthy pace as manufacturers expand capacity. Also, merchandise exports, responsible for much of last year's growth, have reached new heights recently. The optimism reflected in a recent Dun & Bradstreet business expectations survey and a leveling-off of capacity utilization both suggest that there is room for exports to expand even further.

Continued investment and export growth will depend heavily on future interest rate levels and the dollar's foreign exchange value. The dollar rose about 10 percent against other major currencies from November 1988 to June 1989. A stronger dollar threatens the recent progress made on the trade deficit, because it makes imports relatively less expensive in the United States.

The strengthening dollar and falling interest rates are believed to be short-term aberrations. By year-end, it is likely that both the dollar and interest rates will be near their January levels. This is because the factors involved in this reversal are only temporary. Nothing has changed significantly in the fundamental factors, so long-term trends should predominate once again in the second half of this year.

Improvements in the merchandise trade deficit notwithstanding, the deficit probably will remain large due to increased imports—possibly $110 billion in 1989 compared with $120 billion last year. Furthermore, its position as a net debtor because of cumulative past deficits means that the United States now must service this debt. This mounting debt service now offsets most of the gains on the merchandise components.

The large trade deficit will continue to flood currency markets with dollars, which in turn should keep downward pressure on the dollar. As the dollar falls, however, interest rates are likely to increase, directly because of the Federal Reserve's attempts to stabilize and support the dollar, and indirectly because of some acceleration in inflation resulting from higher prices for imported goods.

Despite these factors, the economy should remain relatively healthy. Although a recession is not forecast, slower growth is expected this year and next year. Real GNP growth will likely slow from 3.9 percent in 1988 to 3.0 percent in 1989. Given the 4.5 percent annualized real GNP growth in the first quarter, a great deal of 1989's growth is believed to have occurred already in the first part of this year. Expected higher interest rates probably will impede growth in the second half of 1989, and growth should slow even further to 1.8 percent in 1990.

This growth path is consistent with the soft-landing expectation. However, as always, the economy is subject to unexpected shocks that could turn the soft landing into the crash landing of a full-blown recession.

THE GNP COMPONENTS

By 1991, the economy is expected to resume a quicker pace, rebounding with 3.5 percent growth. The following is an analysis of the outlook of GNP components. Statistical details of these components are shown in Table 1. Additional indicators of macroeconomic activity are given in Table 2.

Consumer Spending

Consumer expenditures constitute about two-thirds of real GNP. Recently, the volume of consumer expenditure growth has slowed because of slower income growth and higher prices for some goods. On average, 84 percent of consumer expenditures are relatively fixed items and services (e.g., food, clothing, shelter, and gasoline). Because their demand is relatively income inelastic, consumer spending growth in these areas should continue at nearly the current rates. On the other hand, spending for durable goods such as automobiles, furniture, and appliances is likely to slow. Because funds for these goods usually are borrowed, and with the outlook of higher interest rates that will raise finance costs, consumer spending on durables is likely to slow. But because only 16 percent of consumer expenditures are for durable goods, a major disruption in this sector probably will be avoided.

Investment

Dataquest predicts that equipment investment spending will be one of the strongest areas of the economy. Since many investment decisions are made 6 to 12 months in advance, the anticipated interest rate increases should not affect this sector until 1990, if at all. Stimulated by a cheap dollar and strong export demand, equipment sales to both domestic and foreign manufacturers should remain relatively buoyant. Until the dollar and interest rates stabilize, however, investment in additional plant capacity should lag somewhat. Residential investment also will remain flat as a result of higher interest rates. Inventory investment should slow by next year as manufacturers react to a riskier economic environment as a result of higher interest rates.

Table 1

Components of Real GNP and Nominal GNP
(Billions of 1982 Dollars)

	Actual		
	1986	1987	1988
Consumption Expenditures	$2,455.2	$2,520.9	$2,592.2
Rate of Change (%)	4.2	1.9	2.8
Business Fixed Investment	$ 433.1	$ 445.2	$ 487.5
Rate of Change (%)	(4.5)	2.8	9.5
Residential Fixed Investment	$ 195.0	$ 195.2	$ 191.8
Rate of Change (%)	17.8	0.1	(1.7)
Government Purchases	$ 760.5	$ 780.2	$ 782.3
Rate of Change (%)	4.0	2.6	0.3
Change in Business Inventories	$ 15.5	$ 34.4	$ 42.5
Net Exports	($ 15.5)	($ 128.9)	($ 100.2)
Equals:			
Gross National Product (1982 $)	$3,721.7	$3,847.0	$3,996.0
Rate of Change (%)	2.8	3.4	3.9
Addendum:			
Implicit Price Deflator (Index, 1982 = 100)	114.0	117.7	121.7
Rate of Change (%)	2.7	3.2	3.4
Gross National Product (Current $)	$4,240.3	$4,526.7	$4,864.3
Rate of Change (%)	5.6	6.8	7.5

(Continued)

Table 1 (Continued)

Components of Real GNP and Nominal GNP (Billions of 1982 Dollars)

	Forecast 1989	1990	1991
Consumption Expenditures	$2,662.1	$2,725.8	$2,812.6
Rate of Change (%)	2.7	2.4	3.2
Business Fixed Investment	$ 514.5	$ 537.1	$ 568.8
Rate of Change (%)	5.5	4.4	5.9
Residential Fixed Investment	$ 191.1	$ 187.9	$ 199.8
Rate of Change (%)	(0.3)	(1.7)	6.3
Government Purchases	$ 805.6	$ 812.2	$ 815.3
Rate of Change (%)	3.0	0.8	0.4
Change in Business Inventories	$ 31.0	$ 4.2	$ 19.8
Net Exports	($ 87.2)	($ 74.6)	($ 76.7)
Equals:			
Gross National Product (1982 $)	$4,116.9	$4,192.7	$4,339.8
Rate of Change (%)	3.0	1.8	3.5
Addendum:			
Implicit Price Deflator (Index, 1982 = 100)	127.6	134.1	140.3
Rate of Change (%)	4.8	5.1	4.6
Gross National Product (Current $)	$5,252.1	$5,623.7	$6,089.1
Rate of Change (%)	8.0	7.1	8.3

Source: Economic Analysis Department
The Dun & Bradstreet Corporation

Table 2

Major Macroeconomic Indicators

	1986	1987	1988
	Billions of Current Dollars		
Nominal GNP	$4,240.3	$4,526.7	$4,864.3
Rate of Change (%)	5.6	6.8	7.5
	Billions of 1982 Dollars		
Real GNP	$3,721.7	$3,847.0	$3,996.0
Rate of Change (%)	2.8	3.4	3.9
	Index, 1982 = 100		
GNP Deflator	114.0	117.7	121.7
Rate of Change (%)	2.7	3.2	3.4
	Billions of 1982 Dollars		
Real Disposable Income	$2,640.9	$2,686.9	$2,788.3
Rate of Change (%)	3.9	1.7	3.8
	Percent		
Personal Saving Rate	4.0	3.7	4.2
	Index, 1977 = 100		
Industrial Production	125.1	129.8	137.2
Rate of Change (%)	1.1	3.7	5.7
	Percent		
Capacity Utilization	79.7	81.0	83.5
Civil Unemployment Rate	7.0	6.2	5.5
	Millions Employed		
Employment, Establishment Basis	99.5	102.2	105.6
Rate of Change (%)	2.0	2.7	3.3

(Continued)

Table 2 (Continued)

Major Macroeconomic Indicators

	1986	1987	1988
	Billions of 1982 Dollars		
Real Final Sales	$3,843.8	$3,941.5	$4,053.7
Rate of Change (%)	3.5	2.5	2.7
	Billions of 1982 Dollars		
Private Domestic Demand	$3,083.3	$3,161.3	$3,271.5
Rate of Change (%)	3.4	2.5	3.5
	Billions of Current Dollars		
After-Tax Profits	$ 129.8	$ 137.8	$ 163.9
Rate of Change (%)	1.5	6.2	18.9
	Interest Rates (%)		
Federal Funds Rate	6.8	6.7	7.6
3-Month Treasury Bills	6.0	5.8	6.7
30-Year Treasury Bonds	7.8	8.6	9.0
	Index, March 1973 = 100		
FRB Exchange Rate	112.3	96.9	92.9
Rate of Change (%)	(21.6)	(13.7)	(4.2)
	Billions of Current Dollars		
Federal Surplus (Unified, Fiscal Year)	($ 221.1)	($ 149.0)	($ 155.0)
Rate of Change (%)	(5.8)	32.6	(4.1)

(Continued)

Table 2 (Continued)

Major Macroeconomic Indicators

	1989	1990	1991
	Billions of Current Dollars		
Nominal GNP	$5,252.1	$5,623.7	$6,089.1
Rate of Change (%)	8.0	7.1	8.3
	Billions of 1982 Dollars		
Real GNP	$4,116.9	$4,192.7	$4,339.8
Rate of Change (%)	3.0	1.8	3.5
	Index, 1982 = 100		
GNP Deflator	127.6	134.1	140.3
Rate of Change (%)	4.8	5.1	4.6
	Billions of 1982 Dollars		
Real Disposable Income	$2,866.4	$2,932.3	$3,034.9
Rate of Change (%)	2.8	2.3	3.5
	Percent		
Personal Saving Rate	5.5	5.8	5.3
	Index, 1977 = 100		
Industrial Production	142.3	145.9	151.5
Rate of Change (%)	3.7	2.5	3.9
	Percent		
Capacity Utilization	83.6	83.1	84.0
Civil Unemployment Rate	5.5	6.2	5.8
	Millions Employed		
Employment, Establishment Basis	108.2	109.5	112.9
Rate of Change (%)	2.5	1.2	3.2

(Continued)

Table 2 (Continued)

Major Macroeconomic Indicators

	1989	1990	1991
	Billions of 1982 Dollars		
Real Final Sales	$4,173.1	$4,263.1	$4,396.7
Rate of Change (%)	2.9	2.2	3.1
	Billions of 1982 Dollars		
Private Domestic Demand	$3,367.7	$3,450.8	$3,581.2
Rate of Change (%)	2.9	2.5	3.8
	Billions of Current Dollars		
After-Tax Profits	$ 172.1	$ 167.0	$ 179.5
Rate of Change (%)	5.0	(3.0)	7.5
	Interest Rates (%)		
Federal Funds Rate	9.5	9.0	8.5
3-Month Treasury Bills	8.3	8.0	7.7
30-Year Treasury Bonds	8.7	8.7	9.2
	Index, March 1973 = 100		
FRB Exchange Rate	97.4	88.3	84.0
Rate of Change (%)	4.9	(9.4)	(4.9)
	Billions of Current Dollars		
Federal Surplus (Unified, Fiscal Year)	($ 167.0)	($ 150.0)	($ 110.0)
Rate of Change (%)	(7.7)	10.2	26.7

Source: Dun & Bradstreet
U.S. Department of Commerce
Federal Reserve Board

Government

Government spending is expected to be an area of weakness in the economy. As Gramm-Rudman-Hollings (GRH) deficit-cutting measures become increasingly difficult to avoid, either reductions in federal government spending or increases in taxes (or some combination of the two) will have to be enacted, either of which will slow economic growth. The fiscal 1990 GRH target is $100 billion. The actual fiscal 1990 deficit, however, is likely to exceed official estimates by at least $40 billion to $50 billion. This shortfall will have to be made up in fiscal 1991, when the GRH deficit target will fall to $64 billion. Thus, Congress and the Bush Administration may be forced to discover more than $80 billion in federal budget deficit reductions (unlikely), revise the GRH targets (likely), or both (the most likely). In addition, large deficits in many state and local governments—57 percent of total real government spending—will force cutbacks in these areas as well.

Foreign Trade

Net exports, the contributions of the trade balance to real GNP, should improve modestly in 1989. The strong European and Japanese economies are likely to continue fueling demand for U.S. exports, particularly if the dollar weakens. Demand should be especially strong for U.S.-made industrial supplies and manufactured goods. However, imports into the United States also will continue to grow, although not as rapidly as exports. Higher oil prices, in particular, will be detrimental to the U.S. balance of trade.

DATAQUEST CONCLUSIONS

Dataquest anticipates that an economic slowdown primarily caused by higher interest rates will begin approximately at the end of this year or in early 1990. To date, the indications are that the economy probably is headed for a soft landing and that a recession can be avoided. It would be premature, however, to assume that the macroeconomic managers have repealed the business cycle, with the latest round of fine-tuning policy measures. Once interest rates peak, which probably will happen in early 1990, economic growth will slow for several months. After this, the growth pace should pick up steam and improve significantly in 1991.

Terrance A. Birkholz

26-Apr-91

ESTIMATED SEMICONDUCTOR REVENUE

Actel

	Worldwide		North America		Japan		Europe		Asia/Pacific		Rest of World (exc. Asia/Pac	
	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89
Total Semiconductor	21	200%	15	200%	1	0%	3	NA	2	100%	0	NA
Total Integrated Circuit	21	200%	15	200%	1	0%	3	NA	2	100%	0	NA
Bipolar Digital (Technology)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
TTL/Other	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
ECL	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital (Function)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Logic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS (Technology)	21	200%	15	200%	1	0%	3	NA	2	100%	0	NA
N/PMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
CMOS	21	200%	15	200%	1	0%	3	NA	2	100%	0	NA
BICMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS (Function)	21	200%	15	200%	1	0%	3	NA	2	100%	0	NA
MOS Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Micro Devices	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Logic	21	200%	15	200%	1	0%	3	NA	2	100%	0	NA
Analog	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Total Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Transistor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Diode	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Thyristor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Other Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Total Optoelectronic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA

Source: Dataquest
May 1991

26-Apr-91

ESTIMATED SEMICONDUCTOR REVENUE
Advanced Micro Devices

	Worldwide		North America		Japan		Europe		Asia/Pacific		Rest of World (exc. Asia/Pac	
	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89
Total Semiconductor	1053	-4%	516	-9%	139	-3%	273	-5%	125	24%	0	NA
Total Integrated Circuit	1053	-4%	516	-9%	139	-3%	273	-5%	125	24%	0	NA
Bipolar Digital (Technology)	407	-14%	232	-19%	47	-20%	86	-11%	42	31%	0	NA
TTL/Other	306	-24%	170	-30%	32	-35%	74	-13%	30	25%	0	NA
ECL	101	38%	62	44%	15	50%	12	0%	12	50%	0	NA
Bipolar Digital (Function)	407	-14%	232	-19%	47	-20%	86	-11%	42	31%	0	NA
Bipolar Digital Memory	65	-24%	36	-23%	5	-44%	22	-19%	2	0%	0	NA
Bipolar Digital Logic	302	-22%	184	-23%	38	-24%	51	-27%	29	-3%	0	NA
MOS (Technology)	570	4%	245	1%	80	11%	166	-1%	79	18%	0	NA
N/PMOS	252	-23%	108	-25%	35	-19%	74	-26%	35	-13%	0	NA
CMOS	318	43%	137	40%	45	55%	92	35%	44	63%	0	NA
BICMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS (Function)	570	4%	245	1%	80	11%	166	-1%	79	18%	0	NA
MOS Memory	253	-2%	115	-8%	47	15%	61	-14%	30	43%	0	NA
MOS Micro Devices	178	3%	71	-5%	18	-22%	47	38%	42	5%	0	NA
MOS Logic	139	17%	59	40%	15	88%	58	-8%	7	17%	0	NA
Analog	76	-1%	39	-5%	12	0%	21	-5%	4	100%	0	NA
Total Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Transistor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Diode	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Thyristor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Other Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Total Optoelectronic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA

Source: Dataquest
May 1991

26-Apr-91

ESTIMATED SEMICONDUCTOR REVENUE
Allegro MicroSystems

	Worldwide		North America		Japan		Europe		Asia/Pacific		Rest of World (exc. Asia/Pac	
	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89
Total Semiconductor	116	-15%	69	-22%	4	-20%	33	3%	10	-9%	0	-100%
Total Integrated Circuit	98	-14%	54	-26%	4	-20%	31	24%	9	-10%	0	-100%
Bipolar Digital (Technology)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
TTL/Other	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
ECL	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital (Function)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Logic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS (Technology)	2	-88%	0	-100%	1	NA	1	-88%	0	NA	0	NA
N/PMOS	0	-100%	0	-100%	0	NA	0	NA	0	NA	0	NA
CMOS	2	-50%	0	-100%	1	NA	1	NA	0	NA	0	NA
BICMOS	0	-100%	0	NA	0	NA	0	-100%	0	NA	0	NA
MOS (Function)	2	-88%	0	-100%	1	NA	1	-88%	0	NA	0	NA
MOS Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Micro Devices	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Logic	2	-88%	0	-100%	1	NA	1	-88%	0	NA	0	NA
Analog	96	-2%	54	-17%	3	-40%	30	76%	9	-10%	0	-100%
Total Discrete	17	-26%	14	-7%	0	NA	2	-71%	1	0%	0	NA
Transistor	11	-15%	9	-10%	0	NA	1	-50%	1	0%	0	NA
Diode	6	100%	5	67%	0	NA	1	NA	0	NA	0	NA
Thyristor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Other Discrete	0	-100%	0	-100%	0	NA	0	-100%	0	NA	0	NA
Total Optoelectronic	1	NA	1	NA	0	NA	0	NA	0	NA	0	NA

Source: Dataquest
May 1991

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ESTIMATED SEMICONDUCTOR REVENUE

Altera

	Worldwide		North America		Japan		Europe		Asia/Pacific		Rest of World (exc. Asia/Pac	
	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89
Total Semiconductor	78	32%	49	26%	10	43%	15	36%	2	100%	2	100%
Total Integrated Circuit	78	32%	49	26%	10	43%	15	36%	2	100%	2	100%
Bipolar Digital (Technology)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
TTL/Other	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
ECL	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital (Function)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Logic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS (Technology)	78	32%	49	26%	10	43%	15	36%	2	100%	2	100%
N/PMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
CMOS	78	32%	49	26%	10	43%	15	36%	2	100%	2	100%
BICMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS (Function)	78	32%	49	26%	10	43%	15	36%	2	100%	2	100%
MOS Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Micro Devices	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Logic	78	32%	49	26%	10	43%	15	36%	2	100%	2	100%
Analog	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Total Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Transistor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Diode	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Thyristor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Other Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Total Optoelectronic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA

Source: Dataquest
May 1991

26-Apr-91 ESTIMATED SEMICONDUCTOR REVENUE

Analog Devices

	Worldwide		North America		Japan		Europe		Asia/Pacific		Rest of World (exc. Asia/Pac	
	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89
Total Semiconductor	381	7%	216	19%	42	-29%	103	8%	19	-5%	1	0%
Total Integrated Circuit	380	6%	215	18%	42	-29%	103	8%	19	-5%	1	0%
Bipolar Digital (Technology)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
TTL/Other	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
ECL	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital (Function)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Logic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS (Technology)	20	0%	11	0%	3	0%	6	0%	0	NA	0	NA
N/PMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
CMOS	20	0%	11	0%	3	0%	6	0%	0	NA	0	NA
BICMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS (Function)	20	0%	11	0%	3	0%	6	0%	0	NA	0	NA
MOS Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Micro Devices	20	0%	11	0%	3	0%	6	0%	0	NA	0	NA
MOS Logic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Analog	360	7%	204	19%	39	-30%	97	9%	19	-5%	1	0%
Total Discrete	1	NA	1	NA	0	NA	0	NA	0	NA	0	NA
Transistor	1	NA	1	NA	0	NA	0	NA	0	NA	0	NA
Diode	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Thyristor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Other Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Total Optoelectronic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA

Source: Dataquest
May 1991

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ESTIMATED SEMICONDUCTOR REVENUE

Appian Technology

	Worldwide		North America		Japan		Europe		Asia/Pacific		Rest of World (exc. Asia/Pac	
	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89
Total Semiconductor	50	35%	33	14%	1	NA	5	25%	11	175%	0	NA
Total Integrated Circuit	50	35%	33	14%	1	NA	5	25%	11	175%	0	NA
Bipolar Digital (Technology)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
TTL/Other	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
ECL	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital (Function)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Logic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS (Technology)	50	35%	33	14%	1	NA	5	25%	11	175%	0	NA
N/PMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
CMOS	50	35%	33	14%	1	NA	5	25%	11	175%	0	NA
BICMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS (Function)	50	35%	33	14%	1	NA	5	25%	11	175%	0	NA
MOS Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Micro Devices	38	27%	25	14%	1	NA	5	25%	7	75%	0	NA
MOS Logic	12	71%	8	14%	0	NA	0	NA	4	NA	0	NA
Analog	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Total Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Transistor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Diode	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Thyristor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Other Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Total Optoelectronic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA

Source: Dataquest
May 1991

26-Apr-91

ESTIMATED SEMICONDUCTOR REVENUE
Applied Micro Circuits Corp.

	Worldwide		North America		Japan		Europe		Asia/Pacific		Rest of World (exc. Asia/Pac	
	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89
Total Semiconductor	28	27%	27	29%	0	NA	1	0%	0	NA	0	NA
Total Integrated Circuit	28	27%	27	29%	0	NA	1	0%	0	NA	0	NA
Bipolar Digital (Technology)	24	20%	23	21%	0	NA	1	0%	0	NA	0	NA
TTL/Other	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
ECL	24	20%	23	21%	0	NA	1	0%	0	NA	0	NA
Bipolar Digital (Function)	24	20%	23	21%	0	NA	1	0%	0	NA	0	NA
Bipolar Digital Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Logic	24	20%	23	21%	0	NA	1	0%	0	NA	0	NA
MOS (Technology)	4	100%	4	100%	0	NA	0	NA	0	NA	0	NA
N/PMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
CMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
BICMOS	4	100%	4	100%	0	NA	0	NA	0	NA	0	NA
MOS (Function)	4	100%	4	100%	0	NA	0	NA	0	NA	0	NA
MOS Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Micro Devices	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Logic	4	100%	4	100%	0	NA	0	NA	0	NA	0	NA
Analog	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Total Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Transistor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Diode	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Thyristor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Other Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Total Optoelectronic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA

Source: Dataquest
May 1991

26-Apr-91

ESTIMATED SEMICONDUCTOR REVENUE

AT&T

	Worldwide		North America		Japan		Europe		Asia/Pacific		Rest of World (exc. Asia/Pac	
	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89
Total Semiconductor	861	-1%	805	-5%	7	NA	29	71%	20	186%	0	NA
Total Integrated Circuit	717	0%	673	-4%	7	NA	21	50%	16	433%	0	NA
Bipolar Digital (Technology)	59	5%	57	6%	0	NA	2	0%	0	NA	0	NA
TTL/Other	46	5%	44	5%	0	NA	2	0%	0	NA	0	NA
ECL	13	8%	13	8%	0	NA	0	NA	0	NA	0	NA
Bipolar Digital (Function)	59	5%	57	6%	0	NA	2	0%	0	NA	0	NA
Bipolar Digital Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Logic	59	5%	57	6%	0	NA	2	0%	0	NA	0	NA
MOS (Technology)	461	12%	431	8%	6	NA	18	50%	6	NA	0	NA
N/PMOS	67	20%	67	20%	0	NA	0	NA	0	NA	0	NA
CMOS	394	11%	364	6%	6	NA	18	50%	6	NA	0	NA
BICMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS (Function)	461	12%	431	8%	6	NA	18	50%	6	NA	0	NA
MOS Memory	13	0%	13	0%	0	NA	0	NA	0	NA	0	NA
MOS Micro Devices	145	3%	141	3%	0	NA	4	0%	0	NA	0	NA
MOS Logic	303	18%	277	11%	6	NA	14	75%	6	NA	0	NA
Analog	197	-21%	185	-25%	1	NA	1	NA	10	233%	0	NA
Total Discrete	130	-12%	126	-12%	0	NA	0	NA	4	0%	0	NA
Transistor	17	-11%	16	-11%	0	NA	0	NA	1	0%	0	NA
Diode	27	-13%	27	-13%	0	NA	0	NA	0	NA	0	NA
Thyristor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Other Discrete	86	-11%	83	-12%	0	NA	0	NA	3	0%	0	NA
Total Optoelectronic	14	40%	6	-14%	0	NA	8	167%	0	NA	0	NA

Source: Dataquest
May 1991

26-Apr-91

ESTIMATED SEMICONDUCTOR REVENUE

Atmel

	Worldwide		North America		Japan		Europe		Asia/Pacific		Rest of World (exc. Asia/Pac	
	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89
Total Semiconductor	123	31%	73	30%	7	-46%	35	84%	8	33%	0	NA
Total Integrated Circuit	123	31%	73	30%	7	-46%	35	84%	8	33%	0	NA
Bipolar Digital (Technology)	14	75%	8	33%	0	NA	6	200%	0	NA	0	NA
TTL/Other	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
ECL	14	75%	8	33%	0	NA	6	200%	0	NA	0	NA
Bipolar Digital (Function)	14	75%	8	33%	0	NA	6	200%	0	NA	0	NA
Bipolar Digital Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Logic	14	75%	8	33%	0	NA	6	200%	0	NA	0	NA
MOS (Technology)	98	34%	58	32%	7	17%	25	47%	8	33%	0	NA
N/PMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
CMOS	98	34%	58	32%	7	17%	25	47%	8	33%	0	NA
BICMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS (Function)	98	34%	58	32%	7	17%	25	47%	8	33%	0	NA
MOS Memory	54	15%	31	11%	3	0%	12	20%	8	33%	0	NA
MOS Micro Devices	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Logic	44	69%	27	69%	4	33%	13	86%	0	NA	0	NA
Analog	11	-15%	7	17%	0	-100%	4	NA	0	NA	0	NA
Total Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Transistor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Diode	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Thyristor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Other Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Total Optoelectronic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA

Source: Dataquest
May 1991

26-Apr-91

ESTIMATED SEMICONDUCTOR REVENUE

Bipolar Integrated Technology

	Worldwide		North America		Japan		Europe		Asia/Pacific		Rest of World (exc. Asia/Pac	
	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89
Total Semiconductor	1	0%	1	0%	0	NA	0	NA	0	NA	0	NA
Total Integrated Circuit	1	0%	1	0%	0	NA	0	NA	0	NA	0	NA
Bipolar Digital (Technology)	1	0%	1	0%	0	NA	0	NA	0	NA	0	NA
TTL/Other	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
ECL	1	0%	1	0%	0	NA	0	NA	0	NA	0	NA
Bipolar Digital (Function)	1	0%	1	0%	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Logic	0	-100%	0	-100%	0	NA	0	NA	0	NA	0	NA
MOS (Technology)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
N/PMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
CMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
BICMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS (Function)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Micro Devices	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Logic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Analog	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Total Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Transistor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Diode	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Thyristor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Other Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Total Optoelectronic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA

Source: Dataquest
May 1991

26-Apr-91 ESTIMATED SEMICONDUCTOR REVENUE

Brooktree

	Worldwide		North America		Japan		Europe		Asia/Pacific		Rest of World (exc. Asia/Pac	
	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89
Total Semiconductor	70	35%	53	26%	7	75%	7	40%	3	200%	0	NA
Total Integrated Circuit	70	35%	53	26%	7	75%	7	40%	3	200%	0	NA
Bipolar Digital (Technology)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
TTL/Other	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
ECL	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital (Function)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Logic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS (Technology)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
N/PMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
CMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
BICMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS (Function)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Micro Devices	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Logic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Analog	70	35%	53	26%	7	75%	7	40%	3	200%	0	NA
Total Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Transistor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Diode	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Thyristor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Other Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Total Optoelectronic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA

Source: Dataquest
May 1991

26-Apr-91 ESTIMATED SEMICONDUCTOR REVENUE

Burr-Brown

	Worldwide		North America		Japan		Europe		Asia/Pacific		Rest of World (exc. Asia/Pac	
	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89
Total Semiconductor	145	3%	45	2%	49	-2%	49	26%	2	-75%	0	NA
Total Integrated Circuit	145	3%	45	2%	49	-2%	49	26%	2	-75%	0	NA
Bipolar Digital (Technology)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
TTL/Other	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
ECL	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital (Function)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Logic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS (Technology)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
N/PMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
CMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
BICMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS (Function)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Micro Devices	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Logic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Analog	145	3%	45	2%	49	-2%	49	26%	2	-75%	0	NA
Total Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Transistor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Diode	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Thyristor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Other Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Total Optoelectronic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA

Source: Dataquest
May 1991

26-Apr-91

ESTIMATED SEMICONDUCTOR REVENUE
California Micro Devices

	Worldwide		North America		Japan		Europe		Asia/Pacific		Rest of World (exc. Asia/Pac	
	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89
Total Semiconductor	27	-10%	21	5%	0	NA	2	0%	4	-43%	0	-100%
Total Integrated Circuit	27	-10%	21	5%	0	NA	2	0%	4	-43%	0	-100%
Bipolar Digital (Technology)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
TTL/Other	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
ECL	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital (Function)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Logic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS (Technology)	8	0%	5	0%	0	NA	1	0%	2	0%	0	NA
N/PMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
CMOS	8	0%	5	0%	0	NA	1	0%	2	0%	0	NA
BICMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS (Function)	8	0%	5	0%	0	NA	1	0%	2	0%	0	NA
MOS Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Micro Devices	8	0%	5	0%	0	NA	1	0%	2	0%	0	NA
MOS Logic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Analog	19	-14%	16	7%	0	NA	1	0%	2	-60%	0	-100%
Total Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Transistor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Diode	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Thyristor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Other Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Total Optoelectronic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA

Source: Dataquest
May 1991

26-Apr-91

ESTIMATED SEMICONDUCTOR REVENUE
Catalyst

	Worldwide		North America		Japan		Europe		Asia/Pacific		Rest of World (exc. Asia/Pac	
	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89
Total Semiconductor	36	16%	14	8%	9	-10%	8	33%	3	NA	2	0%
Total Integrated Circuit	36	16%	14	8%	9	-10%	8	33%	3	NA	2	0%
Bipolar Digital (Technology)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
TTL/Other	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
ECL	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital (Function)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Logic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS (Technology)	35	13%	13	0%	9	-10%	8	33%	3	50%	2	NA
N/PMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
CMOS	35	13%	13	0%	9	-10%	8	33%	3	50%	2	NA
BICMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS (Function)	35	13%	13	0%	9	-10%	8	33%	3	NA	2	0%
MOS Memory	35	13%	13	0%	9	-10%	8	33%	3	NA	2	0%
MOS Micro Devices	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Logic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Analog	1	NA	1	NA	0	NA	0	NA	0	NA	0	NA
Total Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Transistor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Diode	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Thyristor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Other Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Total Optoelectronic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA

Source: Dataquest
May 1991

26-Apr-91

ESTIMATED SEMICONDUCTOR REVENUE

Cherry Semiconductor

	Worldwide		North America		Japan		Europe		Asia/Pacific		Rest of World (exc. Asia/Pac	
	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89
Total Semiconductor	36	13%	25	14%	0	NA	4	0%	7	17%	0	NA
Total Integrated Circuit	36	13%	25	14%	0	NA	4	0%	7	17%	0	NA
Bipolar Digital (Technology)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
TTL/Other	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
ECL	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital (Function)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Logic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS (Technology)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
N/PMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
CMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
BICMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS (Function)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Micro Devices	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Logic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Analog	36	13%	25	14%	0	NA	4	0%	7	17%	0	NA
Total Discrete ,	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Transistor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Diode	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Thyristor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Other Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Total Optoelectronic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA

Source: Dataquest
May 1991

Dataquest
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The Dun & Bradstreet Corporation

Research *Bulletin*

PHILIPS STRENGTHENS ITS POSITION IN SOUTHEAST ASIA

On October 3, 1989, N.V. Philips Gloeilampenfabrieken (Philips) informed the Board of Directors of Taiwan Semiconductor Manufacturing Company (TSMC) that it intended to exercise its option to acquire 51 percent of the shares of TSMC. Philips has stated that no management changes are planned for TSMC.

TSMC was founded in October 1986 as an integrated circuit foundry operation, jointly owned by the development fund of the Republic of China (48.3 percent), Philips of the Netherlands (27.5 percent), and a number of Taiwanese companies (24.2 percent). TSMC has shown remarkable performance during the two and one-half years of its existence. The company achieved a rapid start in early 1987 through a special arrangement with the Industrial Technology Research Institute (ITRI), which made an existing 6-inch fabrication facility available to the venture. Currently, TSMC is delivering 125,000 wafers per year. In 1988, construction began on a new wafer fabrication facility. This plant is scheduled to deliver commercial products in 1990 and ultimately will grow to an output of 480,000 6-inch wafers per year by 1993.

DATAQUEST CONFERS WITH PHILIPS' TOP MANAGEMENT

A Dataquest interview with several members of Philips Components B.U. Integrated Circuits top management revealed the following: Philips has adopted a strategy to further strengthen its global presence in the IC industry, particularly in the Far East, which Philips perceives to be the fastest-growing market of the next decade. With the Asia/Pacific region becoming a major force in the industry, Philips plans to make TSMC its bastion of the IC industry in that region. Philips believes that Asia/Pacific semiconductor consumption will surpass European consumption soon.

DATAQUEST ANALYSIS

Philips' Action—Provoking Concern

Dataquest believes that Philips and the TSMC management face some near-term challenges to assure existing and future foundry customers that all will be well. The knee-jerk reaction often associated with these types of transactions is to assume that Philips will preempt capacity for its own purposes during times of cyclical foundry shortages. Evidently, some "fabless" companies that are heavily dependent on TSMC experienced apprehension over the October 3 announcement. TSMC's decision to allocate a portion of its new capacity to provide foundry services for commodity memory products such as DRAMs and SRAMs may have exacerbated that anxiety. However, as Sigmund Freud said, "Sometimes a cigar is just a cigar." Although Dataquest is not privy to any private brainstorming in smoky Eindhoven back rooms, it appears that Philips is simply executing a well-conceived plan and following an investment strategy that would warm the hearts of most venture capitalists—i.e., to take a minority interest in the venture initially and share the risk with several partners. If the venture profits as originally promoted, Philips can continue with follow-on investments up to the option limits. The venture capitalists of Silicon Valley would be a happier lot if all their deals worked out as well as that of Philips and TSMC.

The Dutch—500 Years of Global Business Experience

For Philips to pursue any action that would not be in the best interests of its customers or would damage what appears to be a highly profitable business at TSMC would be illogical to the

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very logical Dutch, who have been conducting business on a global basis for more than 500 years. During the interview, Philips' management reminded Dataquest that the original shareholders' agreement binds Philips to guarantee that "TSMC will at all times be managed as an independent business enterprise on a commercial basis. Its profit and growth objectives shall bear the same priorities as in independent IC companies in the USA." Furthermore, we sense that Philips has decided that it must look far beyond Europe if it is going to maintain semiconductor growth levels consistent with its contemporaries on the top 10 list of worldwide semiconductor producers.

Asia/Pacific—The Economic Miracle of the 1990s

In a recent newsletter entitled "Semiconductor Megatrends of the 1990s," Dataquest predicted that the Asia/Pacific region will be the fastest growing area of the world in the 1990s in terms of electronics production, including semiconductors. That newsletter also stressed the importance of regional manufacturing and close proximity to customers from both a location and a service standpoint. Philips' decision to increase its commitment in TSMC appears to be consistent with these Dataquest concepts. Philips has action under way or has announced plans for the following:

- Marketing, selling, and order handling in Taiwan and South Korea
- Regional applications labs in Auckland, Bangkok, Bombay, Chengdu, Hong Kong, Seoul, Shanghai, Sidney, Singapore, Taipei, and Tokyo.
- IC design centers in:
  - Japan for consumer applications
  - Taiwan for industrial applications
- Manufacturing
  - Assembly in Taiwan, South Korea, Thailand, and the People's Republic of China
  - Test in Taiwan, South Korea, and Thailand
  - Fab in Taiwan and the People's Republic of China

DATAQUEST CONCLUSIONS

Given this substantial commitment to the Asia/Pacific region, Philips' recent decision to increase its participation in TSMC would appear to be entirely in order with long-term strategic goals. Assuming that Philips continues to execute its plans for the region successfully, Dataquest anticipates that Philips will be a powerful force to be reckoned with in the next decade.

David L. Angel

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Research *Newsletter*

SEMICONDUCTOR MEGATRENDS IN THE 1990s

INTRODUCTION

We are but a short time away from the last decade of this century. Many of our clients are now concentrating heavily on their strategies for the 1990s. What does the coming decade hold? What changes will have to be made to management philosophies in order to be a factor in the future? What new capabilities and financial and human resources will be required? What will be the major transitions in global events? This newsletter presents Dataquest's view of the elements that we believe will drive the semiconductor industry of the next decade. While it is certainly not destiny, it is an opinion based upon countless discussions with our clients throughout the world. It is a nontraditional Dataquest newsletter in that there are no hard facts, only speculation. It is our stake in the ground. We'll have to wait as long as ten years or more to see if we were right. In the meanwhile, we welcome your opinion as to how you foresee the next decade.

SEMICONDUCTOR MEGATRENDS IN THE 1990s

The following list contains our predictions for semiconductor megatrends in the '90s:

- Economic power will displace military power.
- Closeness to your customer will be an imperative.
- Electronics will pervade all aspects of society.
- Technological obsolescences will increase.
- Consolidation and retrenchment will become the norm.
- Southeast Asia's growth will lead the decade.
- The industry's capital intensity will intensify.
- Partnerships will become standard business practice.
- Software will be the king of the '90s.
- Japan will have peaked in growth and the United States will have bottomed.

Economic Power Will Displace Military Power

We believe that economic power will displace military power as the basis for worldwide dominance. Countries will shift their focus away from military spending and concentrate upon strategies to create economic might. Electronic and information transfer industries will be viewed as essential to establishing economic power. Global trade policies will become the new battleground, as entities throughout the world seek to protect or enhance their individual economic strengths. Companies that cannot compete on a global basis will realize growth rates and financial returns that are substantially less than industry averages.

The Imperative of Being Close to Your Customer

Region-based manufacturing will become an imperative of the next decade, as will an entirely new level of service. Driven by trade laws, local content requirements, and the new strategy of establishing factories close to the point of consumption, partnerships, such as the Acer/Texas Instruments consortium to produce DRAMs for the Taiwanese market, will become commonplace. This fact will hold true for the manufacture of electronic equipment as well as components. Japanese

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companies already have begun to establish substantial manufacturing capabilities in the United States, and both U.S. and Japanese companies are moving en masse into Europe with IC production factories. Product and price differentiation will be difficult; hence, service will become a new and powerful marketing tool.

Electronics Will Pervade All Aspects of Society

Electronics will become ubiquitous—a common denominator throughout all levels of society. Consumer electronics (with emphasis upon personal use) that are perceived to enhance one's life or offer opportunities for saving time will be key drivers during the early portion of the next decade. We see widespread consumption of ISDN-driven products, personal cellular telephones, home fax machines, home copiers and laser printers, home automation products, as well as personal entertainment systems. This bodes well for analog products as well as for mixed-signal and conventional digital devices. We do not see HDTV having significant impact on either consumers or IC producers until very late in the next decade.

Technological Obsolescences Will Increase

We predict that during the '90s, technological obsolescences will occur at an even faster rate than in the '80s. Product life cycles, despite increasing product complexity, will be shorter than in the past decade. Innovation, driven by astounding leaps in software technology and the information transfer industry, will place immense pressures on product survivability. Producing a product that can capture market leadership long enough to recover the investment cost of development will become a key challenge.

Consolidation and Retrenchment Will Become the Norm

The European, U.S., and Japanese semiconductor industries are expected to reach full maturation in the decade of the '90s. Annual growth rates will more closely follow those of traditional mature industries such as automobiles. Substantial consolidation will take place in the U.S. semiconductor industry, resulting in only a few, very large U.S. semiconductor producers by the end of the decade. Niche market players will become increasingly rare, finding that their markets of choice are too small to allow for annual research and development investments that are commensurate with industry averages. There will be a shakeout among the Japanese device producers as a result of too many participants entering the IC market from nontraditional sources such as the Japanese steel, chemical, and heavy industry companies. The majority of the retrenchments will come from ASIC entities that lack substantial vertical integration capabilities.

Southeast Asian Growth Will Lead the Decade

Southeast Asia will be the region exhibiting the greatest growth and the largest number of new IC ventures. Thailand will become the fifth tiger. Virtually all of the newly industrialized countries (NICs) will adopt the strategy that an indigenous semiconductor industry is essential to the development of a modern economy. The proliferation of ASIC design tools will enhance this region's goal of becoming independent of both Japan and the United States for the supply of complex ICs. India will become an important electronic equipment consumer and semiconductor device producer. The Eastern Bloc and Soviet countries will become significant electronic equipment consumers toward the end of the decade, as these entities realize the necessity of establishing economic rather than military power. China will be neither a significant consumer nor producer of semiconductors. Despite current rhetoric that China's modernization program is still top priority, the impact of the June 1989 events in Beijing will most likely continue well into the next decade.

The Industry's Capital Intensity Will Intensify

Dataquest foresees that the capital intensity of the industry will intensify. No longer will companies be able to use DRAMs as their sole process drivers. DRAM technology will pace lithography and three-dimensional events (trench capacitors); however, ASIC technology will set the cadence for multiple levels of interconnections, deposited films, and packaging developments. Consequently, broad market participants will have to make significant investments in both DRAM and ASIC technologies. Wafer fabrication facilities will be become product focused rather than process focused. Operations will be built principally for the lifetime of one specific product (e.g., 16Mb factories, 64Mb factories, 256Mb factories), with possible later-stage revamping for less demanding technologies. This scenario favors commodity memory producers over ASIC and analog producers for the greatest leverage of wafer fabrication capital investment.

Partnerships Will Become Standard Business Practice

Partnerships and technology transfer will become key strategies in the next decade. The staggering cost of technology will be only a portion of the problem to be solved. As product lifetimes decrease, the time to market for products will become predominant. Even a minor setback in product development could translate to missing an entire product cycle, recovery from which may be impossible. Partners not only will share the cost of the technology, but also will share the task of getting the product to market in time to minimize the risk of lost opportunity. The NICs will look to the established countries for technology. This know-how will be exchanged for local market access and assistance in establishing regional manufacturing capability. Companies that lack partnering skills or that cannot leverage their technology will suffer against their more adept global competitors.

Software Will Be the King of the '90s

As software standards become pervasive, hardware will become a commodity item. We predict that the Silicon Valley will realize an era of venture capital-backed software start-up companies that will rival the IC company start-up era of the '70s.

Japan Will Have Peaked in Growth; the U.S. Will Have Bottomed

Japan's amazing growth rate will peak very early in the decade. As the Japanese accept their position as the most wealthy people on earth, they will begin to enjoy the fruits of their efforts and lessen their obsession with economic survival. The younger Japanese generation, having never known the hardships of their elders, will be unwilling to make the same sacrifices of unquestioned long work hours, blind devotion to corporate goals, and lack of personal identity. This is not unique to the Japanese, but rather a continuing enactment of the drama that has portrayed every highly successful emerging nation including Ming China, the Ottoman Empire, the countries of Western Europe, Great Britain, and the United States. The United States has bottomed in its descent and is now finally addressing the decline in global competitiveness, deteriorating industries, poor product quality, the drug problem, and the seeming inability to create products that its citizens will buy. We believe that by the end of the century, Japan and the United States will be virtually at parity; however, Japan will still be slightly in the lead. Both nations will have shouldered many of the world's problems and will unite in their mutual anxiety over the ever-growing economic strength of Southeast Asia.

David L. Angel

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Research Newsletter

1990 OUTLOOK FOR CAPITAL SPENDING AND SEMICONDUCTOR SUPPLY: TWO CRITICAL FORCES FOR ELECTRONIC EQUIPMENT MAKERS

SUMMARY

The steadily growing global electronic equipment segment is a major component of worldwide economic growth and is contributing to dramatic shifts in the world's economic balance of power. In 1988, the worldwide electronic equipment market was estimated to be $760 billion (approximately 8 percent) out of $10 trillion of the worldwide output of goods and services as measured by the Organization for Economic Cooperation and Development (OECD). By 1990 , worldwide electronics equipment is forecast to be $851 billion.

In a recently completed focus report entitled *Semiconductor Industry Insights—1990,* Dataquest investigates the relationships among the economic trends in major regions of the world, the growth in capital spending as a driver of electronic equipment demand, and the relationship to semiconductor supply and demand. This newsletter is based on research from that report.

CAPITAL SPENDING—THE ULTIMATE DEMAND DRIVER

Any change in capital spending has a direct and significant impact on equipment demand, particularly in the data processing, communications, or industrial segments. Changes in consumer spending, however, have a greater direct impact on consumer electronic equipment.

The growth in worldwide demand for electronic equipment is determined by the growth in worldwide spending from the following three major economic sectors:

- Private, fixed, nonresidential investments (otherwise known as capital spending)
- Consumer spending
- Government spending

Figure 1 compares constant 1982 dollar values of worldwide consumer and capital spending with current dollar values of worldwide demand for electronic equipment. The following two observations can be made from this comparison:

- Approximately 40 percent of worldwide capital spending accounts for 60 percent of electronic equipment demand.
- Only 3 percent of worldwide consumer spending and some government spending account for the remainder (40 percent) of electronic equipment demand.

Growth of individual equipment segments is a function of the growth of the economic sectors in which the major purchases occur. For example, the data processing, industrial, and communications segments represent nearly 60 percent of the demand but are purchased mostly by the capital spending sector.

CAPITAL SPENDING OUTLOOK FOR 1990

Economic forecasts suggest a considerable slowing of worldwide capital spending through 1990. As shown in Figure 2, growth in capital spending is forecast to slow from approximately 11 percent in 1988 to less than 5 percent in 1990. This slowdown is expected to decrease the demand for electronic equipment from a 17 percent growth in 1988 to less than 5 percent growth by 1990.

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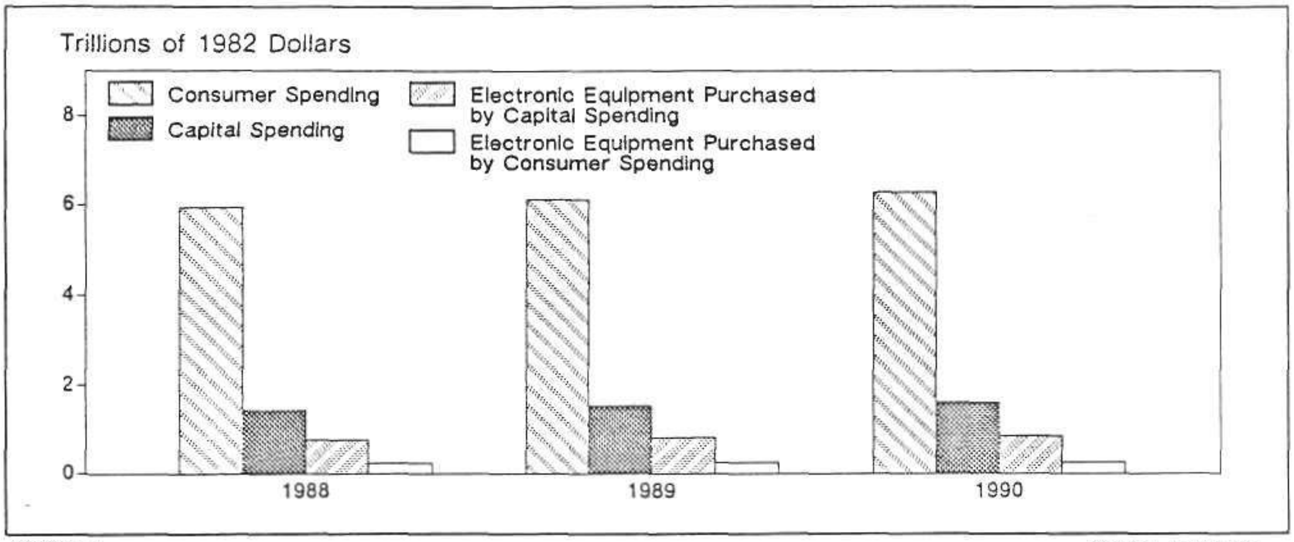
FIGURE 1
Consumer and Capital Spending versus Electronic Equipment Demand by Sector—1988-1990



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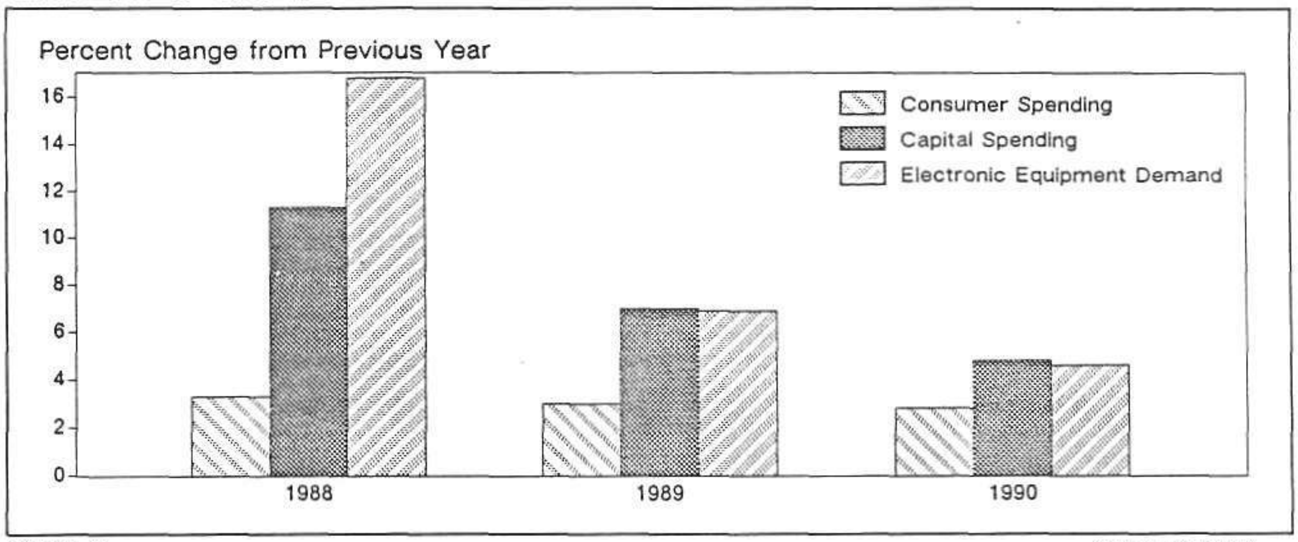
Source: Dataquest October 1989

FIGURE 2
Electronic Equipment Demand and Consumer and Capital Spending Annual Growth—1988-1990



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Source: Dataquest October 1989

Regional Economic Outlook and the Impact on Electronic Equipment

North America

Annual U.S. GNP growth was relatively strong in the first half of 1989 but is forecast to decline sharply from its 1988 level of 4.0 percent to an annualized rate of 1.2 percent by the third quarter and to 0.6 percent by the fourth quarter of 1989 for an average 1989 annual growth of 3.0 percent. The first quarter of 1990 is forecast to decline further to an annualized growth of negative 0.6 percent before a strong recovery in the balance of 1990. This relatively mild economic slowdown is expected to have a more dramatic effect on capital spending. Capital spending through the period is expected to average about 4.0 percent real growth as opposed to the 9.5 percent growth of 1988. As a result, the growth of North American demand for electronic equipment is expected to decline from the 16.2 percent level of 1988 to 5.8 percent in 1989 and only 2.7 percent in 1990.

Europe

The European electronic equipment demand is forecast to grow at an annual rate of 5.9 percent in 1989 and 5.1 percent in 1990, down from the 1988 level of 14.5 percent. Again, this is a result of the forecast slowing of real GNP/GDP growth and its amplified impact on capital spending throughout Europe. The European countries will avoid experiencing the full slowdown in the United States, largely because of the widespread capital spending by both European and Pacific Rim countries in preparation for the European Economic Community (EEC) market consolidation of 1992.

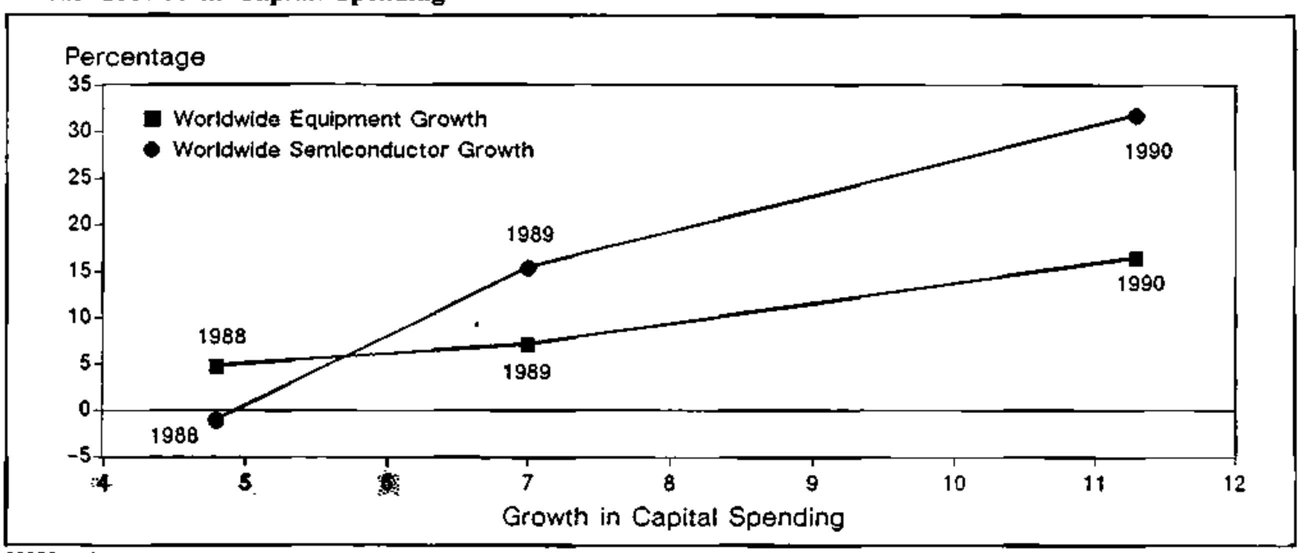
Japan and Asian ROW

Because the capital and consumer spending growth of Japan and the Asian newly industrialized countries (NICs) is not expected to fall as sharply as that of the North American and European regions, the growth rate for electronic equipment demand in these regions remains higher than in the other regions. The continued investment by Japanese electronics companies in offshore production will continue to stimulate demand growth in the Asian NICs. Consequently, the demand share for electronic equipment will continue to shift toward Asia and Japan. From 1988 to 1990, the combined share of Japanese and Asian NICs' demand is forecast to grow from 27 to 28 percent.

Semiconductor Pervasiveness

Electronic equipment production directly determines the demand for semiconductors. The success and growth of electronic equipment producers within a given region determines the size and growth of the total available market for semiconductors within that region. Electronic equipment manufacturers and semiconductor manufacturers are intertwined in the global economy. Figure 3 shows the relationship between year-to-year growth in capital spending and growth in both electronic equipment production and semiconductor consumption. Figure 4 shows the estimated value of semiconductors consumed in the United States versus the estimated value of electronic equipment produced in the United States. In addition to the growth in absolute value, the pervasiveness (semiconductor value as a percentage of total value) also grows each year. *This means that electronic*

FIGURE 3
Annual Growth in Electronic Equipment Demand and Semiconductor Consumption versus Growth in Capital Spending



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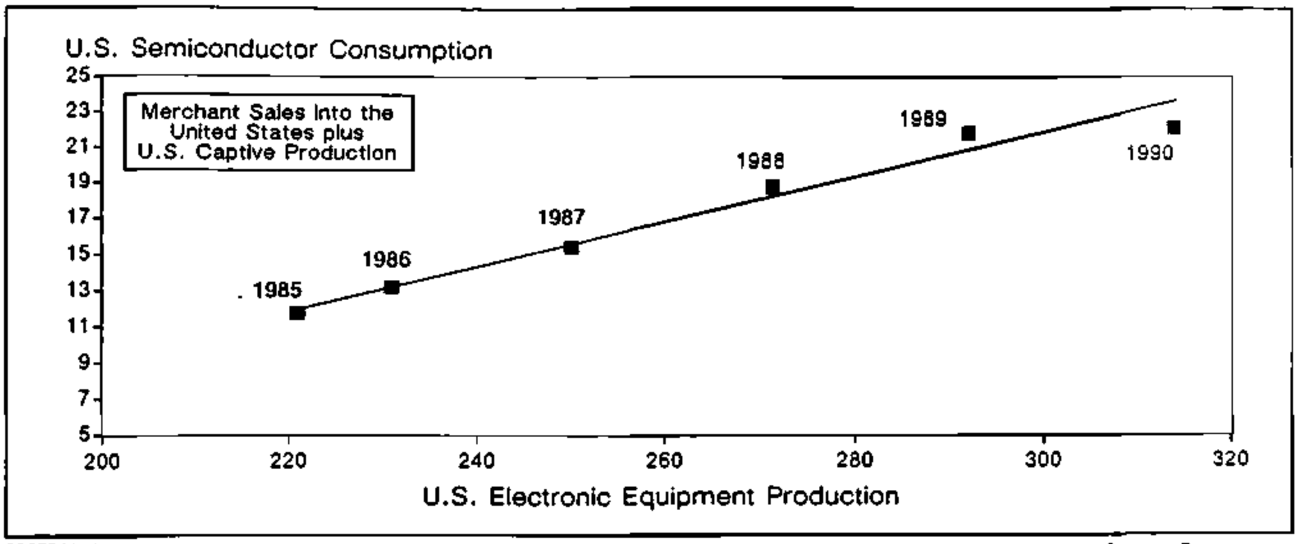
Source: Dataquest October 1989

Figure 4
U.S. Semiconductor Consumption versus U.S. Electronic Equipment Production (Billions of Dollars)



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Source: Dataquest
October 1989

equipment manufacturers are becoming increasingly dependent on access to advanced semiconductor devices to remain technically competitive. Therefore, the economic outlook for the semiconductor industry and future trends in the sources of supply are critical issues for electronic equipment manufacturers.

DATAQUEST ANALYSIS— SEMICONDUCTOR CAPITAL SPENDING CHALLENGE

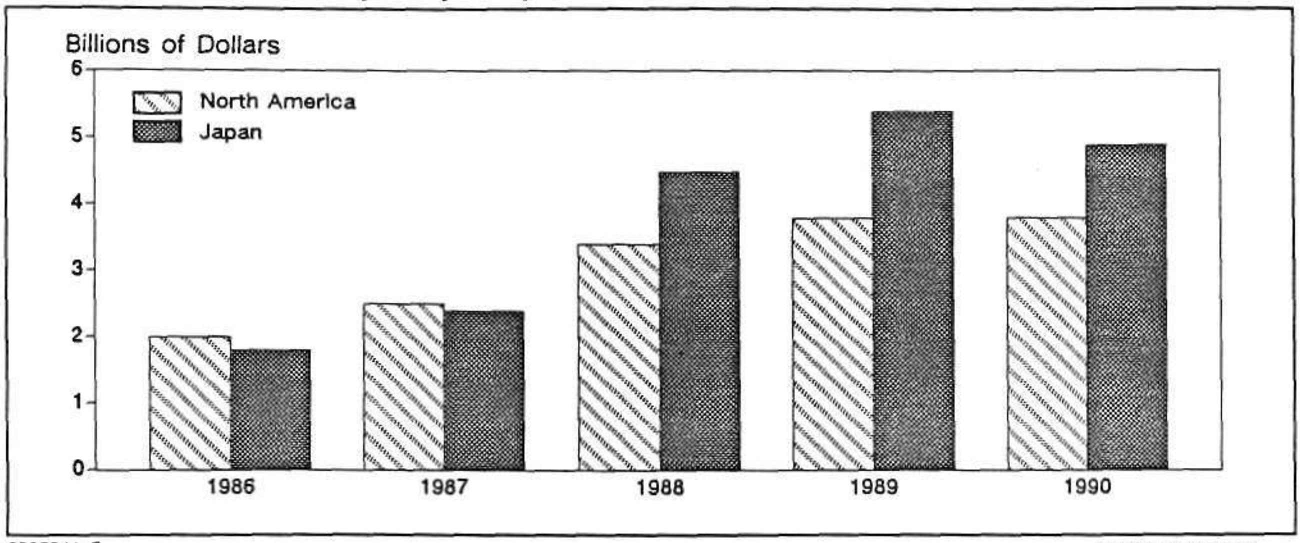
The battle among regional companies for semiconductor market share has more importance than receiving a greater share of total revenue in any given year. For U.S. companies that operate in the highly unforgiving and short-sighted financial environment of the U.S. investment community, market share is the fountainhead of reinvestment. Ultimately, access to investment capital to fund research and development and capital equipment for improving yields or expanding capacity is the lifeblood of long-term survival.

Capital spending on semiconductor production equipment for North American and Japanese companies is shown in Figure 5. A key question regarding the future of the U.S. semiconductor industry is whether or not it can obtain the funds to keep up with Japanese capital spending. In dollar terms, U.S. companies have not kept up with Japanese companies since the early 1980s. The expected Japanese spending levels exceed those of the United States by almost 50 percent and are expected to do so through 1990. The net effect of these spending-level differences is shown in Figure 6. It is clear that Japanese companies had a larger 1988 base of semiconductor production capacity than U.S. companies, and they are adding to that base at a faster pace.

Dataquest believes that U.S. semiconductor companies are failing to invest quickly enough in the rapidly growing semiconductor industry and therefore are giving away market share. A strategic question for U.S. equipment manufacturers is how to ensure a secure source of semiconductors as the manufacturing capability for leading-edge devices shifts farther and farther away.

Mel Thomsen

FIGURE 5
Estimated Semiconductor Capital Spending—1986-1990



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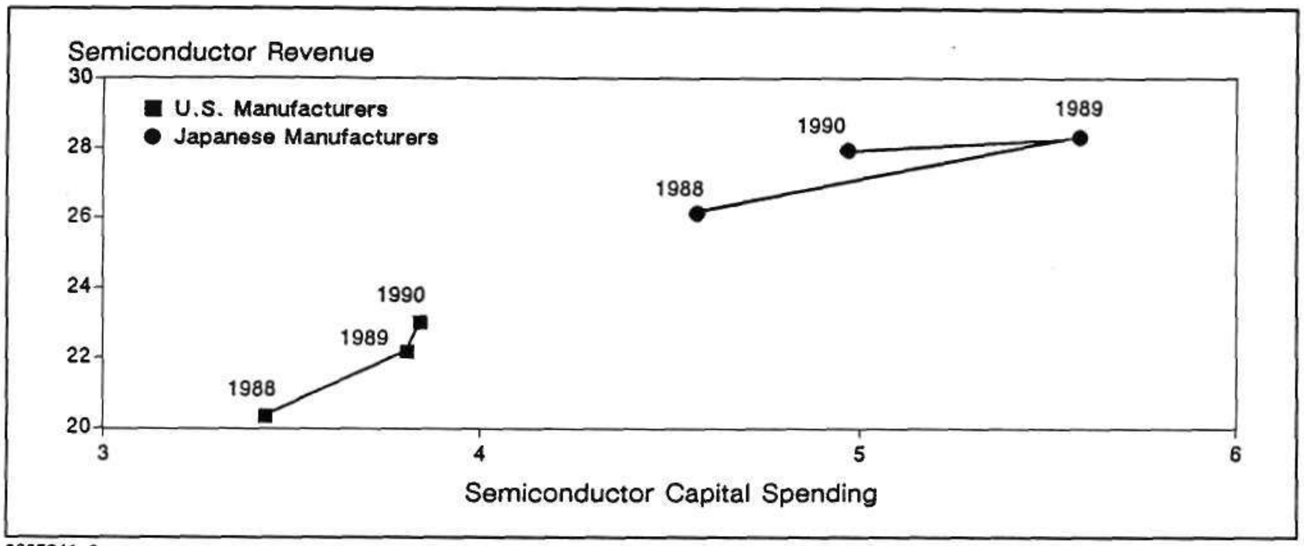
Source: Dataquest
October 1989

FIGURE 6
Semiconductor Revenue versus
Capital Spending—1988-1990



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Source: Dataquest
October 1989

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Research Newsletter

DRAMS DROP DRAMATICALLY! (PRICES, THAT IS)

SUMMARY

Dataquest's early 1989 prediction of 1Mb DRAM prices falling lower than $10.00 by the fourth quarter of 1989 appears to be coming true. Dataquest has learned that virtually all of the major Japanese DRAM producers are rapidly scaling back production of 1Mb DRAMs in an attempt to forestall a complete collapse of 1Mb DRAM prices on the world market. We believe that several of the major producers are accumulating inventory at an acute rate. We have observed large contract prices as low as ¥1,300 ($9.29) in Tokyo, an effort, we believe, to reduce inventory and regain control over the market. It may be too late. Sources in Southeast Asia report 1Mb DRAM contracts being written in the $7.00 range. We very recently learned of a large allocation of parts entering the United States with an $8.00 price tag. All of this is occurring at a time when non-Japanese DRAM producers are increasing production and realizing substantial yield increases. Although not assiduously supported, there is a growing opinion that prices could go as low as ¥900 in Tokyo before beginning to edge upward again. In the face of all of these recent events, there is, nevertheless, the potential of a 1Mb DRAM shortage by late spring of 1990.

FIRST IMPRESSIONS ARE USUALLY LASTING

In the first quarter of 1989, Dataquest advised its semiconductor clients of the following predictions regarding 1Mb DRAMs in 1989:

- Dataquest believed that there would be a softening in the worldwide semiconductor industry in the fourth quarter of 1989.
- Dataquest believed that the supply of 100ns, 1Mb DRAMs had already exceeded the demand and that the supply of 80ns, 1Mb DRAMs would exceed demand by early summer.
- Dataquest believed that the selling price of 80ns, 1Mb DRAMs would be less that $10 by the fourth quarter of 1989.
- Dataquest believed that non-Japanese DRAM suppliers, specifically Samsung, would be major factors in the market.

IT DOESN'T ALWAYS TURN OUT THE WAY YOU PLANNED

In April of this year, the authors of this newsletter, Dave Angel and Fred Jones (head of Dataquest's memory group), visited nearly all of the major Japanese DRAM producers. We presented the scenario outlined above, which was met with less than enthusiastic acceptance. Rather, there was virtually a universal consensus, from the Japanese perspective, that the following statements more accurately represented the 1989 DRAM story:

- There would not be a decline in the semiconductor industry in 1989. Rather, the downturn would occur in the second quarter of 1990.
- Prices for 1Mb DRAMs would not fall below the $12 to $15 range in 1989.
- South Korean suppliers would not be able to ramp up production of 80ns parts fast enough to significantly affect 1989 shipments or prices.
- The Japanese suppliers were much more sophisticated than in previous semiconductor cycles and were confident in their ability to manage the situation so that severe oversupply and price erosion would not result.

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Trust Your Instincts

Although neither Dave nor Fred was entirely sanguine about this possible version of the 1989 DRAM world, it was recognized that if this many major DRAM producers believed this version to be true, combined with an obviously improved ability to manage the situation, it was possible that a sharp downturn in 1989 prices could be moderated. As such, we revised our forecast to reflect a fourth quarter selling price of $12. It now appears that we should have trusted our instincts and retained our original forecast.

DAMAGE CONTROL

Based upon information received this week, we have learned that Hitachi, NEC, and Toshiba are all cutting back production of 1Mb DRAMs. Hitachi has acknowledged a 10 percent reduction in 1Mb production; however, other sources suggest that the number is closer to 15 percent. NEC has cancelled plans to increase production from 6 million per month to 8 million per month. Toshiba earlier reduced production from 10 million to 9 million per month and is now reported to be idling to 8 million per month. We believe that virtually all of the major Japanese DRAM producers are currently redirecting production toward SRAMs and mask ROMs and away from DRAMs.

MORE BAD NEWS

Other factors that we believe will exacerbate the situation and force prices downward include the following:

- Dataquest believes that 1Mb finished goods inventories among several of the top Japanese DRAM producers has grown sharply. One leading producer may have as much as two months inventory. This is not mysterious. Like a battleship moving at top speed, it takes a certain amount of time to slow down (or redirect) production. Bear in mind that virtually all major and second-tier suppliers have been focusing all of their energies on increasing production of 1Mb DRAMs, only now to have to throw the switch into reverse on very short notice. It makes sense that the overshoot represents more than just a few million parts.
- The non-Japanese suppliers, including South Korean, U.S., and European DRAM producers, are continuing to increase production. It has been reported that Samsung is now producing 6 million 1Mb DRAMs per month, up from a previous level of 2 million to 3 million per month. This is still significantly less than Samsung's stated capacity for 1Mb DRAMs. Yield among later-starting Japanese and non-Japanese producers has improved substantially in the last quarter, particularly for the high-speed parts. Hence, even without starting more wafers, the number of die being produced is spiraling upward. Not unlike a nuclear reactor that is going critical, despite of all the best efforts to stop the action, considerable damage will be done before conditions are under control once again.

DATAQUEST ANALYSIS

We believe that the Japanese DRAM producers will take necessary steps to reduce inventories and defend falling market shares. "Necessary steps" translates to lowering prices. We have already observed large contract prices of ¥1,300 ($9.29 @ ¥140/US$1) in Tokyo. One of the top three Japanese DRAM producers has denied that it planned to lower 1Mb DRAM prices to ¥1,300 for Southeast Asian destinations. This may be largely academic at this point. Dataquest has observed 1Mb DRAM prices from South Korean sources being quoted as low as $7.80 in Southeast Asia. Nor are the United States or Europe immune from falling prices. We have learned that there are approximately 2 million 1Mb, South Korean-sourced DRAMs in stock in the United States targeted for sale in the $8.00 range.

Our view of the *average* price situation for 1Mb DRAMs at this time is as follows:

Quarter 4 1989	$10.00	Quarter 2 1990	$8.00
Quarter 1 1990	$ 8.90	Quarter 3 1990	$7.50

Haven't We Met Before?

There is one scenario that suggests that we could return to a mild 1Mb DRAM shortage by the second quarter of 1990. With the major Japanese suppliers standing on the production brake pedal, as many as 5 million to 10 million units could be pulled out of the market by early spring of 1990.

By this time, the South Korean, the U.S., and potentially the European suppliers will be experiencing severe price shock and will have concluded that they also should curtail production. All of this could occur just at the time when the electronics industry is recovering from the forecast mild slowdown in quarter 4 of 1989 and quarter 1 of 1990. Users will have all but eliminated inventory throughout the fall and winter as a defense against inventories being valued higher than existing market prices, à la Apple. The renewed demand for 1Mb devices will encounter a supply industry that has idled production and changed its focus to SRAMs. We believe that there could be an undershoot in supply of 1Mb DRAMs similar to the overshoot mentioned above.

The last remaining unknown in this complex equation is the effect of the 4Mb DRAM. Will the leading 1Mb DRAM suppliers, sensing that the high-profit days of this device are over, increase production of the 4Mb devices and combine them with price reductions to ensure retention of market leadership and induce users to convert to 4Mb devices? If so, this action could lead to an entirely new round of worldwide DRAM price cutting, given that the volume supply of 4Mb DRAMs is coming to market just at a time when memory prices are clearly soft. We will address this issue in another newsletter to be released shortly. **Have courage!**

David L. Angel
O. Fred Jones

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Research Newsletter

WORLDWIDE SEMICONDUCTOR OUTLOOK: FOURTH QUARTER 1989

INTRODUCTION

Dataquest has lowered its forecast for worldwide semiconductor industry growth in 1989 slightly, from 12.3 percent in the July forecast to 11.0 percent in this forecast. Second quarter results were slightly lower than the July forecast, and memory pricing is dropping slightly faster than anticipated in that forecast. In the short term, we now believe that the industry is experiencing a minirecession that began in the third quarter of 1989 and will continue through the first quarter of 1990. We are seeing increased semiconductor inventories at both the vendor and user levels, sharp decreases in 1Mb DRAM prices, and a definite slowing of semiconductor order rates. We believe that the situation will begin to improve in the second quarter of 1990 and that shipments will be moderately strong by the fourth quarter of 1990, with a 1.5 percent worldwide growth rate in 1990.

In the long term, Dataquest believes that the industry will experience moderate growth in 1991 and strong growth in 1992 and 1993, with the peak year of the growth cycle occurring in 1993. This forecast is based on the peaking of volume shipments of 4Mb DRAMs, the availability of 8-inch wafers for volume production, historical cyclical trends, and the 1992 effect in Europe. We believe that 1994 will be a year of significantly slower growth and could be the beginning of a major industry recession.

Dataquest expects the Asia/Pacific region to be the fastest growing region through 1994, Europe to be the second-fastest growing region, and Japan and North America to be almost on par with each other. Europe already is benefiting from a major move by both electronic equipment and semiconductor manufacturers to manufacture in Europe because of preparations for a unified Europe in 1992. We expect some of the semiconductor shipments that previously would have been consumed in North America or Japan to be consumed in Europe in the future.

Table 1 compares Dataquest's July quarterly regional forecast with the October forecast. In each region, our forecast was quite close to the actuals, which were based on Dataquest's polling of the industry. Table 2 gives our new annual forecast by region for 1989 through 1994. Table 3 provides Dataquest's worldwide forecast by product for 1989 through 1994.

REGIONAL ANALYSES

Japan

Exchange rates could again have a major effect on dollar-based Japanese semiconductor consumption. In 1985 through 1988, the yen rose dramatically, thereby artificially raising consumption in dollars. However, in 1989 the trend is reversing itself slightly, and the dollar has been appreciating against the yen. This could cause dollar growth to be lower than yen growth.

Many Japanese electronic equipment and automobile manufacturers are moving their manufacturing to North America and Europe. This relocation should cause semiconductor consumption in those regions to grow at a faster rate than Japanese consumption, thus reversing the prevailing trend of the 1980s.

Changes in consumer behavior in Japan also will have a dampening effect on semiconductor consumption. For some time, the Japanese have been ever ready to purchase the latest electronic gadgets. This trend is slowing as the Japanese consumer electronics market becomes saturated. This change will adversely affect consumer electronic equipment production and semiconductor consumption in Japan to a degree.

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TABLE 1
Worldwide Semiconductor Consumption
Comparison of July 1989 and October 1989 Forecasts
Quarter-to-Quarter Percent Change by Geographic Region

Region	1988	Q1 1989	Q2 1989	Q3 1989	Q4 1989	Total 1989
North America July	23.2%	4.7%	5.3%	0.7%	(0.9%)	15.0%
North America October	23.2%	4.7%	5.8%	(0.5%)	(1.8%)	14.4%
Japan July	39.2%	(6.7%)	3.0%	0.7%	(1.1%)	8.1%
Japan October	39.2%	(6.7%)	1.1%	0.8%	(2.3%)	6.3%
Europe July	30.7%	8.6%	(1.9%)	(3.2%)	9.2%	14.7%
Europe October	30.7%	8.6%	(1.7%)	(3.6%)	3.4%	13.1%
Asia/ROW July	45.0%	(6.5%)	6.9%	6.5%	5.6%	17.1%
Asia/ROW October	45.0%	(6.5%)	8.7%	2.6%	2.3%	15.3%
Total World July	33.0%	(0.8%)	3.3%	0.7%	1.5%	12.3%
Total World October	33.0%	(0.8%)	2.9%	(0.1%)	(0.6%)	11.0%
		Q1 1990	Q2 1990	Q3 1990	Q4 1990	Total 1990
North America July		(3.0%)	(2.4%)	3.2%	4.8%	(1.1%)
North America October		(2.5%)	1.4%	3.0%	2.5%	0.3%
Japan July		(3.2%)	1.4%	2.3%	3.8%	0.2%
Japan October		(4.1%)	3.8%	0.8%	6.6%	(0.4%)
Europe July		(0.9%)	1.7%	(0.5%)	6.7%	6.5%
Europe October		1.7%	2.0%	(2.8%)	7.4%	3.8%
Asia/ROW July		(1.2%)	2.9%	3.1%	5.2%	13.3%
Asia/ROW October		(1.7%)	2.5%	2.6%	3.7%	7.6%
Total World July		(2.5%)	0.5%	2.2%	4.8%	2.4%
Total World October		(2.3%)	2.6%	1.1%	5.1%	1.5%

Source: Dataquest
October 1989

During most of the 1980s, Japan has experienced trade problems with the United States and Europe. Changes in political leadership in Japan and its major trading partners could exacerbate these problems over the period of our forecast.

Electronics companies in the newly industrialized economies (NIEs), such as Samsung and GoldStar, are providing stiff competition to Japanese electronics firms, both equipment and semiconductor manufacturers, with their strong growth, heavy capital investment, and lower labor costs.

The following applications are driving the semiconductor market in Japan:

- Office automation—Word processors, copiers, facsimiles, and laser printers
- Computers—Laptops, mainframes, and supercomputers
- Artificial intelligence (AI)
- Satellites and military/space programs
- Automobiles
- Domestic—Microwave ovens, refrigerators, washing machines, and dishwashers

TABLE 2
Worldwide Semiconductor Consumption (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994
North America	$15,844	$18,124	$18,187	$20,770	$24,936	$32,876	$34,850
Percent Change	23.2%	14.4%	0.3%	14.2%	20.1%	31.8%	6.0%
Japan	20,772	22,082	21,998	25,114	30,061	38,642	42,111
Percent Change	39.2%	6.3%	(0.4%)	14.2%	19.7%	28.5%	9.0%
Europe	8,491	9,600	9,969	11,454	13,735	17,991	20,010
Percent Change	30.7%	13.1%	3.8%	14.9%	19.9%	31.0%	11.2%
Asia/ROW	5,752	6,633	7,141	8,573	10,675	14,803	16,308
Percent Change	45.0%	15.3%	7.7%	20.1%	24.5%	38.7%	10.2%
Total World	$50,859	$56,439	$57,295	$65,911	$79,407	$104,312	$113,279
Percent Change	33.0%	11.0%	1.5%	15.0%	20.5%	31.4%	8.6%

Source: Dataquest
October 1989

- Audio and video equipment
- High-definition television (HDTV)
- Integrated services digital network (ISDN)
- Home automation and security systems

The GDP forecast for Japan is slightly higher than for the United States and Europe, but significantly lower than the Asian economies of South Korea, Hong Kong, and Taiwan. In early 1989, Japanese consumers restrained their spending out of respect for the dying Emperor Hirohito. After months of scandal, a new Japanese Prime Minister is in office, and the socialists have become a strong influence in the Diet, campaigning on a pledge to remove the 3 percent sales tax (VAT) and replace that lost revenue with capital gains taxes.

During the next five years, domestic demand is expected to provide the main boost to Japan's growth, rising by an average of 4.25 percent. External demand is expected to contract, cutting Japan's trade surplus.

MITI forecasts corporate capital expenditure in the current fiscal year to slow to 11 percent, down from 20 percent last year. Manufacturers will increase their investments more than the average, growing 15.5 percent.

In 1988, wages increased 4 percent, while inflation was only 1 percent. Therefore, real income and private consumption increased. The proposed socialist tax reforms, if instituted, should help boost consumer spending.

Overcapacity for semiconductor production is not expected to be a problem in Japan, at least through 1993. In 1994, capacity utilization rates may drop, however, the result of large fabs that will be built in the early 1990s and a drop in demand. Dataquest expects semiconductor capital spending in Japan to grow approximately 2 percent in 1990 and resume very strong growth (between 30 and 40 percent) in 1991 through 1993. We believe that capital spending will decrease sharply in 1994.

Semiconductor inventory levels in Japan are rising. Inventories were up 7 percent at the end of the second quarter from the beginning of the year, and MOS memory inventories were up 20 percent from the beginning of the year.

North America

Surveys of semiconductor purchasers in North America show that average semiconductor orders have been declining rather dramatically since July, although lead times have remained fairly stable at about 10 weeks. Semiconductor inventory levels (at OEMs) are currently much higher than target inventory levels, primarily because of DRAM inventory levels.

The U.S. GNP is forecast to grow by only 2.6 percent in both 1989 and 1990, a definite slowdown from 1988's 4.4 percent (restated in July 1989). Dataquest expects GNP growth to pick up in the latter half of 1990 and increase to 3.2 percent growth in 1991. Dun & Bradstreet's outlook indicates that the economy will slow down in the second half of 1989 and the first half of 1990 but will stop short of recession. Overall capital spending is expected to improve, but not dramatically.

Dataquest does not anticipate a semiconductor production overcapacity situation in the United States until 1994, because U.S. manufacturers are better controlling their investment in new plants. We believe that semiconductor capital spending will be up 11 percent in 1989, will be flat in 1990, and will resume strong growth in 1991 through 1993.

Dataquest's indicators for the North American semiconductor market all show that the current slowdown is more than a seasonal "blip" for both semiconductor suppliers and users. Dataquest expects the fourth quarter to be worse than the third for suppliers as backlog built in the first half finally erodes. With orders down, inventories up, and system demand shaky, we do not foresee a recovery to occur earlier than the second quarter of 1990. System OEMs will continue to focus heavily on cost-cutting measures (e.g., pricing, inventories, and quality) that will have a negative impact on suppliers without their own cost-reduction plans in place. Dataquest believes that semiconductor suppliers must match the economizing now occurring in their customer bases.

TABLE 3
Worldwide Semiconductor Consumption (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	$50,859	$56,439	$57,295	$65,911	$79,407	$104,312	$113,279
Percent Change	33.0%	11.0%	1.5%	15.0%	20.5%	31.4%	8.6%
Total Integrated Circuit	$41,068	$46,761	$47,537	$55,111	$67,301	$90,264	$97,765
Percent Change	37.4%	13.9%	1.7%	15.9%	22.1%	34.1%	8.3%
Bipolar Digital	5,200	4,409	4,089	4,255	4,497	4,832	4,577
Percent Change	9.2%	(15.2%)	(7.3%)	4.1%	5.7%	7.4%	(5.3%)
Bipolar Memory	689	543	497	492	457	442	421
Percent Change	11.0%	(21.2%)	(8.5%)	(1.0%)	(7.1%)	(3.3%)	(4.8%)
Bipolar Logic	4,511	3,866	3,592	3,763	4,040	4,390	4,156
Percent Change	9.0%	(14.3%)	(7.1%)	4.8%	7.4%	8.7%	(5.3%)
MOS Digital	26,988	33,554	34,474	40,385	50,312	69,981	75,630
Percent Change	54.5%	24.3%	2.7%	17.1%	24.6%	39.1%	8.1%
MOS Memory	11,692	16,884	17,078	19,415	24,143	35,417	38,300
Percent Change	93.1%	44.4%	1.1%	13.7%	24.4%	46.7%	8.1%
MOS Microdevice	7,144	7,431	7,781	9,412	11,666	15,914	17,486
Percent Change	39.9%	4.0%	4.7%	21.0%	23.9%	36.4%	9.9%
MOS Logic	8,152	9,239	9,615	11,558	14,503	18,650	19,844
Percent Change	29.2%	13.3%	4.1%	20.2%	25.5%	28.6%	6.4%
Analog	8,880	8,798	8,974	10,471	12,492	15,451	17,558
Percent Change	16.0%	(0.9%)	2.0%	16.7%	19.3%	23.7%	13.6%
Total Discrete	$7,612	$7,622	$7,649	$8,424	$9,380	$10,835	$11,873
Percent Change	14.4%	0.1%	0.4%	10.1%	11.3%	15.5%	9.6%
Total Optoelectronic	$2,179	$2,056	$2,109	$2,376	$2,726	$3,213	$3,641
Percent Change	27.5%	(5.6%)	2.6%	12.7%	14.7%	17.9%	13.3%

Source: Dataquest
October 1989

Europe

The situation in Europe is more positive than in Japan and North America because of the "1992 Effect." Many Japanese and North American electronic equipment manufacturers are planning to build, are building, or have built plants in Europe in preparation for 1992. In response to this increased demand, foreign chip suppliers also are building plants in Europe. These developments have had a very strong psychological effect on many of the European manufacturers that currently have facilities in the Asia/Pacific region, causing them to move these facilities back onshore to Europe. GEC-Plessey Telecom's plan to assemble PCs in Scotland is a classic example of this European shift to production back onshore.

Consumer and telecommunications applications are driving the semiconductor market in Europe. New products include CT2 cellular telephony and satellite receivers for domestic television services. The current slowdown in the European semiconductor market is the result of reduced demand from the data processing sector (specifically PC clone manufacturers), as well as a slowdown in demand from the telecommunications central office switching gear sector, which is in the midst of European Community (EC) PTT deregulation. Dataquest's industry surveys show that semiconductor users have been in a phase of reducing inventories for the past three months. This trend is expected to continue through the end of 1989 as DRAMs and SRAMs become more easily available. The major European data processing manufacturers are in a particularly bad state currently, with more than six months of inventory in some semiconductor products. Dataquest expects the unification of European standards in 1992 to have a strongly positive effect on the development of new end-equipment markets for semiconductors in the long term. Especially promising are Group Standarde Mobile (GSM), a pan-European cellular telephone standard, and Radio Data Systems (RDS), a service that offers special-report broadcasts for car radios.

The major European economies are forecast to have GNP growth on par with or slightly above the United States in 1989 and 1990. In France, VAT rates have been reduced on luxury items, books, and public transport. Some consumer electronics goods (such as hi-fis) are subject to the luxury VAT. West Germany has inflation fears prompted by the fall of the deutsche mark, increasing consumer prices, higher oil prices, and large wage increases. Some consumer taxes are going up in West Germany. The United Kingdom is plagued by extremely high interest rates of approximately 14 percent. As a result, demand for mortgages and housing prices have dropped. Inflation is still high at 8 percent.

Asia/Pacific

The Asia/Pacific region will continue to be the fastest-growing region for semiconductor consumption during the period of this forecast. The economies of the Four Tigers and other Asian countries are expected to have continuing high GNP growth rates that range from 6.2 percent to 9.7 percent through 1989 and 1990. Problems that face the Asian market in the short term are wage hikes, domestic unrest, currency appreciation, and international trade tensions. Continuing into the long term, the governments' drives for technology development and the emergence of larger domestic markets for electronic goods will assist semiconductor shipment growth into this region.

Semiconductor capital spending continues to be very strong in Asia. Dataquest forecasts this region to have the highest capital spending increases of any region during our forecast period.

DATAQUEST CONCLUSIONS

The slowdown in the worldwide semiconductor industry has begun. A minirecession started in the third quarter and is forecast to last through the second quarter of 1990. Dataquest believes that the semiconductor industry will pick up again in the third quarter of 1990 as computer demand turns up, inventory problems are worked through, and prices begin to increase.

The Asia/Pacific region, with its fast-growing economy and aggressive capital spending, is poised to continue as the fastest-growing semiconductor market. Europe is already reaping the benefits of the 1992 Effect, which should continue to gain momentum over the coming years. We have no doubt that Europe's gains will come at the expense of the Japanese and North American markets.

Patricia S. Cox

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Research Newsletter

FINAL 1988 WORLDWIDE SEMICONDUCTOR MARKET SHARE ESTIMATES BY APPLICATION SEGMENT

SUMMARY

This newsletter presents Dataquest's final estimates for 1988 worldwide application segment market share by semiconductor vendor. Dataquest is publishing these data for the first time, the results of a recent survey of the top 40 worldwide semiconductor suppliers by region. The following is Dataquest's analysis based on this new information:

- Data processing emerged as the leading application market worldwide for semiconductors in 1988 with shipments of $21,606 million, representing 42.5 percent of the market.
- Not surprisingly, Japan had the largest market share, with $20,772 million in semiconductor shipments maintained by both a strong data processing and consumer base, which together represent 72.6 percent of the Japanese market.
- A large portion of growth within the data processing application segment was fueled by MOS digital technology, with shipments of $14,270 million, or 66.0 percent. In particular, MOS memory drove most of the growth, representing 55.6 percent of MOS digital within the data processing application segment.
- NEC was the leading vendor in the data processing segment, with shipments of $2,188 million representing 10.1 percent of the market.

Table 1 lists each of the application segments worldwide along with their respective semiconductor shipments in dollars and percentages of the market.

TABLE 1
Estimated 1988 Worldwide Semiconductor Shipments by Application Segment (Millions of Dollars)

Company	Revenue	Percent
Data Processing	$21,606	42.5%
Communications	7,641	15.0
Industrial	5,912	11.6
Consumer	10,959	21.5
Military	2,257	4.4
Transportation	2,484	4.9
Total	$50,859	100.0%

Note: Does not include North American captive shipments.
Columns may not add to totals shown because of rounding.

Source: Dataquest October 1989

REGIONAL ANALYSIS

Figure 1 illustrates that Japan-based companies are leaders in both the data processing and consumer markets with $11,795 million and $7,435 million in semiconductor shipments, respectively. Japanese companies represented a 49.3 percent share of the data processing market and a 67.7 percent share of the consumer market. These companies held 48.5 percent of the total semiconductor market (including captive) in 1988.

North America was slightly ahead of Japan in a close competition in the worldwide data processing application segment with a 7 percent difference in semiconductor shipments between regions (see Figure 2). Japan holds a dominating lead in the consumer applications segment, which is virtually untapped by foreign suppliers. This situation presents a potential market opportunity for these suppliers, because the consumer applications market represented the second largest worldwide application market in 1988.

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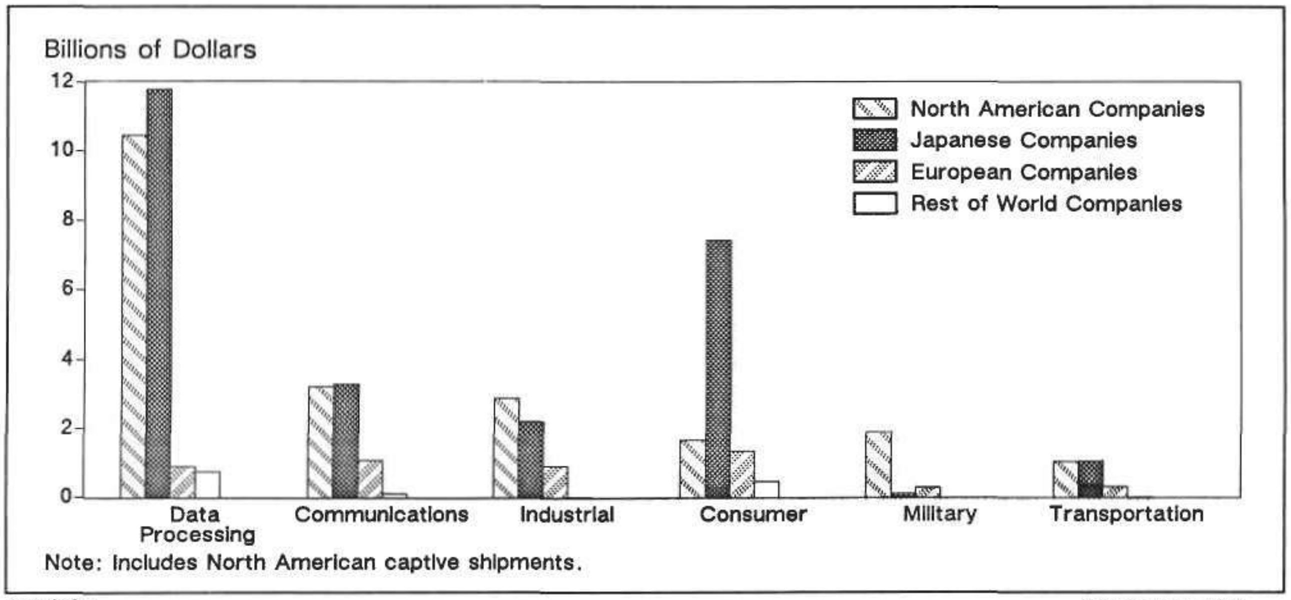
FIGURE 1
Estimated 1988 Worldwide Semiconductor Shipments by Company Base



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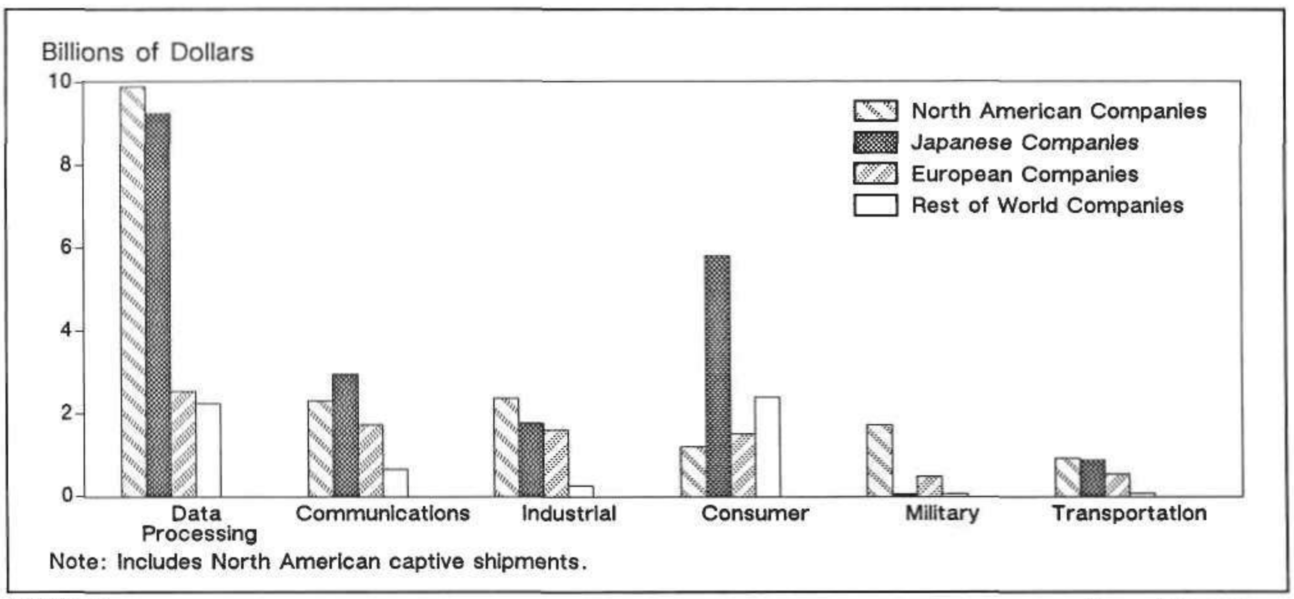
Source: Dataquest October 1989

FIGURE 2
Estimated 1988 Worldwide Semiconductor Shipments Consumption by Region



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Source: Dataquest October 1989

COMPONENT ANALYSIS

Table 2 provides an analysis of semiconductor shipments by semiconductor product type within each of the six application markets. Data processing emerged as the largest application for semiconductors, with shipments of $21,606 million representing 42.5 percent of total semiconductors shipped to all application segments. A large percentage of semiconductor shipments into the data processing segment is fueled by MOS digital, which represents 66.0 percent of the data processing segment. Of the data processing segment, a majority (55.6 percent) is fueled by MOS memory, mainly DRAMs that are supplied largely by Japanese manufacturers.

The consumer applications segment was the second-largest category, with shipments of $10,959 million representing 21.6 percent of all application segments. Predictably, a high percentage of analog shipments (33.1 percent of consumer) supported much of the consumer segment growth with a large base of regional suppliers.

VENDOR ANALYSIS

As mentioned previously, NEC emerged as the leader in the data processing segment, with semiconductor shipments of $2,188 million. The company mainly supplies DRAM memory chips used in such systems as mainframes, supercomputers, personal computers, and laptops. Toshiba and Hitachi also were very strong in this application segment with sales of $1,990 million and $1,734 million, respectively. Growth was due largely to these companies' DRAM shipments, where leading chip technologies (256K, 1Mb, and 4Mb DRAMs) pull in a premium in supporting the computer industry where demand is high. Intel ranked number four with semiconductor shipments of $1,725 million; its growth was fueled by the popularity of its 8086 family of microprocessors (especially 80286, 80386, and 80486 MPUs), which are used in many of IBM's personal computers. In 1988, Intel's microprocessor sales amounted to 46.8 percent of Intel's total worldwide semiconductor sales of $2,350 million.

NEC also emerged as the leader in communications, with sales of $858 million or 11.2 percent of the worldwide market supported by sales in mobile communications and central office switching equipment. Motorola was the number two vendor, which is not surprising because Motorola relies heavily on using its own semiconductors in the production of its communication products. Motorola sees this as a growing opportunity fueled by its line of radios and mobile and cellular phone products. Motorola held 10.5 percent of the market worldwide with sales of $806 million.

Motorola led industrial application shipments, with $510 million in shipments, or 8.6 percent of the market supplying testers and detection systems. Toshiba ranked second with sales of $463 million or 7.8 percent of the market; NEC ranked third with sales of $348 million. Both NEC and Toshiba supply semiconductors to a number of industrial equipment suppliers that support such equipment as industrial robotics, manufacturing automation, process control, and medical/diagnostic systems.

The consumer application segment is supported by many Japanese manufacturers because of Japan's heavy production of such hot consumer products as videocameras, large television receivers, compact disc players, and videocassette recorders (VCRs). However, this market is quietly

TABLE 2
Estimated 1988 Worldwide Semiconductor Market by Semiconductor Product and Application Segment (Millions of Dollars)

	Data Processing	Communications	Industrial	Consumer	Military	Transportation	Total
Total Semiconductor	$21,606	$7,641	$5,912	$10,959	$2,257	$2,484	$50,859
Integrated Circuit	$19,068	$6,020	$4,220	$ 8,170	$1,819	$1,771	$41,068
Bipolar Digital	2,828	937	551	231	497	156	5,200
Memory	460	103	31	14	84	8	700
Logic	2,368	834	31	217	413	148	4,500
MOS Digital	14,270	3,787	2,533	4,316	893	1,189	26,988
Memory	7,938	1,104	934	1,164	288	264	11,692
Micro	3,202	1,096	765	1,378	200	503	7,144
Logic	3,130	1,587	834	1,774	405	422	8,152
Analog	1,970	1,296	1,136	3,623	429	426	8,880
Discrete	$ 1,933	$1,223	$1,459	$ 1,990	$ 362	$ 645	$ 7,612
Optoelectronic	$ 605	$ 398	$ 233	$ 799	$ 76	$ 68	$ 2,179

Note: Does not include North American captive shipments.

Source: Dataquest
October 1989

slowing as the yen remains strong and production begins to move offshore to the Asia/Pacific and Rest of World (ROW) regions. Matsushita emerged as the leader in this segment, with semiconductor shipments of $1,091 million.

Harris (GE/RCA) led semiconductor shipments in the military segment with $245 million or 10.9 percent of the market. This share includes Harris' recent acquisitions of GE Solid State (GESS) and GE Microelectronics Center in Research Triangle Park, North Carolina. Harris is a key supplier of radiation-hardened (rad-hard) devices, gallium arsenide (GaAs) components, and custom/semicustom circuits to the military. Harris' development of new technologies such as silicon-on-insulator (SOI), which is used to increase circuit speed and radiation hardness, has ensured Harris' place as a major supplier in this market.

In the transportation application segment, Motorola emerged as the leader, with sales of $360 million or 14.5 percent of the worldwide market. Motorola is a major supplier to the three largest North American automobile manufacturers (Chrysler, Ford, and GM). Interestingly enough, it is not surprising to find both Hitachi and Toshiba as leading vendors to the transportation industry, with semiconductor shipments of $244 million and $215 million, respectively, because Japanese car production in 1988 was approximately equal to that of North America.

Tables 3 through 8 list the top 10 vendors within each of the six application segments, as well as their respective market shares in both dollars and percentage of the market.

Table 3
Estimated 1988 Worldwide Semiconductor Market Share Rankings Data Processing Segment (Millions of Dollars)

Company	Revenue	Percent
NEC	$ 2,188	10.1%
Toshiba	1,990	9.2
Hitachi	1,734	8.0
Intel	1,725	8.0
Fujitsu	1,677	7.8
Texas Instruments	1,359	6.3
Mitsubishi	1,034	4.8
Motorola	771	3.6
Advanced Micro Devices	667	3.1
National Semiconductor	652	3.0
Total—Top 10 Companies	$13,797	63.9%
Total North America*	$ 8,125	37.6%
Total Japan	11,795	54.6
Total Europe	915	4.2
Total Rest of World	771	3.6
Total—All Companies	$21,606	100.0%

*Does not include North American captive shipments
Note: Columns may not add to totals shown because of rounding.
Source: Dataquest October 1989

Table 4
Estimated 1988 Worldwide Semiconductor Market Share Rankings Communications Segment (Millions of Dollars)

Company	Revenue	Percent
NEC	$ 858	11.2%
Motorola	806	10.5
AT&T	628	8.2
Toshiba	599	7.8
Fujitsu	586	7.7
Texas Instruments	485	6.3
Hitachi	411	5.4
Philips-Signetics	367	4.8
SGS-Thomson	229	3.0
National Semiconductor	225	2.9
Total—Top 10 Companies	$5,194	68.0%
Total North America*	$3,176	41.6%
Total Japan	3,296	43.1
Total Europe	1,044	13.7
Total Rest of World	125	1.6
Total—All Companies	$7,641	100.0%

*Does not include North American captive shipments
Note: Columns may not add to totals shown because of rounding.
Source: Dataquest October 1989

Table 5
Estimated 1988 Worldwide Semiconductor Market Share Rankings Industrial Segment (Millions of Dollars)

Company	Revenue	Percent
Motorola	$ 510	8.6%
Toshiba	463	7.8
Hitachi	348	5.9
Mitsubishi	326	5.5
Texas Instruments	322	5.4
NEC	319	5.4
National Semiconductor	326	5.5
Philips-Signetics	243	4.1
SGS-Thomson	231	3.9
Harris	220	3.7
Total—Top 10 Companies	$3,308	56.0%
Total North America*	$2,741	46.4%
Total Japan	2,229	37.7
Total Europe	926	15.7
Total Rest of World	16	0.3
Total—All Companies	$5,912	100.0%

*Does not include North American captive shipments
Note: Columns may not add to totals shown because of rounding.
Source: Dataquest October 1989

Table 6
Estimated 1988 Worldwide Semiconductor Market Share Rankings Consumer Segment (Millions of Dollars)

Company	Revenue	Percent
Matsushita	$ 1,091	10.0%
Toshiba	1,069	9.8
NEC	1,032	9.4
Hitachi	798	7.3
Mitsubishi	750	6.8
Philips-Signetics	710	6.5
Sanyo	698	6.4
Sharp	522	4.8
Sony	468	4.3
Motorola	377	3.4
Total—Top 10 Companies	$ 7,515	68.6%
Total North America*	$ 1,665	15.2%
Total Japan	7,435	67.8
Total Europe	1,368	12.5
Total Rest of World	491	4.5
Total—All Companies	$10,959	100.0%

*Does not include North American captive shipments
Note: Columns may not add to totals shown because of rounding.
Source: Dataquest October 1989

DATAQUEST CONCLUSIONS

Indigenous semiconductor suppliers have a majority of market share across all application segments within their regional markets. Two of these segments, data processing and consumer, are especially significant because of the global opportunities they create and the technological expertise they imply.

The data processing market, where strong regional growth is expected to continue, provides semiconductor suppliers with both a growing domestic revenue source and an opportunity for increased global participation. The importance of data processing applications in sustaining worldwide competitiveness can be seen by regional consortia efforts such as JESSI (Europe) and Sematech (United States)—both of which are evidence that developing technology is likely to remain onshore in support of domestic application markets.

To compete effectively within this application segment, regional suppliers will need to balance new semiconductor technology developments in memory—especially high-density DRAMs (256K, 1Mb, 4Mb), high-end microprocessors (32/64-bit RISC and CISC), and leading-edge ASICs (gate arrays, PLDs)—with strategic partnerships and alliances and consortium participation and support to remain effective within a forming global market.

The consumer market, which is the second-largest application market in semiconductor shipments, presents ample opportunity for regional suppliers that should not be ignored. Currently, Japan-based companies hold a dominating lead of 68 percent worldwide in consumer applications. A scattering of regional participants such as Motorola, Philips, SGS-Thomson, Siemens, and Texas Instruments supply analog, memory (nonvolatile), microcontroller, and discrete devices to this market.

Table 7
Estimated 1988 Worldwide Semiconductor Market Share Rankings Military Segment (Millions of Dollars)

Company	Revenue	Percent
Harris	$ 245	10.9%
Motorola	211	9.3
Texas Instruments	207	9.2
National Semiconductor	194	8.6
Advanced Micro Devices	154	6.8
Analog Devices	92	4.1
Philips-Signetics	86	3.8
SGS-Thomson	83	3.7
LSI Logic	82	3.6
Intel	73	3.2
Total—Top 10 Companies	$1,427	63.2%
Total North America*	$1,814	80.4%
Total Japan	123	5.4
Total Europe	320	14.2
Total Rest of World	0	0
Total—All Companies	$2,257	100.0%

*Does not include North American captive shipments
Note: Columns may not add to totals shown because of rounding.

Source: Dataquest October 1989

Table 8
Estimated 1988 Worldwide Semiconductor Market Share Rankings Transportation Segment (Millions of Dollars)

Company	Revenue	Percent
Motorola	$ 360	14.5%
Toshiba	244	9.8
Hitachi	215	8.7
Texas Instruments	124	5.0
NEC	123	5.0
National Semiconductor	117	4.7
SGS-Thomson	113	4.5
Harris	109	4.4
Oki Semiconductor	102	4.1
Intel	97	3.9
Total—Top 10 Companies	$1,604	64.6%
Total North America*	$1,065	42.9%
Total Japan	1,064	42.8
Total Europe	344	13.8
Total Rest of World	11	0.4
Total—All Companies	$2,484	100.0%

*Does not include North American captive shipments
Note: Columns may not add to totals shown because of rounding.

Source: Dataquest October 1989

The opportunity in consumer applications is present for regional vendors that want to supply *high-end* consumer products to the market. It is within the high-end portion of the market that regional suppliers can leverage their technology know-how to become fairly successful. Concentrating on the low-end commodity consumer portion of the market, where minimum manufacturing costs and technology know-how are required to participate effectively, does not present as great an opportunity for regional suppliers; it is best left to those regions that are more cost effective.

Carolyn Doles

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Research Newsletter

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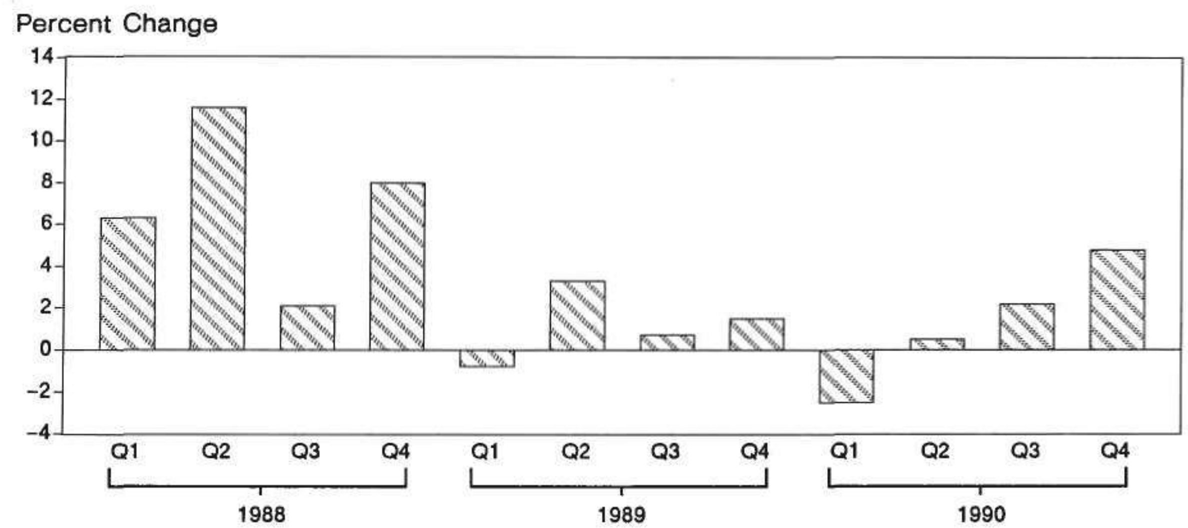
WORLDWIDE SEMICONDUCTOR OUTLOOK: THIRD QUARTER 1989

SUMMARY

The worldwide semiconductor industry recession we have been forecasting to begin in third quarter 1989 appears to be under way. Surprisingly, it began in Japan and Asia/Rest of World (ROW) in the first quarter, but was not recognized by Dataquest at that time. The North American and European markets were quite strong in the first quarter, in stark contrast to Japan and Asia. During the second quarter, North America continued to show strength, Europe showed a definite slump, and Japan and Asia recovered from their first-quarter declines. Our latest quarterly worldwide semiconductor consumption growth forecast is shown in Figure 1.

Figure 1

Worldwide Semiconductor Consumption
Quarter-to-Quarter Percent
Change in U.S. Dollars



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Source: Dataquest
July 1989

COMPARISON WITH OUR PREVIOUS FORECAST

Table 1 compares Dataquest's current quarterly consumption forecast with the forecast we published in April. The North American forecast is somewhat more positive now for both 1989 and 1990, although we continue to believe that 1990 will be a negative year for the North American market. Our Japan forecast has been revised downward for 1989, due to a disastrous first quarter that had not been predicted in our previous forecast. Our European forecast is even more optimistic than previously, a result of continued growth of foreign company manufacturing in Europe. Our Asia forecast has been downgraded for 1989 because of an extremely poor first quarter.

Table 1

Worldwide Semiconductor Consumption
Comparison of April 1989 and July 1989 Forecasts
Quarter-to-Quarter Forecast
Percent Change by Geographic Region

Region	1988	Q1/89	Q2/89	Q3/89	Q4/89	1989
North America April	24.7%	7.3%	4.3%	(1.8%)	(5.2%)	14.6%
North America July	23.2%	4.7%	5.3%	0.7%	(0.9%)	15.0%
Japan April	35.6%	1.8%	2.3%	(1.4%)	(4.7%)	14.9%
Japan July	39.2%	(6.7%)	3.0%	0.7%	(1.1%)	8.1%
Europe April	31.0%	3.4%	2.2%	(3.4%)	1.5%	10.2%
Europe July	30.7%	8.6%	(1.9%)	(3.2%)	9.2%	14.7%
Asia/ROW April	42.6%	7.5%	4.9%	0.5%	(1.6%)	26.3%
Asia/ROW July	45.0%	(6.5%)	6.9%	6.5%	5.6%	17.1%
Total World April	31.9%	4.4%	3.2%	(1.6%)	(3.5%)	15.3%
Total World July	33.0%	(0.8%)	3.3%	0.7%	1.5%	12.3%
		Q1/90	Q2/90	Q3/90	Q4/90	1990
North America April		(1.9%)	(0.3%)	2.3%	3.9%	(3.8%)
North America July		(3.0%)	(2.4%)	3.2%	4.8%	(1.1%)
Japan April		(2.8%)	3.5%	3.2%	4.5%	(1.3%)
Japan July		(3.2%)	1.4%	2.3%	3.8%	0.2%
Europe April		0.4%	2.2%	(1.3%)	4.9%	2.5%
Europe July		(0.9%)	1.7%	(0.5%)	6.7%	6.5%
Asia/ROW April		1.2%	3.0%	3.2%	4.3%	6.5%
Asia/ROW July		(1.2%)	2.9%	3.1%	5.2%	13.3%
Total World April		(1.5%)	2.0%	2.2%	4.3%	(0.5%)
Total World July		(2.5%)	0.5%	2.2%	4.8%	2.4%

Source: Dataquest
July 1989

OUR CURRENT FORECAST

Table 2 gives our current quarterly forecast by region for 1989 and 1990. Tables 3 and 4 give the worldwide quarterly forecast by product, in dollars and percent, respectively.

Table 2

Worldwide Semiconductor Consumption
(Millions of Dollars)

	1988	Q1/89	Q2/89	Q3/89	Q4/89	1989
North America	$15,844	$ 4,375	$ 4,606	$ 4,640	$ 4,600	$18,221
Percent Change	23.2%	4.7%	5.3%	0.7%	(0.9%)	15.0%
Japan	20,772	5,483	5,650	5,687	5,626	22,446
Percent Change	39.2%	(6.7%)	3.0%	0.7%	(1.1%)	8.1%
Europe	8,491	2,455	2,408	2,330	2,545	9,738
Percent Change	30.7%	8.6%	(1.9%)	(3.2%)	9.2%	14.7%
Asia/ROW	5,752	1,527	1,632	1,738	1,836	6,733
Percent Change	45.0%	(6.5%)	6.9%	6.5%	5.6%	17.1%
Total World	$50,859	$13,840	$14,296	$14,395	$14,607	$57,138
Percent Change	33.0%	(0.8%)	3.3%	0.7%	1.5%	12.3%

	Q1/90	Q2/90	Q3/90	Q4/90	1990
North America	$ 4,463	$ 4,356	$ 4,495	$ 4,711	$18,025
Percent Change	(3.0%)	(2.4%)	3.2%	4.8%	(1.1%)
Japan	5,448	5,525	5,652	5,867	22,492
Percent Change	(3.2%)	1.4%	2.3%	3.8%	0.2%
Europe	2,523	2,567	2,554	2,724	10,368
Percent Change	(0.9%)	1.7%	(0.5%)	6.7%	6.5%
Asia/ROW	1,814	1,867	1,925	2,025	7,631
Percent Change	(1.2%)	2.9%	3.1%	5.2%	13.3%
Total World	$14,248	$14,315	$14,626	$15,327	$58,516
Percent Change	(2.5%)	0.5%	2.2%	4.8%	2.4%

Source: Dataquest
July 1989

Table 3

Worldwide Semiconductor Consumption
(Millions of Dollars)

	1988	Q1/89	Q2/89	Q3/89	Q4/89	1989
Total Semiconductor	$50,859	$13,840	$14,296	$14,395	$14,607	$57,138
Total IC	$41,068	$11,427	$11,873	$11,982	$12,188	$47,470
Bipolar Digital	$ 5,200	$ 1,128	$ 1,162	$ 1,118	$ 1,124	$ 4,532
Memory	689	149	135	125	119	528
Logic	4,511	979	1,027	993	1,005	4,004
MOS	$26,988	$ 8,119	$ 8,466	$ 8,600	$ 8,757	$33,942
Memory	11,692	4,077	4,335	4,524	4,590	17,526
Microdevices	7,144	1,790	1,810	1,809	1,835	7,244
Logic	8,152	2,252	2,321	2,267	2,332	9,172
Analog	$ 8,880	$ 2,180	$ 2,245	$ 2,264	$ 2,307	$ 8,996
Discrete	$ 7,612	$ 1,893	$ 1,892	$ 1,880	$ 1,901	$ 7,566
Optoelectronic	$ 2,179	$ 520	$ 531	$ 533	$ 518	$ 2,102

	Q1/90	Q2/90	Q3/90	Q4/90	1990
Total Semiconductor	$14,248	$14,315	$14,626	$15,327	$58,516
Total IC	$11,939	$11,970	$12,237	$12,795	$48,941
Bipolar Digital	$ 1,038	$ 1,043	$ 1,056	$ 1,095	$ 4,232
Memory	116	121	121	121	479
Logic	922	922	935	974	3,753
MOS	$ 8,641	$ 8,603	$ 8,850	$ 9,277	$35,371
Memory	4,550	4,485	4,613	4,825	18,473
Microdevices	1,809	1,844	1,939	2,040	7,632
Logic	2,282	2,274	2,298	2,412	9,266
Analog	$ 2,260	$ 2,324	$ 2,331	$ 2,423	$ 9,338
Discrete	$ 1,819	$ 1,828	$ 1,850	$ 1,972	$ 7,469
Optoelectronic	$ 490	$ 517	$ 539	$ 560	$ 2,106

Source: Dataquest
July 1989

Table 4

Worldwide Semiconductor Consumption
(Percent Change in Dollars)

	1988	Q1/89	Q2/89	Q3/89	Q4/89	1989
Total Semiconductor	33.0%	(0.8%)	3.3%	0.7%	1.5%	12.3%
Total IC	37.4%	0.1%	3.9%	0.9%	1.7%	15.6%
Bipolar Digital	9.2%	(3.2%)	3.0%	(3.8%)	0.5%	(12.8%)
Memory	11.0%	(12.9%)	(9.4%)	(7.4%)	(4.8%)	(23.4%)
Logic	9.0%	(1.5%)	4.9%	(3.3%)	1.2%	(11.2%)
MOS	54.5%	3.1%	4.3%	1.6%	1.8%	25.8%
Memory	93.1%	7.0%	6.3%	4.4%	1.5%	49.9%
Microdevices	39.9%	(2.7%)	1.1%	(0.1%)	1.4%	1.4%
Logic	29.2%	1.4%	3.1%	(2.3%)	2.9%	12.5%
Analog	16.0%	(8.3%)	3.0%	0.8%	1.9%	1.3%
Discrete	14.4%	(3.5%)	(0.1%)	(0.6%)	1.1%	(0.6%)
Optoelectronic	27.5%	(9.6%)	2.1%	0.4%	(2.8%)	(3.5%)

	Q1/90	Q2/90	Q3/90	Q4/90	1990
Total Semiconductor	(2.5%)	0.5%	2.2%	4.8%	2.4%
Total IC	(2.0%)	0.3%	2.2%	4.6%	3.1%
Bipolar Digital	(7.7%)	0.5%	1.2%	3.7%	(6.6%)
Memory	(2.5%)	4.3%	0.0%	0.0%	(9.3%)
Logic	(8.3%)	0	1.4%	4.2%	(6.3%)
MOS	(1.3%)	(0.4%)	2.9%	4.8%	4.2%
Memory	(0.9%)	(1.4%)	2.9%	4.6%	5.4%
Microdevices	(1.4%)	1.9%	5.2%	5.2%	5.4%
Logic	(2.1%)	(0.4%)	1.1%	5.0%	1.0%
Analog	(2.0%)	2.8%	0.3%	3.9%	3.8%
Discrete	(4.3%)	0.5%	1.2%	6.6%	(1.3%)
Optoelectronic	(5.4%)	5.5%	4.3%	3.9%	0.2%

Source: Dataquest
July 1989

North America

Following strong first and second quarters of 1989, our outlook for the North American market is for real softening of shipments beginning in the third quarter and continuing through the second quarter of 1990. We expect third and fourth quarter 1990 to show a resumption of strong growth. MOS memory will continue to outpace the general semiconductor market growth. Although we forecast 1989 total semiconductor growth to be 15 percent, it would be 0 percent if MOS memory were out of the picture.

Signs in the market are mixed. Distribution appears to be soft, and the automotive market is flat. For some companies, the electronic data processing (EDP) market remains good; for others, it is flat. Digital Equipment Corporation and Sun Microsystems have announced cost-cutting plans that include layoffs and salary reductions. IBM has become very conservative in its purchasing plans. Several companies—both semiconductor suppliers and users—are expected to announce decreased earnings in the second quarter. From a macroeconomic point of view, interest rates fell slightly, creating a better climate for capital investment; however, the index of leading indicators is falling.

Japan

The first quarter was a disaster in Japan, with semiconductor consumption down 6.7 percent. Both consumer and industrial electronics production were down, with consumer production declining by 18 percent. Particularly hard hit were color televisions (down 29 percent) and VCRs (down 19 percent). We believe that consumers in Japan delayed purchasing these items because of new tax laws that took effect April 1. As of April 1, a flat 3 percent sales tax on all items went into effect; previously, only luxury items (including color TVs and VCRs) were taxed, but at a 10 percent rate.

Europe

Second quarter 1989 was down by 1.9 percent in Europe, the result of a stronger U.S. dollar (which has the effect of lowering the growth rate expressed in dollar terms), 2 to 3 percent decreases in 1Mb DRAM prices, and a slight slowdown in the personal computer build rate. The outlook for the third quarter is for a seasonally based negative growth as well as a 5 percent drop in 1Mb DRAM prices. The 14.7 percent growth forecast for 1989 in dollars is equivalent to more than 19.0 percent growth in local currency terms. In 1990, we expect the 1992 effect to continue, although slower growth is forecast for the first half of 1990. We already are witnessing a shifting of semiconductor total available market (TAM) from Asia and Japan as more companies (including Apple, Canon, Citizen, Epson, NEC, Oki, Samsung, Sanyo, Sun, and Toshiba) begin the process of procuring semiconductors in Europe for their European production facilities.

Asia/ROW

The Asia/ROW market declined 6.5 percent in the first quarter of 1989. We believe that a very high inventory situation existed in the first quarter and worked its way out during the second quarter. Personal computer clone production in Asia softened during the first quarter also. Additionally, several Taiwanese electronics companies have been moving their manufacturing operations to less developed nations, such as Thailand and Malaysia, thus disrupting current production.

DATAQUEST CONCLUSIONS

We at Dataquest stand by our earlier predictions that 1989 and 1990 will be slow years for the worldwide semiconductor industry. Worldwide growth is expected to be 12.3 percent in 1989 and 2.4 percent in 1990, both of which estimations are well below the historical average growth rate of 17.0 percent. Because there is not an overcapacity situation in the industry, and purchasers are managing their inventories much better than in previous silicon cycles, we do not foresee a devastating depression of the type that occurred in 1985. DRAM prices are remaining at levels higher than previously forecast; we believe that this justifies our current outlook.

Patricia S. Cox

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Research Bulletin

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MEMORIES: YESTERDAY AND TOMORROW

Yesterday there were four U.S. merchant DRAM suppliers with silicon fabrication facilities: Alliance Semiconductor, Micron Technology, Motorola, and Texas Instruments. Soon there will be five. The new player on the U.S. scene is U.S. Memories.

U.S. Memories is an independent company started with seed money from seven U.S. semiconductor companies. The seven are: Advanced Micro Devices, Digital Equipment Corporation, Hewlett-Packard, Intel, International Business Machines, LSI Logic, and National Semiconductor. U.S. Memories currently is a company in the process of formation. For it to become a going concern, the company has listed the following preconditions: 1) that several more semiconductor companies provide financial backing; 2) that several systems companies provide financial backing and that this backing exceed the contributions made by the semiconductor manufacturers; 3) that participating systems companies guarantee to purchase 50 percent of U.S. Memories' output; 4) that negotiations for the transfer of IBM's submicron 4Mb DRAM technology be successfully completed; and 5) that a detailed business plan be completed. Full funding is contingent upon completion of these tasks.

The venture will require about $1 billion, with approximately half in the form of an equity investment and the other half from the financial community. By the end of 1989, the company hopes to have all of its preconditions met and to select a site. U.S. Memories plans to have a new fab built and producing in volume by the first half of 1991.

The president and CEO of the new company is Sanford (Sandy) Kane, who will be resigning soon from his present position as vice president of technology at IBM. Mr. Kane was instrumental in SEMATECH's founding and site selection. The chairman of the new company is Wilfred (Wilf) Corrigan, Chairman and CEO of LSI Logic.

DATAQUEST ANALYSIS

U.S. Memories emerged as a result of ongoing efforts by the Semiconductor Industry Association (SIA) to rejuvenate the present U.S. semiconductor industry. Successful formation of a large-scale company based on collaboration of multiple American semiconductor suppliers and systems manufacturers will be unique; this may be the first time in electronics industry history that a number of U.S. semiconductor manufacturers and their customers have shared resources, risk, and output. The purchase guarantee of 50 percent of the company's output will make the company structurally similar to many of its vertically integrated competitors such as Fujitsu and Hitachi, which also consume a large fraction of their own DRAMs.

The company believes that government support is crucial for its success. It does not expect support to be in the form of direct funding or subsidies, but rather, in the form of knocking down potential antitrust barriers. U.S. Memories believes that the federal government will be helpful in this regard.

U.S. Memories' targeted first half 1991 entry date into the 4Mb DRAM market is aggressive from a start-up development standpoint. Although the company's introduction date is ahead of the forecast peak year for 4Mb DRAMs, most Japanese DRAM manufacturers will be ramping up 4Mb DRAM production during 1990, and customer samples of 16Mb DRAMs will be available in 1991. Those companies that have reached volume production levels of 4Mb DRAMs by the time that U.S. Memories enters the market in 1991 could competitively price their products too low for a late entrant to compete, particularly when the FMV regulations elapse in 1991.

Obviously, a maverick cooperative project of this type has innumerable potential problems. However, the strong leadership of Sanford Kane, the endorsement and assistance from some of the most respected executives in the industry, and affiliation with the SIA all provide credence to this unusual start-up company. In addition, we believe that all of these factors should positively impact U.S. Memories' fund-raising efforts.

Yesterday there were four U.S. merchant DRAM manufacturers. Soon there will be five. Yesterday U.S. systems companies were uneasy about their perceived dependance on one set of "foreign suppliers." Tomorrow, with the advent of U.S. Memories, they hope to have taken a significant step toward regaining control of their own destinies. Yesterday U.S. semiconductor manufacturers were worried about losing control of the technology driver DRAMs. With the formation of Sematech last year and U.S. Memories this year, they believe that these efforts will improve their technological position.

George Burns
Fred Jones

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Research Bulletin

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FIRST QUARTER GROWTH FALLS SHORT OF EXPECTATIONS

OVERVIEW

Europe and the United States on Target but Japan and ROW Down

Worldwide shipments of semiconductor devices in the first quarter of 1989 were down approximately 0.6 percent from those of the fourth quarter of 1988, according to WSTS statistics. The WSTS report shows worldwide semiconductor shipments of $13,952 billion in Q4 1988 and $13,869 billion in Q1 1989. Although this was not entirely a surprise to Dataquest, we and others had predicted that Q1 1989 would be up from Q4 1988 by as much as 4.0 percent. The chief factors that produced the down quarter were negative growth in Japan and the Rest of World (ROW) region. Japan's and ROW's semiconductor consumption was down 6.3 and 6.5 percent, respectively, compared with Q4 1988. However, Q1 1989 semiconductor consumption in Europe and the United States was up 8.8 and 4.7 percent, respectively, compared with Q4 1988. Many of our clients have asked if this is the beginning of the semiconductor recession that most forecasters suggest is not far off. This concern is exacerbated by a softening in several business segments experienced by many IC producers in May.

Current Business Conditions

A survey of Dataquest's clients worldwide, both IC producers and consumers, provided very mixed signals, including the following:

- A definite slowing in non-DRAM business is occurring in Europe. European and U.S. sources reported soft distribution sales in Europe in May, and they expect the European book-to-bill ratio for May to be less than one.
- Distribution in the United States became soft during the first part of June, although there are some exceptions. Most distributors told us that they are experiencing a slowing of "short-term" orders. One major Silicon Valley distributor reported that "the phone stopped ringing ten days ago."
- The worst toll appears to be in the sale of logic ICs, while analog chip sales vary from "terrible" to "surprisingly good." Of three major analog IC suppliers surveyed, one reported flat sales, one reported "severe price erosion," and the third reported that its analog business was good enough to raise prices on June quotes. Even with the best software the industry can produce, it is difficult, with these data, to see a trend developing.
- Several Japanese suppliers of non-DRAM products to the United States confirmed slow sales in May.

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- Memory sales continue to be stable.
- The PC business is still good. Motorola and Intel report greater than 1:1 book-to-bill ratios for their Apple- and IBM-related microprocessors.

DATAQUEST ANALYSIS

Poor Q1 Japanese Consumer Electronics Sales

The Q1 anomaly originated in Japan. As stated herein, the WSTS reports Q1 to be down 6.3 percent, while MITI reports Q1 to be negative 9.1 percent compared with Q4 1988. Very slow sales in consumer electronics appear to be at fault. VCR production was off 19 percent in Q1 1989 in Japan, and color television production was down 29.0 percent. MITI forecasts a significant improvement in Japan during Q2 1989, stating that Japanese semiconductor production in April was up 25.6 percent over April 1988, with MOS up 39.5 percent over April 1988. Virtually all memory suppliers report stable conditions with "no signs of price declines in sight." We are not quite as sanguine. We are observing reports of increased memory return material authorization (RMA) activity and more liberal cancellation options for DRAM orders that are not at the customers' shipping docks on the contract due dates. This situation infers that most DRAM users are in comfortable inventory situations and are managing their inventories to avoid overstocking. A representative of a major consumer of memory devices advised us last week that the company was still on its purchasing plan, had no plans to increase its memory purchases beyond the current plan, and was watching the next few months "very cautiously." This suggests to us that the stable memory situation could become very turbulent by fall if the industry softness we are seeing in May continues. A second indicator is the level of inquiry activity received by Dataquest's memory analysts. Memory inquiries have nearly tripled in the last two weeks, which also suggests a change in the wind. In the past, this type of increased concern often has been accompanied by changing market conditions.

Inventory Growth in Non-DRAM Products

Some understanding of May's softness can be gained via an analysis of the current inventory situation. In May, the non-DRAM inventory target for Dataquest's population of IC users was 21 inventory days. Actual inventory days in May were 25 days for non-DRAM ICs. In June, the target is 21 inventory days. However, to date, the actual inventory is running nearly 34 days, an increase from May of 9 days. We believe that users will want to see their actual inventories return closer to the 22- to 23-day range before the industry will see an improvement in new non-DRAM bookings.

Current Thoughts on the Remainder of 1989

Dataquest will release its revised forecast for 1989 and 1990 in July; however, the hallway consensus is as follows. We believe that Q2 1989 will still show positive growth, probably in the 3 percent range worldwide, as compared with Q1. Japan's substantial improvement in Q2 seems to support this contention. We think that Q3 1989 will range from flat to very slightly positive, largely dependent on what happens in memories and PCs. Negative growth will begin in Q4 and will continue into Q1 and perhaps Q2 1990. Essentially, the aggregate of all inputs suggests that flat to slightly negative business conditions will prevail for the remainder of the year, rather than a sharp drop in sales. However, with inputs as diverse as those we received this week, this situation could change with little notice. We will continue to advise our clients on this situation.

David Angel

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Research *Newsletter*

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FINAL 1988 WORLDWIDE SEMICONDUCTOR MARKET SHARE ESTIMATES

SUMMARY

This newsletter presents Dataquest's final estimates of 1988 worldwide semiconductor revenue for the major semiconductor suppliers of the world. After publishing our preliminary estimates in January, we received updated information on several companies, most notably Advanced Micro Devices, Fujitsu, Mitsubishi, National Semiconductor, NEC, Philips, Sony, and Toshiba. In addition, we have added several companies to our data base, including Mosel, a U.S. SRAM supplier, and Quality Technologies, a U.S. optoelectronics supplier (formerly the Optoelectronic Division of General Instruments).

Our research also resulted in an increase in our estimates of the total semiconductor market size in 1989, to $50,859 million. Japanese companies supplied 51 percent of that amount, North American companies supplied 37 percent, European companies 10 percent, and rest of world (ROW) companies supplied almost 3 percent. We consider these numbers to be final and do not anticipate any changes to 1988 data from now on.

Changes in rank occurred among the top 20 companies during the time between the preliminary market share newsletter and the final statistics. SGS-Thomson moved up to 12th place, and Advanced Micro Devices moved down to 13th place. Sony moved up to 16th place, and Oki moved down to 17th place.

Table 1 shows the total 1988 semiconductor revenue of all companies surveyed, both by company base and by region sold into.

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Table 1

Final Estimated 1988 Market Share Analysis (Millions of Dollars)

Company Base	Regional Market: North America	Japan	Europe	ROW	World
North America	$11,146	$ 1,965	$3,664	$1,811	$18,586
Percent of Regional Market	70%	9%	43%	31%	37%
Percent of Company Sales	60%	11%	20%	10%	100%
Japan	$ 3,277	$18,630	$1,466	$2,569	$25,942
Percent of Regional Market	21%	90%	17%	45%	51%
Percent of Company Sales	13%	72%	6%	10%	100%
Europe	$ 1,006	$ 115	$3,196	$ 600	$ 4,917
Percent of Regional Market	6%	1%	38%	10%	10%
Percent of Company Sales	20%	2%	65%	12%	100%
ROW	$ 415	$ 62	$ 165	$ 772	$ 1,414
Percent of Regional Market	3%	0	2%	13%	3%
Percent of Company Sales	29%	4%	12%	55%	100%
World	$15,844	$20,772	$8,491	$5,752	$50,859
Percent of Regional Market	100%	100%	100%	100%	100%
Percent of Company Sales	31%	41%	17%	11%	100%

Source: Dataquest
June 1989

WORLDWIDE MARKET AND RANKINGS

Table 2 shows Dataquest's estimates of the worldwide semiconductor market by product for 1987 and 1988. Total market growth was 33.0 percent, led by MOS memory and MOS microdevices, which grew 93.1 percent and 39.9 percent, respectively.

Table 2

Estimated Worldwide Semiconductor Market
(Millions of Dollars)

	1987	1988	Percent Change
Total Semiconductor	$38,251	$50,859	33.0%
Total Integrated Circuit	$29,887	$41,068	37.4%
Bipolar Digital	$ 4,760	$ 5,200	9.2%
Bipolar Memory	$ 621	$ 689	11.0%
Bipolar Logic	$ 4,139	$ 4,511	9.0%
ASIC	$ 1,677	$ 1,863	11.1%
Standard Logic	$ 2,264	$ 2,399	6.0%
Other Logic	$ 198	$ 249	25.8%
MOS Digital	$17,473	$26,988	54.5%
MOS Memory	$ 6,056	$11,692	93.1%
MOS Micro Device	$ 5,108	$ 7,144	39.9%
MOS Logic	$ 6,309	$ 8,152	29.2%
ASIC	$ 4,242	$ 5,836	37.6%
Standard Logic	$ 1,126	$ 1,307	16.1%
Other Logic	$ 941	$ 1,009	7.2%
Analog	$ 7,654	$ 8,880	16.0%
Monolithic	$ 6,376	$ 7,418	16.3%
Hybrid	$ 1,278	$ 1,462	14.4%
Discrete	$ 6,655	$ 7,612	14.4%
Optoelectronic	$ 1,709	$ 2,179	27.5%

Source: Dataquest
June 1989

Figure 1 lists the top 20 semiconductor suppliers worldwide in 1988, led by NEC at $4,543 million. The fastest-growing company among the top 20 was Samsung, which increased its revenue by 175.9 percent. This growth was a result of tremendous growth in DRAM sales. Within the top 10 companies, the highest growth was recorded by Intel, at 57.6 percent, a result of its predominant position in the microprocessor market and its decision to sole-source the popular 80386.

Tables 3 through 10 list the top 20 companies worldwide in the categories of total integrated circuit, total bipolar digital, total MOS digital, MOS memory, MOS microdevice, analog, total discrete, and total optoelectronic.

Figure 1

Final Estimated 1988 World Semiconductor Market Share Ranking Top 20 Manufacturers

Company	1988 Rank	1987 Rank		1987 Sales (Millions of Dollars)	1988 Sales (Millions of Dollars)	Percent Change
NEC	1	1		3,368	4,543	34.9%
Toshiba	2	2		3,029	4,395	45.1%
Hitachi	3	3		2,618	3,506	33.9%
Motorola	4	4		2,434	3,035	24.7%
Texas Instruments	5	5		2,127	2,741	28.9%
Fujitsu	6	6		1,801	2,607	44.8%
Intel	7	10		1,491	2,350	57.6%
Mitsubishi	8	9		1,492	2,312	55.0%
Matsushita	9	11		1,457	1,883	29.2%
Philips-Signetics	10	7		1,602	1,738	8.5%
National Semiconductor	11	8		1,506	1,650	9.6%
SGS-Thomson	12	13		859	1,087	26.5%
Advanced Micro Devices	13	12		986	1,084	9.9%
Sanyo	14	14		851	1,083	27.3%
Sharp	15	18		590	1,036	75.6%
Sony	16	19		571	950	66.4%
Oki	17	17		651	947	45.5%
Samsung	18	23		328	905	175.9%
AT&T	19	15		802	859	7.1%
Siemens	20	16		657	784	19.3%

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Source: Dataquest June 1989

Table 3

Final Estimated
1988 World Semiconductor Market Share Ranking—Top Twenty
Total Integrated Circuit
(Millions of Dollars)

1988 Rank	1987 Rank	Company	1987 Revenue	1988 Revenue	Percent Change
1	1	NEC	2,795	3,884	39.0%
2	2	Toshiba	2,194	3,316	51.1%
3	4	Hitachi	1,946	2,729	40.2%
4	3	Texas Instruments	2,024	2,637	30.3%
5	6	Fujitsu	1,660	2,420	45.8%
6	7	Intel	1,491	2,350	57.6%
7	5	Motorola	1,758	2,259	28.5%
8	9	Mitsubishi	1,239	1,975	59.4%
9	8	National Semiconductor	1,431	1,575	10.1%
10	11	Matsushita	994	1,328	33.6%
11	10	Philips	1,186	1,281	8.0%
12	12	Advanced Micro Devices	986	1,084	9.9%
13	14	Oki	619	902	45.7%
14	22	Samsung	291	850	192.1%
15	13	SGS-Thomson	646	833	28.9%
16	16	Sanyo	556	811	45.9%
17	17	Sharp	367	751	104.6%
18	15	AT&T	595	688	15.6%
19	18	Sony	361	621	72.0%
20	20	Siemens	354	483	36.4%
		Total Market	29,887	41,068	37.4%
		Japanese Companies	13,981	20,375	45.7%
		U.S. Companies	12,496	15,990	28.0%
		European Companies	2,845	3,429	20.5%
		Rest of World (ROW) Companies	565	1,274	125.5%

Source: Dataquest
June 1989

Table 4

Final Estimated
1988 World Semiconductor Market Share Ranking—Top Twenty
Total Bipolar Digital
(Millions of Dollars)

1988 Rank	1987 Rank	Company	1987 Revenue	1988 Revenue	Percent Change
1	1	Texas Instruments	854	940	10.1%
2	4	Fujitsu	495	653	31.9%
3	2	National Semiconductor	521	550	5.6%
4	3	Advanced Micro Devices	500	536	7.2%
5	5	Hitachi	463	501	8.2%
6	6	Motorola	429	435	1.4%
7	7	Philips	405	413	2.0%
8	8	NEC	247	292	18.2%
9	10	Mitsubishi	122	127	4.1%
10	9	Toshiba	125	108	(13.6%)
11	12	Plessey	68	94	38.2%
12	17	Harris	30	62	106.7%
13	11	AT&T	79	61	(22.8%)
14	14	Raytheon	51	55	7.8%
15	18	Sanyo	29	41	41.4%
16	16	Oki	32	38	18.8%
17	13	Siemens	63	36	(42.9%)
18	22	Goldstar	22	32	45.5%
19	21	Chips & Technologies	25	30	20.0%
20	20	Matsushita	26	30	15.4%
		Total Market	4,760	5,200	9.2%
		Japanese Companies	1,540	1,791	16.3%
		U.S. Companies	2,589	2,761	6.6%
		European Companies	594	598	0.7%
		Rest of World (ROW) Companies	37	50	35.1%

Source: Dataquest
June 1989

Table 5

Final Estimated
1988 World Semiconductor Market Share Ranking—Top Twenty
Total MOS Digital
(Millions of Dollars)

1988 Rank	1987 Rank	Company	1987 Revenue	1988 Revenue	Percent Change
1	1	NEC	2,006	3,123	55.7%
2	2	Toshiba	1,593	2,639	65.7%
3	3	Intel	1,473	2,328	58.0%
4	4	Hitachi	1,173	1,885	60.7%
5	5	Fujitsu	1,014	1,616	59.4%
6	7	Mitsubishi	812	1,453	78.9%
7	6	Motorola	990	1,399	41.3%
8	8	Texas Instruments	784	1,271	62.1%
9	9	Matsushita	592	875	47.8%
10	10	Oki	566	841	48.6%
11	18	Samsung	242	765	216.1%
12	15	Sharp	312	682	118.6%
13	11	National Semiconductor	415	485	16.9%
14	12	Advanced Micro Devices	414	482	16.4%
15	13	SGS-Thomson	344	461	34.0%
16	14	Philips	342	402	17.5%
17	16	AT&T	300	380	26.7%
18	17	LSI Logic	262	375	43.1%
19	28	Micron Technology	115	331	187.8%
20	23	Siemens	171	327	91.2%
		Total Market	17,473	26,988	54.5%
		Japanese Companies	8,921	14,494	62.5%
		U.S. Companies	6,880	9,754	41.8%
		European Companies	1,250	1,684	34.7%
		Rest of World (ROW) Companies	422	1,056	150.2%

Source: Dataquest
June 1989

Table 6

Final Estimated
1988 World Semiconductor Market Share Ranking—Top Twenty
Total MOS Memory
(Millions of Dollars)

1988 Rank	1987 Rank	Company	1987 Revenue	1988 Revenue	Percent Change
1	2	Toshiba	679	1,516	123.3%
2	1	NEC	838	1,490	77.8%
3	4	Hitachi	576	1,114	93.4%
4	3	Fujitsu	634	1,067	68.3%
5	5	Mitsubishi	492	966	96.3%
6	6	Texas Instruments	445	834	87.4%
7	9	Samsung	170	650	282.4%
8	7	Intel	326	392	20.2%
9	8	Oki	193	353	82.9%
10	11	Sharp	130	344	164.6%
11	12	Micron Technology	115	331	187.8%
12	16	Motorola	89	236	165.2%
13	15	Matsushita	91	230	152.7%
14	10	Advanced Micro Devices	155	207	33.5%
15	13	NMB Semiconductor	104	199	91.3%
16	14	SGS-Thomson	95	185	94.7%
17	24	Siemens	52	150	188.5%
18	17	Integrated Device Technology	85	135	58.8%
19	18	National Semiconductor	80	135	68.8%
20	28	Hyundai	30	106	253.3%
		Total Market	6,056	11,692	93.1%
		Japanese Companies	3,909	7,597	94.3%
		U.S. Companies	1,701	2,836	66.7%
		European Companies	235	464	97.4%
		Rest of World (ROW) Companies	211	795	276.8%

Source: Dataquest
June 1989

Table 7

Final Estimated
1988 World Semiconductor Market Share Ranking—Top Twenty
Total MOS Microdevice
(Millions of Dollars)

1988 Rank	1987 Rank	Company	1987 Revenue	1988 Revenue	Percent Change
1	1	Intel	1,087	1,835	68.8%
2	2	NEC	566	790	39.6%
3	3	Motorola	520	699	34.4%
4	4	Hitachi	402	525	30.6%
5	6	Mitsubishi	267	381	42.7%
6	5	Toshiba	283	346	22.3%
7	9	Texas Instruments	169	234	38.5%
8	7	Matsushita	199	230	15.6%
9	10	Fujitsu	146	202	38.4%
10	8	Advanced Micro Devices	178	183	2.8%
11	11	National Semiconductor	140	150	7.1%
12	12	Oki	101	134	32.7%
13	15	Chips & Technologies	87	130	49.4%
14	14	SGS-Thomson	95	118	24.2%
15	13	Philips	100	114	14.0%
16	17	Western Digital	70	100	42.9%
17	16	Zilog	75	90	20.0%
18	23	Siemens	44	88	100.0%
19	18	Sanyo	53	70	32.1%
20	22	Harris	44	62	40.9%
		Total Market	5,108	7,144	39.9%
		U.S. Companies	2,663	3,872	45.4%
		Japanese Companies	2,096	2,817	34.4%
		European Companies	310	401	29.4%
		Rest of World (ROW) Companies	39	54	38.5%

Source: Dataquest
June 1989

Table 8

Final Estimated
1988 World Semiconductor Market Share Ranking—Top Twenty
Total Analog
(Millions of Dollars)

1988 Rank	1987 Rank	Company	1987 Revenue	1988 Revenue	Percent Change
1	3	Toshiba	476	569	19.5%
2	2	National Semiconductor	495	540	9.1%
3	6	Sanyo	377	471	24.9%
4	1	NEC	542	469	(13.5%)
5	4	Philips	439	466	6.2%
6	5	Texas Instruments	386	426	10.4%
7	8	Motorola	339	425	25.4%
8	7	Matsushita	376	423	12.5%
9	10	Mitsubishi	305	395	29.5%
10	14	Sony	217	386	77.9%
11	11	SGS-Thomson	282	352	24.8%
12	9	Hitachi	310	343	10.6%
13	12	Analog Devices	280	340	21.4%
14	13	Rohm	235	271	15.3%
15	15	AT&T	216	247	14.4%
16	21	Sanken	119	157	31.9%
17	16	Fujitsu	151	151	0
18	17	Harris	139	146	5.0%
19	19	Burr-Brown	120	144	20.0%
20	23	Silicon Systems	88	125	42.0%
		Total Market	7,654	8,880	16.0%
		Japanese Companies	3,520	4,090	16.2%
		U.S. Companies	3,027	3,475	14.8%
		European Companies	1,001	1,147	14.6%
		Rest of World (ROW) Companies	106	168	58.5%

Source: Dataquest
June 1989

Table 9

Final Estimated
1988 World Semiconductor Market Share Ranking—Top Twenty
Total Discrete
(Millions of Dollars)

1988 Rank	1987 Rank	Company	1987 Revenue	1988 Revenue	Percent Change
1	1	Toshiba	703	864	22.9%
2	2	Motorola	652	752	15.3%
3	3	Hitachi	625	707	13.1%
4	4	NEC	518	571	10.2%
5	5	Philips	390	432	10.8%
6	6	Matsushita	318	377	18.6%
7	7	Mitsubishi	227	310	36.6%
8	13	Rohm	200	287	43.5%
9	11	Fuji Electric	206	279	35.4%
10	9	SGS-Thomson	213	254	19.2%
11	10	Sanyo	210	210	0
12	14	Sanken	162	207	27.8%
13	8	Siemens	218	201	(7.8%)
14	16	International Rectifier	151	192	27.2%
15	18	General Instrument	132	164	24.2%
16	12	AT&T	200	161	(19.5%)
17	15	ITT	160	146	(8.8%)
18	17	General Electric	146	145	(0.7%)
19	19	Powerex	106	115	8.5%
20	23	Sony	72	112	55.6%
		Total Market	6,655	7,612	14.4%
		Japanese Companies	3,376	4,056	20.1%
		U.S. Companies	2,051	2,171	5.9%
		European Companies	1,125	1,250	11.1%
		Rest of World (ROW) Companies	103	135	31.1%

Source: Dataquest
June 1989

Table 10

Final Estimated
1988 World Semiconductor Market Share Ranking—Top Twenty
Total Optoelectronic
(Millions of Dollars)

1988 Rank	1987 Rank	Company	1987 Revenue	1988 Revenue	Percent Change
1	1	Sharp	223	285	27.8%
2	4	Sony	138	217	57.2%
3	5	Toshiba	132	215	62.9%
4	2	Hewlett-Packard	186	213	14.5%
5	3	Matsushita	145	178	22.8%
6	10	Rohm	70	109	55.7%
7	9	Fujitsu	71	105	47.9%
8	7	Siemens	85	100	17.6%
9	11	NEC	55	88	60.0%
10	8	Telefunken Electronic	77	74	(3.9%)
11	12	Hitachi	47	70	48.9%
12	6	Sanyo	85	62	(27.1%)
13	14	Texas Instruments	39	41	5.1%
14	30	Quality Technologies	0	40	
15	13	TRW	43	36	(16.3%)
16	19	Oki	25	36	44.0%
17	15	Honeywell	30	30	0
18	17	Mitsubishi	26	27	3.8%
19	18	Philips	26	25	(3.8%)
20	20	Motorola	24	24	0
		Total Market	1,709	2,179	27.5%
		Japanese Companies	1,093	1,511	38.2%
		U.S. Companies	383	425	11.0%
		European Companies	230	238	3.5%
		Rest of World (ROW) Companies	3	5	66.7%

Source: Dataquest
June 1989

DATAQUEST CONCLUSIONS

As we stated in our preliminary market share newsletter, in 10 years the Japanese semiconductor companies have grown from 28 percent of the worldwide market to 51 percent. North American companies' market share has decreased correspondingly during the same period, dropping from 55 percent of the market in 1978 to 37 percent in 1988. ROW companies did not enter the arena until 1982, and their rapid growth and decision to focus on DRAM and SRAM products propelled them to an almost 3 percent position worldwide in 1988.

Because of continuing strong growth in the MOS memory market in 1989, we believe that Japanese and ROW companies stand to further penetrate the world market, although very depressed Q1'89 results in their domestic markets could counteract any growth in Europe and North America. Because of extremely strong growth in the European market, domestic European manufacturers are poised to have an extraordinarily good year as preparations begin in earnest for a unified European Community in 1992.

Patricia S. Cox

Note: Complete worldwide market share listings will be published in the Semiconductor Industry Service (SIS) and Semiconductor User Information Service (SUIS) binders in July. For more information before then, please contact the Components Group Client Inquiry Center at (408) 437-8099.

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Research Newsletter

JAPAN'S SEMICONDUCTOR TRADE PRACTICES ESCAPE SUPER 301 DESIGNATION

SUMMARY

On May 25, United States Trade Representative (USTR) Carla Hills put an end to speculation about Japan's inclusion on the "Super 301" list for semiconductor trade practices. Although Japan will be investigated under U.S. trade law for committing "priority practices" (i.e., trade barrier erection) in connection with telecommunications satellites and supercomputers, semiconductors will not be a subject of the USTR's investigative focus. Among those that believe they should be is the Semiconductor Industry Association (SIA). The SIA had submitted a petition under Section 301 of U.S. trade law to investigate Japan for violation of the semiconductor trade agreement signed in 1986—specifically because of the lack of progress perceived by the SIA in the further opening of the Japanese market to U.S. semiconductor manufacturers.

Although the specific reasons for Ms. Hills' decision not to include Japan's semiconductor trade practices on the 301 list are unknown to us, her decision would seem to vindicate the position taken by the Electronic Industries Association of Japan (EIAJ). This newsletter provides a look at Japan's side of the semiconductor trade issue, as put forward by the EIAJ, and at the likely obstacles to its future negotiations with the SIA.

THE EIAJ's POSITION

The EIAJ's arguments against inclusion on the 301 list can basically be reduced to the following position: identifying Japan as a "priority country" on the basis of semiconductor trade practices can serve no useful purpose, since a means of addressing such issues already exists through the U.S.-Japan Semiconductor Trade Arrangement (hereafter referred to as the Arrangement). Among the EIAJ's many valid points are the following:

- The Super 301 adds nothing new because all of the important issues concerning semiconductor trade are already subject to negotiation under the terms of the Arrangement.
- Super 301's new enforcement authority is unnecessary because there is authority under prior Section 301 provisions to impose remedies for breach of the Arrangement.

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- Super 301 designation would be redundant, since the negotiations contemplated by Super 301 have been under way for more than two and one-half years.

- The Arrangement is already accomplishing the objectives of Super 301 by having established a framework for ongoing negotiations seeking increased U.S. exports to Japan.

In addition to the well-reasoned arguments stated above, the EIAJ countered the SIA's petition to the USTR with a threat to terminate the Arrangement. The Arrangement, reasoned the EIAJ, was entered into as a means to suspend the existing Section 301 proceeding, which would have imposed punitive duties on Japanese memory products. Reinstating such proceedings under the guise of the new Super 301 label would have "altered the basis" of the Arrangement, and under its termination provisions would have given Japan a legal basis to abandon it.

LIGHTING A FIRE UNDER MITI

Faced with such a compelling, and no doubt earnest, threat, it is quite likely that the USTR chose not to muddy the waters of semiconductor trade between Japan and the United States by moving the issues out of their current forum. If so, the USTR's decision was the wisest course of action. Surprisingly, the SIA has so far expressed no outrage over Ms. Hills' actions. But then again, the SIA has not really lost any ground. Any additional negotiating leverage that the Super 301 may have offered had it been applied to the issue of semiconductor trade was most likely realized through the act of petitioning the USTR. Since the SIA filed its petition for action under section 301, Japan's Ministry of International Trade and Industry (MITI) has stepped up its campaign to increase foreign semiconductor market share in Japan. On April 17, MITI assembled approximately 160 Japanese companies in Tokyo and instructed them to submit action plans concerning how they would increase semiconductor purchases from foreign suppliers. MITI also introduced an 11-point plan aimed at resolving U.S. market barrier complaints. To enforce its market access proposals, MITI has committed to the following actions:

- MITI will encourage semiconductor user companies to make action plans and update them biannually. MITI will follow up on their implementation.

- MITI will conduct periodic surveys regarding procurement of foreign semiconductors and will publicize the results in statistical form.

- MITI will survey, when appropriate, the implementation of design-ins and the establishmemt of long-term relationships between Japanese electronics companies and foreign component suppliers.

MEASURING MARKET ACCESS: THE EYE OF THE STORM

To date, much of the furor over the implementation of the Arrangement has centered on the issue of measuring market access—and this issue has in turn centered on the interpretation of the now infamous "side letter," dated September 1, 1986, between Ambassador Matsunaga of Japan and Ambassador Yeutter of the United States. One particularly controversial section of the letter reads:

> The Government of Japan recognizes the U.S. semiconductor industry's expectation that semiconductor sales in Japan of foreign capital-affiliated companies will grow to at least slightly above 20 percent of the Japanese market in five years. The Government of Japan considers that this can be realized and welcomes its realization. The attainment of such an expectation depends on competitive factors, the sales efforts of the foreign capital-affiliated companies, the purchasing efforts of the semiconductor users in Japan and the efforts of both Governments.

Not surprisingly, the EIAJ's contention is that the above wording does not constitute a market share guarantee, but rather an admission that given the "underlying competitiveness" of foreign semiconductor suppliers, a 20 percent market share penetration of the Japanese semiconductor market would be a realistic achievement. Given this premise, the EIAJ has naturally balked at the SIA's efforts to judge the market access goals of the Arrangement by a linear projection of market share, beginning with third quarter 1986, that aims at a 20 percent penetration by 1991.

The EIAJ states a number of reasons why it would rather see market access judged by the implementation of policy rather than by adherence to a percentage target. The core of these reasons, which will no doubt form the basis of continuing talks between the SIA and the EIAJ, comprise the following points:

- Consumer electronics applications account for nearly 40 percent of semiconductor consumption in Japan. Because the United States lacks an indigenous consumer electronics production base, U.S. semiconductor suppliers are not geared to the needs of this market.

- Although the data processing market in Japan is now growing at a faster rate than the consumer electronics segment (by Dataquest's reckoning, it is now the largest segment of Japan's electronics industry), foreign companies would have to provide nearly 40 percent of this segment's semiconductor needs to reach the SIA's 20 percent market share target. Unfortunately, the EIAJ estimates that 40 percent of the data processing end market comprises semiconductor memory products—mainly DRAMs.

- Although sales of MOS microcomponents have contributed to tremendous revenue gains in the Japanese market by companies such as Intel and Motorola (65 and 54 percent sales growth in yen, respectively, in 1988), the EIAJ notes that this market segment accounts for only about 14 percent of the total Japanese semiconductor market.

- ASIC demand is rising sharply in the Japanese market. At present, however, many ASICs sold by U.S. companies are actually produced in Japanese foundries. The EIAJ also points out that competitive pressures have driven a number of U.S. companies from the standard gate array market and into special product niches. Although the margins in such markets may be better, they represent considerably less significant revenue opportunities.

SOLUTIONS OR SANCTIONS?

It would be a serious mistake to interpret the recent decision of the USTR as a softening of semiconductor trade resolve within the U.S. government. In a question-and-answer session following the Super 301 announcements, Ms. Hills left no doubt as to her position on U.S./Japan semiconductor trade: "The United States is closely monitoring Japan's compliance with the 1986 Semiconductor Arrangement in the context of an existing Section 301 proceeding. We imposed sanctions in 1987 for noncompliance with the Arrangement, and are prepared to do so again if warranted."

Resolution of the issues facing the EIAJ and SIA will not be easy, and while the Japanese maintain that policy and patience are the solution, the SIA's position (and perhaps that of the USTR) is that only the "crowbar" of trade sanctions will produce results. A recent newsletter written by David Angel, director of Dataquest's Semiconductor Industry Service, nevertheless noted that "Dataquest believes that Japan is sincerely concerned about the trade issues. The major Japanese companies and MITI genuinely believe that they are taking the hard steps that will ultimately lead to markets more open to foreign suppliers of semiconductor components, and evidence indicates that this is true."

The alternatives to compromise, under both the Arrangement and the Super 301, unfortunately include sanctions. The USTR allows 150 days for consultation with foreign governments whose nations have been placed on the Section 301 list—theoretically, the U.S.-Japan Semiconductor Trade Arrangement has until its expiration in 1991 to work its desired results. In the event that these negotiations fail, the United States may find its flexibility in imposing effective sanctions to be somewhat limited. In an increasingly global economy, trade retaliation aimed at the defense of one industry may impair the competitiveness of another. A case in point is the current "hit list" of Japanese products that may face 100 percent tariffs in the wake of the Super 301 proceedings. This list includes semiconductor manufacturing equipment—specifically e-beam lithography equipment, wafer steppers, and die-bonding and wire-bonding assembly equipment.

DATAQUEST CONCLUSIONS

However the sanctioning of Japanese semiconductor manufacturing equipment may affect the balance of trade for U.S. telecommunications equipment and supercomputers, it would put U.S. chipmakers at a competitive disadvantage by requiring them to pay a 100 percent premium for Japanese semiconductor manufacturing equipment. The growing dependence of U.S. chip producers on Japan-based equipment suppliers is epitomized by the fact that the industry's flagship consortium effort, Sematech, will rely initially on stepper equipment from Nikon in transferring the AT&T SRAM process to its Austin facility. In 1988, Nikon ranked as the world's largest stepper supplier.

The original list of sanctioned Japanese products, created by the Reagan administration in response to the semiconductor trade situation, was carefully arrived at in an effort to minimize any negative impact on U.S. systems companies. The sanctions list recently proposed by the USTR may, in an ironic turnabout, compromise the interests of the U.S. semiconductor industry on behalf of systems manufacturers. The message that should be coming through in all this is that nobody wins in an adversarial approach to trade problems.

Michael J. Boss

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PACIFIC STOCK EXCHANGE PLANS DRAM FUTURES: GOOD-BYE, LEARNING CURVE—HELLO, SPOT AND LONG

Beginning in 1990, the Pacific Stock Exchange (PSE) in San Francisco plans to trade futures contracts in DRAMs. An application will be filed soon with the Commodity Futures Trading Commission. Pricing of DRAMs has been influenced by the industry's well-understood learning curve, but if the idea of futures contracts works, the dynamics of DRAM pricing will be very different.

From time to time, DRAMs vary widely in selling price, causing users to be uncertain about their buying strategy, which in turn tends to destabilize the market. Futures contracts will be offered for 1,000 chips per contract for periods of three, six, or nine months into the future. According to a PSE spokesperson, the contracts will stabilize prices of these critical computer components, thereby giving equipment manufacturers greater certainty about future costs of goods.

This move by the PSE is a significant departure from the traditional commodity business, representing the first time for futures contracts to be traded for something other than farm products, oil, or precious metals. Many differences exist between traditional commodities, such as wheat and gold, and DRAMs, just as many differences exist between the commodity industries and the semiconductor industry. Consequently, members of the stock exchange as well as the buyers and sellers will themselves have an opportunity for a learning experience.

Similarities as well as differences exist between DRAMs and true commodities, especially pertaining to the manufacturers. Oil, gold, and DRAMs have relatively few manufacturers; these manufacturers communicate rapidly and efficiently among themselves, they all have large capital investments, and they control the market channel.

Nevertheless, the essential differences between a manufactured product and natural resources are many. Three essential characteristics separating commodities from manufactured goods are product life cycle, product differentiation, and uncontrollable influences upon supply. Wheat and gold have long life cycles, while generations of DRAMs come and go in just a few years. The most important difference is that the supply of agricultural products is strongly influenced by random events, such as the weather, while the supply of manufactured goods usually is dependent on business decisions. One of the strongest parameters in business decisions, ironically, is the consideration of future prices.

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A ROSE IS A ROSE IS A ROSE—BUT ALL DRAMs ARE NOT ALIKE

Considerable differentiation occurs among DRAMs. Speed range, package style, testing parameters, quality, and other features create a wide variety of product options that do not exist in traditional commodities. The proliferation of futures contracts required to cover these variants may be traded so sparsely as to keep the concept from meeting the economists' definition of an efficient market. Industry trends clearly are against a commodity market. Manufacturers are trying to distance themselves from competitors by creating unique product variations based on parameters, packaging, and architecture (video RAMs, for example). Enough perceived differences exist among various manufacturers to create confusion about how futures contracts will work.

THE KEY QUESTIONS

Several key questions arise. Will futures contracts really stabilize market pricing or actually make it more volatile? If this idea catches on, will spot and long futures prices become the de facto price standards, set by speculators rather than by honest negotiation between sellers and buyers? Will DRAM manufacturers be able to make more money by buying futures and then influencing the supply rather than selling chips in the open market? Will DRAM buyers really understand how to use this tool as a hedge for future price protection? Can futures possibly work in a market environment that has many government controls such as the present Semiconductor Chip Agreement and its foreign market value provisions?

Probably the most important questions is: What is in it for the manufacturers? This idea obviously will not work without the consensus of most of the major DRAM manufacturers. If futures prices become the standard by which purchase orders are written, then this concept offers manufacturers an opportunity to participate in a form of forward pricing without violating provisions of the chip agreement.

DATAQUEST ANALYSIS

This idea is unusual and has many industry veterans scratching their heads over procedures and possible benefits. We believe that any idea with the potential to solve industry problems should be given due consideration. However, we also believe that not many semiconductor buyers have enough experience with commodities markets to take advantage of this trading vehicle. Eventually, only the largest buyers will be in a position to understand and use this hedge. These are the very companies that do not need such a hedge, because they usually write purchase contracts that specify the price for at least as long as the options.

Supply and demand of commodity products is fairly stable and tied to demographics and other well-understood factors such as acres planted or rainfall. Futures contracts provide price protection against random events causing variations in the supply side. This is not the case with the DRAM market, where the major perturbations are caused by fluctuations in demand that are large compared with the short-term supply. This happens because buyers cannot anticipate their own future needs accurately. Consequently, we wonder just how futures contracts can serve as a market stabilizer in that environment.

Mel Thomsen

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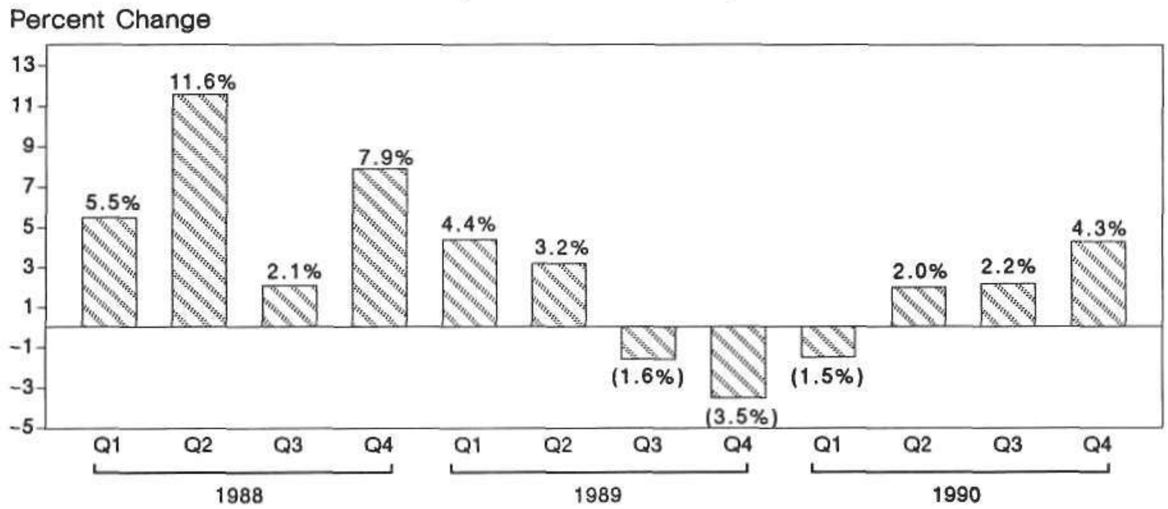
WORLDWIDE SEMICONDUCTOR INDUSTRY UPDATE: WHERE IS THE CLIFF?

INTRODUCTION

The worldwide semiconductor industry is continuing to ride the crest of the boom wave of 1988. Following the fourth quarter of 1988, in which the industry grew 7.9 percent worldwide, Dataquest forecasts first-quarter growth of 4.4 percent in 1989 and second-quarter growth of 3.2 percent, fueled mainly by surprisingly strong shipments of MOS memory. The effect of MOS memory on first-quarter growth is such that if it were excluded from the numbers, the industry growth would be only 1 percent. For all of 1989, we forecast 15.3 percent growth worldwide, with negative growth beginning in the third quarter and continuing through the first quarter of 1990. We believe that the industry will resume positive growth in the second quarter of 1990, resulting in negative 0.5 percent growth for the year 1990. Figure 1 shows the quarter-to-quarter growth rates for the worldwide semiconductor industry through 1990.

Figure 1

**Worldwide Semiconductor Consumption
Quarter-to-Quarter Growth Rates
(Percent of Dollars)**



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Source: Dataquest
April 1989

Table 1 shows the worldwide quarterly growth forecast by regions of the world.

Table 1

Worldwide Semiconductor Consumption
Quarter-to-Quarter Forecast by Geographic Region
(Millions of Dollars)

	1988	Q1/89	Q2/89	Q3/89	Q4/89	1989
North America	16,013	4,543	4,739	4,655	4,411	18,348
Percent Change	24.7%	7.3%	4.3%	(1.8%)	(5.2%)	14.6%
Japan	20,332	5,852	5,987	5,901	5,625	23,366
Percent Change	35.6%	1.8%	2.3%	(1.4%)	(4.7%)	14.9%
Europe	8,491	2,332	2,384	2,303	2,338	9,357
Percent Change	31.0%	3.4%	2.2%	(3.4%)	1.5%	10.2%
Asia/Rest of World	5,650	1,724	1,807	1,816	1,786	7,133
Percent Change	42.6%	7.5%	4.9%	0.5%	(1.6%)	26.3%
Total World	50,486	14,451	14,918	14,675	14,160	58,204
Percent Change	31.9%	4.4%	3.2%	(1.6%)	(3.5%)	15.3%

	Q1/90	Q2/90	Q3/90	Q4/90	1990
North America	4,327	4,316	4,415	4,585	17,643
Percent Change	(1.9%)	(0.3%)	2.3%	3.9%	(3.8%)
Japan	5,466	5,656	5,837	6,101	23,060
Percent Change	(2.8%)	3.5%	3.2%	4.5%	(1.3%)
Europe	2,346	2,398	2,367	2,483	9,594
Percent Change	0.4%	2.2%	(1.3%)	4.9%	2.5%
Asia/Rest of World	1,807	1,862	1,921	2,003	7,593
Percent Change	1.2%	3.0%	3.2%	4.3%	6.4%
Total World	13,947	14,231	14,540	15,172	57,890
Percent Change	(1.5%)	2.0%	2.2%	4.4%	(0.5%)

Source: Dataquest
April 1989

In January 1989, we forecast 9.0 percent growth for the worldwide semiconductor industry in 1989. We have raised that forecast to 15.3 percent growth now, in response to a changed scenario that includes the following:

- Revision of fourth-quarter shipment numbers by WSTS, Inc., which brought the fourth-quarter growth rate up significantly

- Very low January 1989 billings, followed by dramatic growth in February billings, which led us to a more bullish outlook for both first and second quarters of 1989

- Firmness in MOS memory prices for the first quarter and slight decreases forecast for the second quarter, combined with strong fourth quarter 1988 bookings for MOS memory

FORECAST BY PRODUCT

The driving force behind the 1989 industry growth is MOS memory, particularly DRAMs and SRAMs. Pricing in the first quarter of 1989 stayed firm with the fourth quarter of 1988, and second quarter 1989 pricing appears to be headed down only slightly. However, by the third quarter, we expect prices to be much lower. Overall unit growth of memories will be up approximately 10 percent over 1988, while dollar growth will be up 46.6 percent. New applications for DRAMs will include digital copiers, digital fax machines, digital VCRs, and HDTV.

The outlook for microdevices and logic is significantly different. Microdevice growth began to slow in the fourth quarter of 1988 because of overbuying of key microprocessors such as the 80386, combined with a sluggish personal computer industry. The PC industry is expected to grow more slowly in 1989 than in 1988, at about 12 percent in units. We expect microdevice growth in 1989 to be 5.6 percent. MOS logic growth, at 11.3 percent, we expect to be fairly stable.

The bipolar memory and logic markets both did extremely poorly in the second half of 1988, and we expect this negative growth to continue in 1989, as many applications switch to CMOS and BiCMOS. Pricing on bipolar PLDs and bipolar standard logic dropped severely in the fourth quarter of 1988.

We expect all product areas to begin recovering in the last three quarters of 1990, with the exception of MOS memory, which will begin its recovery one quarter later.

Tables 2 and 3 show our worldwide quarterly semiconductor consumption forecast by product type.

Table 2

Worldwide Semiconductor Consumption
Quarter-to-Quarter Forecast by Product
(Millions of Dollars)

	1988	Q1/89	Q2/89	Q3/89	Q4/89	1989
Total Semiconductor	50,486	14,451	14,918	14,675	14,161	58,204
Total IC	40,800	11,826	12,241	12,034	11,579	47,680
Bipolar Digital	5,197	1,135	1,171	1,150	1,126	4,582
Memory	670	162	157	146	137	601
Logic	4,527	973	1,014	1,004	990	3,981
MOS	26,780	8,350	8,653	8,465	8,020	33,487
Memory	11,571	4,277	4,446	4,322	3,918	16,963
Microdevice	7,127	1,861	1,915	1,882	1,868	7,526
Logic	8,082	2,212	2,292	2,261	2,233	8,998
Analog	8,823	2,341	2,417	2,420	2,433	9,611
Discrete	7,543	2,011	2,040	2,023	1,990	8,064
Optoelectronic	2,143	614	637	618	591	2,461

	Q1/90	Q2/90	Q3/90	Q4/90	1990
Total Semiconductor	13,947	14,231	14,540	15,172	57,890
Total IC	11,379	11,579	11,839	12,354	47,151
Bipolar Digital	1,069	1,078	1,102	1,144	4,393
Memory	135	142	143	144	565
Logic	933	936	959	1,000	3,829
MOS	7,926	7,993	8,225	8,617	32,761
Memory	3,831	3,793	3,890	4,068	15,582
Microdevice	1,891	1,996	2,069	2,159	8,115
Logic	2,203	2,204	2,266	2,390	9,064
Analog	2,385	2,508	2,512	2,592	9,997
Discrete	1,972	2,022	2,048	2,138	8,180
Optoelectronic	596	629	653	681	2,558

Source: Dataquest
April 1989

Table 3

Worldwide Semiconductor Consumption
Quarter-to-Quarter Forecast by Product
(Percent Change)

	1988	Q1/89	Q2/89	Q3/89	Q4/89	1989
Total Semiconductor	31.9%	4.4%	3.2%	(1.6%)	(3.5%)	15.3%
Total IC	36.4%	4.4%	3.5%	(1.7%)	(3.8%)	16.9%
Bipolar Digital	9.1%	(2.2%)	3.2%	(1.9%)	(2.0%)	(11.8%)
Memory	7.9%	(0.7%)	(3.1%)	(7.0%)	(6.5%)	(10.2%)
Logic	9.3%	(2.4%)	4.2%	(1.1%)	(1.4%)	(12.1%)
MOS	53.1%	6.9%	3.6%	(2.2%)	(5.3%)	25.0%
Memory	90.3%	13.5%	3.9%	(2.8%)	(9.3%)	46.6%
Microdevice	39.8%	1.3%	2.9%	(1.7%)	(0.7%)	5.6%
Logic	28.1%	0.4%	3.6%	(1.4%)	(1.2%)	11.3%
Analog	15.3%	(0.9%)	3.3%	0.1%	0.6%	8.9%
Discrete	13.2%	3.4%	1.5%	(0.8%)	(1.6%)	6.9%
Optoelectronic	25.4%	8.7%	3.6%	(2.9%)	(4.3%)	14.8%

	Q1/90	Q2/90	Q3/90	Q4/90	1990
Total Semiconductor	(1.5%)	2.0%	2.2%	4.3%	(0.5%)
Total IC	(1.7%)	1.8%	2.2%	4.4%	(1.1%)
Bipolar Digital	(5.1%)	0.9%	2.2%	3.8%	(4.1%)
Memory	(0.9%)	5.1%	0.7%	0.3%	(6.1%)
Logic	(5.7%)	0.3%	2.4%	4.3%	(3.8%)
MOS	(1.2%)	0.8%	2.9%	4.8%	(2.2%)
Memory	(2.2%)	(1.0%)	2.6%	4.6%	(8.1%)
Microdevice	1.2%	5.6%	3.6%	4.4%	7.8%
Logic	(1.3%)	0	2.8%	5.5%	0.7%
Analog	(2.0%)	5.2%	0.2%	3.2%	4.0%
Discrete	(0.9%)	2.6%	1.3%	4.4%	1.4%
Optoelectronic	0.7%	5.6%	3.7%	4.3%	4.0%

Source: Dataquest
April 1989

LONG-TERM FORECAST

Tables 4 and 5 show our five-year outlook for the worldwide semiconductor industry by region. Table 4 gives the dollars and percent growth, while Table 5 shows the changes in each region as a percentage of the total market. As expected, the Rest of World (ROW) region will grow fastest over time, increasing its share of the worldwide market at the expense of Japan, North America, and Europe.

Table 4

Worldwide Semiconductor Consumption
by Geographic Region
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	CAGR 88-93
North America	16,013	18,348	17,643	20,304	24,585	33,340	15.8%
Percent Change	24.7%	14.6%	(3.8%)	15.1%	21.1%	35.6%	
Japan	20,332	23,366	23,060	26,656	31,931	42,548	15.9%
Percent Change	35.6%	14.9%	(1.3%)	15.6%	19.8%	33.2%	
Europe	8,491	9,357	9,594	11,126	14,564	17,135	15.1%
Percent Change	31.0%	10.2%	2.5%	16.0%	30.9%	17.7%	
Asia/Rest of World	5,650	7,133	7,593	9,374	11,954	16,337	23.7%
Percent Change	42.6%	26.2%	6.4%	23.5%	27.5%	36.7%	
Total World	50,486	58,204	57,890	67,460	83,034	109,360	
Percent Change	31.9%	15.3%	(0.5%)	16.5%	23.1%	31.7%	16.7%

Source: Dataquest
April 1989

Table 5

Worldwide Semiconductor Consumption
by Geographic Region
as a Percentage of Worldwide Consumption
(Percent of Dollars)

	1988	1989	1990	1991	1992	1993
North America	31.7%	31.5%	30.5%	30.1%	29.6%	30.5%
Japan	40.3	40.1	39.8	39.5	38.5	38.9
Europe	16.8	16.1	16.6	16.5	17.5	15.7
Asia/Rest of World	11.2	12.3	13.1	13.9	14.4	14.9
Total World	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest
April 1989

The worldwide five-year forecast by product is shown in Table 6.

Table 6

Worldwide Semiconductor Consumption
Five-Year Forecast by Product
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	CAGR 88-93
Total Semiconductor	50,486	58,204	57,890	67,460	83,034	109,360	16.7%
Total IC	40,800	47,679	47,152	55,515	69,427	93,767	18.1%
Bipolar Digital	5,197	4,582	4,394	4,654	5,085	5,623	1.6%
Memory	670	601	565	553	512	494	(5.9%)
Logic	4,527	3,981	3,829	4,101	4,573	5,129	2.5%
MOS	26,780	33,486	32,761	39,226	50,303	71,093	21.6%
Memory	11,571	16,962	15,582	18,383	23,550	36,561	25.9%
Microdevice	7,127	7,526	8,115	9,870	12,835	16,801	18.7%
Logic	8,082	8,998	9,064	10,973	13,918	17,731	17.0%
Analog	8,823	9,611	9,997	11,635	14,039	17,051	14.1%
Discrete	7,543	8,064	8,180	9,060	10,265	11,677	9.1%
Optoelectronic	2,143	2,461	2,558	2,885	3,342	3,916	12.8%

Source: Dataquest
April 1989

Historically, the semiconductor industry has enjoyed a boom every four to five years. Most recently, the booms have occurred in 1984 and 1988, with a runover still occurring in the first half of 1989. We believe that the next worldwide boom year will be 1993, with growth of 31.7 percent. Given the fact that the industry experienced severe recessions in 1975 and 1985, we believe that another serious downturn could occur in the 1994 to 1995 time frame, although that is beyond the time period covered in this forecast.

Europe

The European market is the one to watch over the next few years, as both multinational and local companies plan for the opening of the single European market in 1992. Currently, several Japanese and U.S. OEMs are building plants in Europe to take advantage of the expected "1992 Effect." To take advantage of the tax system, these plants will find it necessary to purchase most of their semiconductor needs locally. As a result, several new semiconductor plants also are in the works to supply those needs. In addition, major European multinational companies—such as Siemens—are planning to move more manufacturing into Europe. We believe that semiconductor consumption will be shifted to some degree from North America and Japan into Europe. We believe that, because of 1992, European consumption will peak in 1992 before the peak hits in the other regions of the world. Therefore, Europe will gain share of the worldwide market in 1992. After 1992, however, we expect normal growth patterns to resume.

Japan

Japanese consumption continues to be fueled by domestic demand. New applications such as extended-definition television (EDTV)—to be followed by high-definition television (HDTV) in the 1990s—and POS terminals are expected to be very strong markets. The POS terminal demand is a response to the new sales tax instituted in Japan in April of this year; terminals that can automatically calculate the tax and total a sale will be needed. Automatic teller machine (ATM) growth continues to be strong, as does demand for personal computers at securities firms and laptop computers at midsize companies. Capital spending by semiconductor companies will be well below 1984 yen levels in 1989 and 1990. Return on investment for semiconductor capital expenditures is now above 1 in Japan, for the first time since 1984.

North America

The North American market will experience a slowdown in GNP and capital spending in the second half of 1989. We expect U.S. capital spending plans currently in place to be maintained, but higher interest rates will scare off spending plans for the second half of 1989.

Capital spending by semiconductor companies will be back up to 1984 dollar levels in 1989 and 1990, but capital spending as a percent of revenue will be about half that of 1984. We expect it to creep up in the 1991 to 1993 time frame.

Asia-Pacific/Rest of World

The Asian semiconductor market will be driven by consumer applications, as the domestic markets of China and Thailand heat up from unleashed consumer demand. Communications applications are expected to have extremely strong growth as well, as the newly industrialized and developing countries of Asia improve their telecommunications infrastructure. In addition, the personal computer industry in Taiwan, which experienced strong growth in 1988, is expected to continue to be a driving factor.

DATAQUEST CONCLUSIONS

As evidenced by the 32 percent worldwide growth experienced in 1988, the semiconductor industry is still a strong, dynamic industry, with the capability to surprise skeptics.

In spite of Asia's strong growth, we believe that the ROW region will not overtake Europe in total dollar size until sometime after 1993. Europe will get a new lease on life as a result of the single European market scheduled for 1992.

MOS memory, which drove the industry in 1988 and will continue to do so in 1989, will remain the fastest-growing product through 1993. Microdevices will grow the second fastest.

Dataquest believes that the semiconductor industry will begin its descent over the cliff in the second half of 1989. It will have a gentle landing in 1989 and 1990, however, compared with the crash landing the industry experienced in 1985. From 1991 through 1993, we expect the worldwide semiconductor industry to be healthy and growing.

Patricia S. Cox

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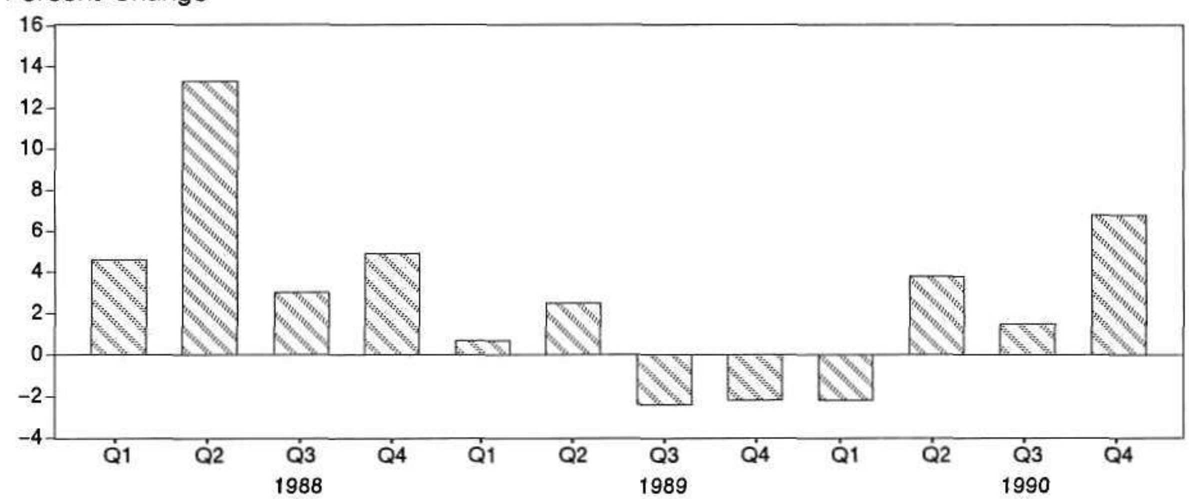
WORLDWIDE SEMICONDUCTOR OUTLOOK: FIRST QUARTER 1989

SUMMARY

As we promised in December, we have reexamined the outlook for the worldwide semiconductor industry through 1989 and 1990. The general picture has not changed; basically, events are occurring according to our October forecast assumptions. The major change is that fourth quarter 1988 was lower than forecast for the U.S. and ROW markets. In the case of the U.S. market, this was mainly due to inventory corrections. In the ROW market, a definite softening in the PC market occurred. We expect most regions to be fairly strong in the first half of 1989, with the exception of Japan, which experienced unusually strong growth in fourth quarter 1989. We retain our forecast of three negative quarters beginning in the third quarter of 1989, as memory prices fall and the U.S. economy softens slightly. The second half of 1990 should be a period of recovery. Figure 1 shows our quarterly forecast for the worldwide semiconductor industry.

Figure 1

Worldwide Semiconductor Consumption
Quarter-to-Quarter Percent Change in U.S. Dollars



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Source: Dataquest
February 1989

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MARKET CONDITIONS

Table 1 gives our total semiconductor estimates and forecast by region and by quarter for 1988 through 1990.

Table 1

Worldwide Semiconductor Consumption (Millions of Dollars)

	1988 Q1	1988 Q2	1988 Q3	1988 Q4	1988 Total
United States	$ 3,560	$ 4,025	$ 4,279	$ 4,149	$16,013
Percent Change	2.2%	13.1%	6.3%	(3.0%)	24.7%
Japan	4,405	4,995	5,160	5,772	20,332
Percent Change	2.3%	13.4%	3.3%	11.9%	35.6%
Europe	1,967	2,203	2,084	2,237	8,491
Percent Change	11.6%	12.0%	(5.4%)	7.3%	31.0%
ROW	1,235	1,424	1,499	1,497	5,655
Percent Change	10.1%	15.3%	5.3%	(0.1%)	42.8%
Total	$11,167	$12,647	$13,022	$13,655	$50,491
Percent Change	4.6%	13.3%	3.0%	4.9%	31.9%

	1989 Q1	1989 Q2	1989 Q3	1989 Q4	1989 Total
United States	$ 4,294	$ 4,393	$ 4,394	$ 4,280	$17,361
Percent Change	3.5%	2.3%	0	(2.6%)	8.4%
Japan	5,610	5,717	5,488	5,203	22,018
Percent Change	(2.8%)	(1.9%)	(4.0%)	(5.2%)	8.3%
Europe	2,262	2,314	2,122	2,217	8,915
Percent Change	1.1%	2.3%	(8.3%)	4.5%	5.0%
ROW	1,579	1,661	1,742	1,745	6,727
Percent Change	5.5%	5.2%	4.9%	0.2%	19.0%
Total	$13,745	$14,085	$13,746	$13,445	$55,021
Percent Change	0.7%	2.5%	(2.4%)	(2.2%)	9.0%

	1990 Q1	1990 Q2	1990 Q3	1990 Q4	1990 Total
United States	$ 4,194	$ 4,110	$ 4,110	$ 4,316	$16,730
Percent Change	(2.0%)	(2.0%)	0	5.0%	(3.6%)
Japan	4,891	5,361	5,618	6,129	21,999
Percent Change	(6.0%)	9.6%	4.8%	9.1%	(0.1%)
Europe	2,270	2,340	2,282	2,474	9,366
Percent Change	2.4%	3.1%	(2.5%)	8.4%	5.1%
ROW	1,794	1,832	1,841	1,874	7,341
Percent Change	2.8%	2.1%	0.5%	1.8%	9.1%
Total	$13,149	$13,643	$13,851	$14,793	$55,436
Percent Change	(2.2%)	3.8%	1.5%	6.8%	0.8%

Source: Dataquest
February 1989

United States

The outlook in the U.S. market is for modest growth in the first half of 1989, then slowing in the second half of the year and the first half of 1990. Recovery will begin in the fourth quarter of 1990. Economic signs are mixed. Although the U.S. economy is expected to experience slower growth in 1989—2.5 percent—than in 1988, inflation is still low, and unemployment is at its lowest point in 14 years. However, the trade and budget deficits and the savings-and-loan industry crisis are clouding up the scene. On the bright side, Dun & Bradstreet surveys show that, while total capital spending may not be strong in 1989, investment in the high-tech area—i.e., for computer systems, office equipment, and automation—will remain high as companies strive for increased efficiency and modernization.

Dataquest surveys of semiconductor purchasing managers show that actual semiconductor inventory levels are coming down, and are only one to two days above target levels. Dataquest forecasts 1989 total computer shipments to be up by 9.4 percent and all electronic equipment production to be up 7.6 percent, versus 8.5 percent in 1988. Workstation growth is expected to be very high. In the PC arena, several new products have already been introduced this year by Apple and Digital Equipment Corporation.

The first half of 1989 will be helped along by latent demand from 1988. Many systems either were not shipped because of lack of memory chips or were shipped without memories, which will be added in 1989.

The Japanese companies that dominate the DRAM market are slowing their annual production increases in an attempt to prevent serious market gluts such as the one experienced in 1984 and 1985. As a result, the supply-demand situation in DRAMs will be kept in check. Also, the price curve for 4Mb DRAMs is higher than for previous generations, so price erosion will not be as serious. We expect DRAM prices to fall during 1989 and come back up in 1990 as 4Mb models become more widespread.

Japan

Japanese market growth will be about the same as U.S. market growth in 1989. We expect 1990 growth to be flat. Pricing will decline about 5 percent by the end of 1989, but some memory prices, particularly of 1Mb DRAMs, will be down 50 percent.

Electronic equipment growth will be 7.6 percent in 1989, about the same as in the United States. The Japanese economy is forecast to be quite strong in 1989, with real GNP growth of 4 percent.

Europe

We expect the European market to grow about 5.0 percent in both 1989 and 1990. Worldwide growth will be 9.0 percent and 0.8 percent, respectively, in those years. Although Europe will likely continue to experience the seasonal negative third quarter in both years, we believe that Europe will avoid the recession affecting the U.S. and Japanese markets largely because of the "1992 effect," when the European Economic Community becomes one market. This has already led to increased manufacturing by foreign companies in the European market. For example, Citizen, Compaq, NEC, Oki, and Sanyo are manufacturing computers and office equipment in Europe. Because of stringent local content laws, these companies will be forced to increase their local purchases of semiconductors within Europe drastically. This will have an adverse effect on Japanese market growth.

We believe that first quarter 1989 billings ASPs will be firm compared with fourth quarter 1988, but bookings ASPs will soften, leading to lower billings ASPs in second quarter 1989. Main areas of price pressure will be in DRAMs, some areas of specialized analog, and programmable logic devices.

On a positive note, we expect some new applications to take off by the middle of 1989. Chief among these is cellular telephone technology.

ROW

The ROW market, as usual, is expected to surpass all other regions in growth for both 1989 and 1990, growing 19 percent in 1989 and 9 percent in 1990. Fourth quarter 1988 growth was flat due to a soft PC market. Growth in 1989 will likely be fueled by a 21 percent increase in consumer electronics production and a 14 percent increase in data processing production.

Although a more protectionist U.S. market is expected as Congress tries to deal with the trade deficit, we see strong growth in trade activity among the ROW countries, which will help to counteract the U.S. import restrictions.

Foreign investment in the region has been and is likely to continue to be very strong. Japan is leading the way in offshore activity within ROW. U.S. governmental technology-flow restrictions will be greatly relaxed in 1989, which will help China's electronics industry growth.

DATAQUEST CONCLUSIONS

The years 1989 and 1990 will be slow ones for the worldwide semiconductor industry, following the two very strong years of 1987 and 1988. Bright spots include increased activity in Europe because of the 1992 effect and continuing strong growth in ROW. Japan, Europe, and the United States are all involved in high-definition television (HDTV) research and development. This, along with cellular telephone technology, could evolve into a major driver of the semiconductor industry, leading to the industry recovery we expect in the final quarter of 1990.

Patricia S. Cox

(Note: The total semiconductor consumption statistics in this newsletter are consistent with our company semiconductor market share data base, to be published in February and included in the Semiconductor Industry Service (SIS), Japanese Semiconductor Industry Service (JSIS), North American Semiconductor Markets (NASM) service, and the European Semiconductor Industry Service (ESIS) research reference binders.)

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PRELIMINARY 1988 WORLDWIDE SEMICONDUCTOR MARKET SHARES: JAPANESE GAIN SHARE; MEMORIES AND MICROS DOMINATE MARKET

SUMMARY

Dataquest's preliminary 1988 semiconductor market share survey has been completed. An analysis of the data shows the following:

- Worldwide market growth slowed in the fourth quarter of 1988 after a very strong showing in the first three quarters, resulting in total market growth of 32.9 percent.

- Japanese companies gained market share on all fronts, taking 50 percent of the worldwide market.

- U.S. companies gained market share in Japan for the first time since 1984.

- MOS memory and microdevices drove the market; those companies with memory and micro strength did extremely well.

Table 1 shows the total 1988 semiconductor revenue of the 112 companies surveyed by company base and by region sold into.

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Table 1

Preliminary 1988 Market Share Analysis—Top 112 Companies (Millions of Dollars)

	Regional Market				
Company Base	North America	Japan	Europe	ROW	World
North America	11,262	1,956	3,725	1,859	18,802
Percent of Regional Market	70%	10%	44%	33%	37%
Percent of Company Sales	60%	10%	20%	10%	100%
Japan	3,242	17,913	1,438	2,496	25,089
Percent of Regional Market	20%	89%	17%	44%	50%
Percent of Company Sales	13%	71%	6%	10%	100%
Europe	1,056	106	3,163	600	4,925
Percent of Regional Market	7%	1%	37%	11%	10%
Percent of Company Sales	21%	2%	64%	12%	100%
ROW	420	62	165	704	1,351
Percent of Regional Market	3%	0	2%	12%	3%
Percent of Company Sales	31%	5%	12%	52%	100%
Total World	15,980	20,037	8,491	5,659	50,167
Percent of Regional Market	100%	100%	100%	100%	100%
Percent of Company Sales	32%	40%	17%	11%	100%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
January 1989

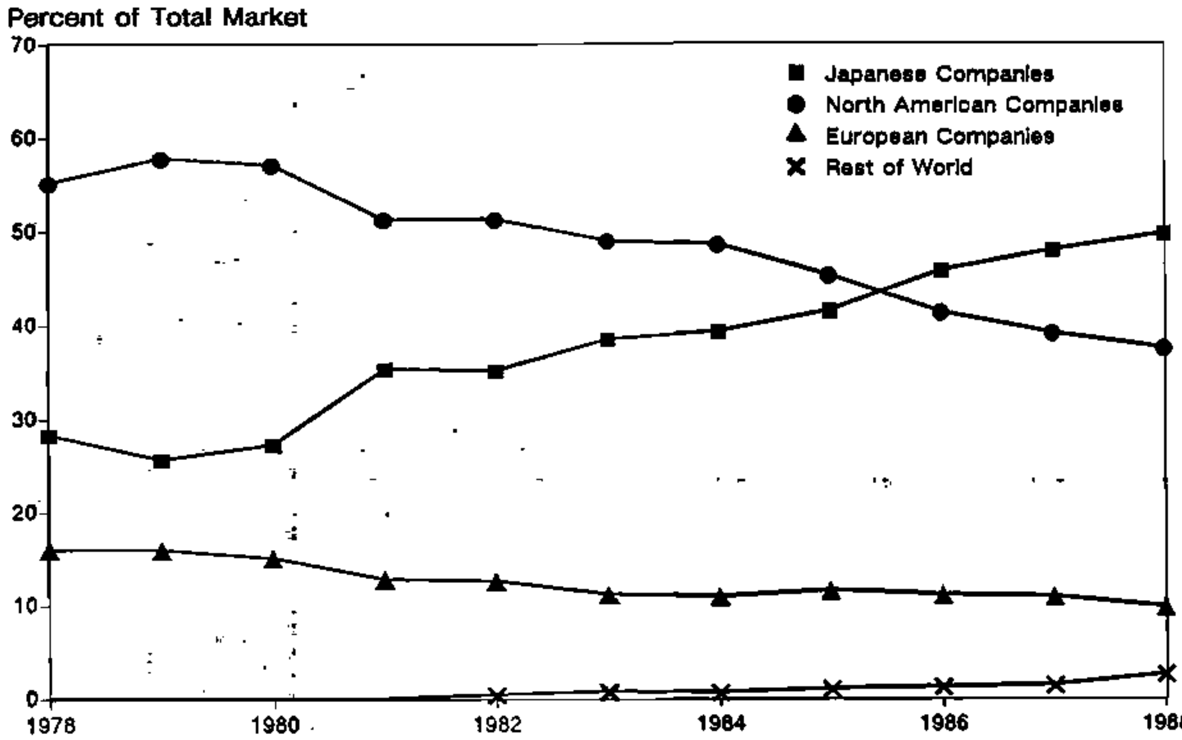
WORLDWIDE MARKET

Dataquest's preliminary survey of 1988 results for the top 112 worldwide semiconductor suppliers shows that the worldwide semiconductor industry grew 32.9 percent. This figure is less than our current forecast of 35.8 percent, mainly due to a slowdown in the North American and Rest of World (ROW) markets in the fourth quarter. Although the ranking of the top five suppliers in the market remained the same as in 1987, the market dynamics were clearly different in 1988. As Table 1 shows, North American companies' sales accounted for 10 percent of the total Japanese semiconductor market; this is the highest market share the United States has attained since 1984. On the other hand, Japanese companies' sales accounted for 20 percent of the North American market in 1988. This is an all-time record for the Japanese, due mainly to their dominance in DRAMs.

As also shown in Table 1, Japanese companies grew in 1988 to 50 percent of the worldwide semiconductor market, while North American companies dropped to 37 percent of the worldwide market. European companies also dropped to 10 percent, and ROW companies grew to 3 percent (up from 1.6 percent in 1987). Figure 1 illustrates the market share trends from 1978 through 1988.

Figure 1

Worldwide Semiconductor Market Shares by Company Base



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Source: Dataquest
January 1989

RANKINGS

The Companies

Looking back to 1978, the top five semiconductor companies were Texas Instruments, Motorola, Philips, NEC, and Hitachi. In 1983, things changed substantially. The ranking at that time was Motorola, Texas Instruments, NEC, Hitachi, and Toshiba. In 1988, the companies were the same, but the ranking was NEC, Toshiba, Hitachi, Motorola, and Texas Instruments. No European company has been among the top five semiconductor companies since 1982. Toshiba is aggressively moving to surpass NEC as the number one supplier; however, that event did not occur in 1988. Among companies in the top 10, Intel had the highest growth, at 57.6 percent, due to its tremendous strength in microprocessors and the high demand for its 80386. One ROW company—Samsung—jumped from number 23 in 1987 to number 18 in 1988, becoming the first ROW company to join the top 20 ranking. Figure 2 lists the top 20 semiconductor companies worldwide.

Figure 2

Top 20 Worldwide Semiconductor Manufacturers for 1988

Company	1988 Rank	1987 Rank		1987 Sales	1988 Sales	Percent Change
				(Millions of Dollars)		
NEC	1	1		3,368	4,534	34.6%
Toshiba	2	2		3,029	4,302	42.0%
Hitachi	3	3		2,618	3,506	33.9%
Motorola	4	4		2,431	3,035	24.8%
Texas Instruments	5	5		2,127	2,741	28.9%
Fujitsu	6	6		1,801	2,359	31.0%
Intel	7	10		1,491	2,350	57.6%
Mitsubishi	8	9		1,492	2,278	52.7%
Matsushita	9	11		1,457	1,886	29.4%
Philips-Signetics	10	7		1,602	1,764	10.1%
National Semiconductor	11	8		1,506	1,700	12.9%
Advanced Micro Devices	12	12		986	1,106	12.2%
Sanyo	13	14		851	1,085	27.5%
SGS-Thomson	14	13		859	1,083	26.1%
Sharp	15	18		590	1,037	75.8%
Oki	16	17		651	947	45.5%
Sony	17	19		574	924	61.0%
Sansung	18	23		327	905	176.8%
AT&T	19	15		802	859	7.1%
Siemens	20	16		657	784	19.3%

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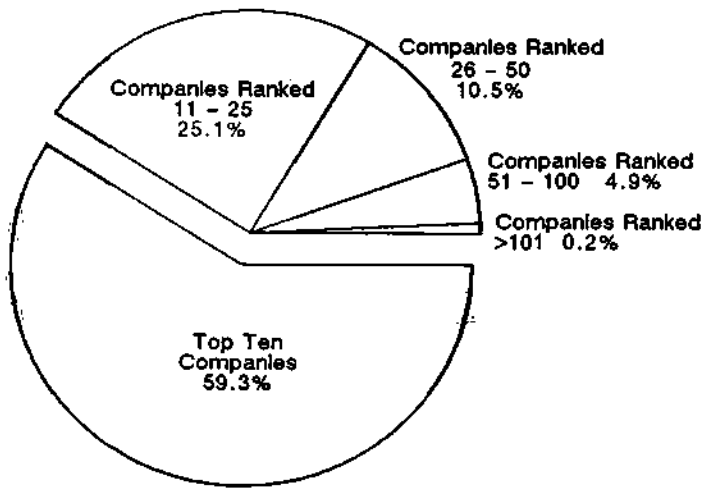
Source: Dataquest
January 1989

Market Concentration

In 1988, the top 10 companies accounted for well over half of total worldwide semiconductor market revenue. The top 25 companies together accounted for 84 percent of the market. The remaining companies (ranked 26 through 112) accounted for only 16 percent of the worldwide market. Figure 3 shows the revenue concentration percentages.

Figure 3

**1988 Worldwide Semiconductor Market Share—
Concentration of Revenue**



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Source: Dataquest
January 1989

PRODUCT MARKETS

The products driving 1988's strong market growth were memories—especially DRAMs and SRAMs—and microdevices. Table 2 shows worldwide industry growth by product for the 112 companies surveyed. MOS ASIC revenue also showed very strong growth of 37.0 percent. In a total market that grew 32.9 percent, MOS memory grew 91.1 percent and MOS microdevices grew 42.8 percent. If MOS memory were removed from the picture, total industry growth would have been only 21.8 percent. The removal of both MOS memory and MOS microdevices would leave a total market growth of only 17.6 percent. The importance of memory and micros is shown graphically in Figure 4.

Table 2

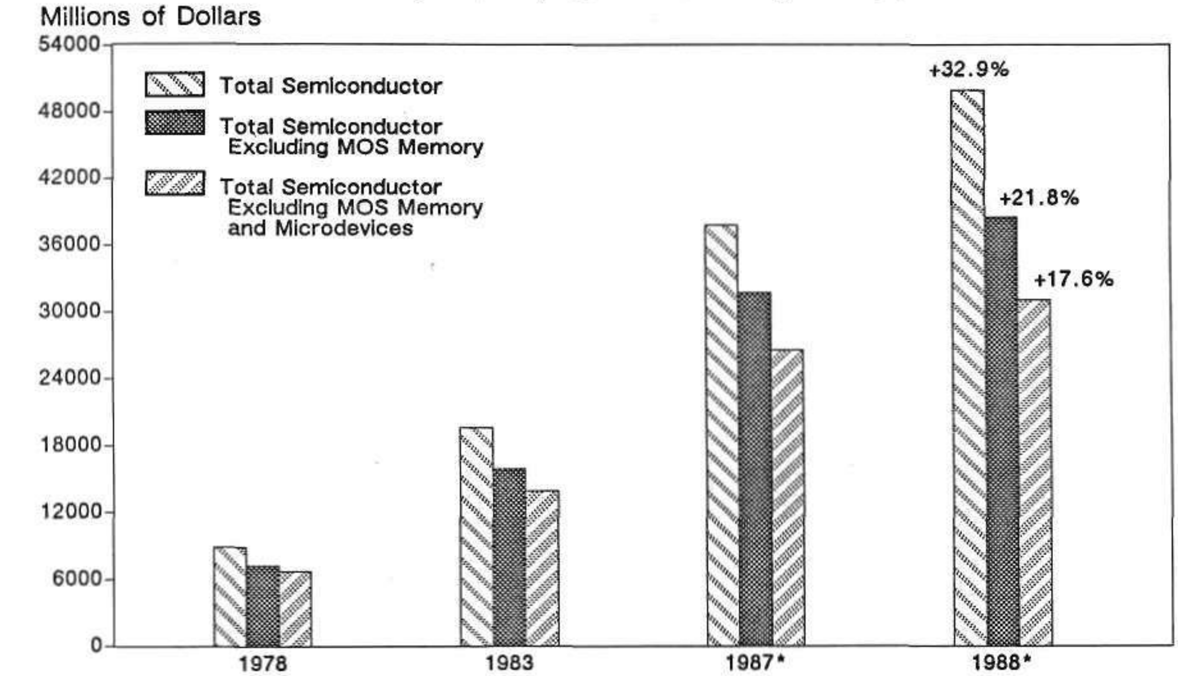
Worldwide Semiconductor Market
Revenue Base of Top 112 Companies
(Millions of Dollars)

	1987	1988	Percent Change
Total Semiconductor	37,759	50,167	32.9%
Total Integrated Circuit	29,568	40,689	37.6%
Bipolar Digital	4,730	5,162	9.1%
Bipolar Memory	620	669	7.9%
Bipolar Logic	4,110	4,493	9.3%
ASIC	1,671	1,855	11.0%
Standard Logic	2,243	2,398	6.9%
Other Logic	196	240	22.4%
MOS Digital	17,465	26,964	54.4%
MOS Memory	6,047	11,555	91.1%
MOS Microdevice	5,204	7,429	42.8%
MOS Logic	6,214	7,980	28.4%
ASIC	4,189	5,741	37.0%
Standard Logic	1,105	1,265	14.5%
Other Logic	920	974	5.9%
Analog	7,373	8,563	16.1%
Monolithic	6,443	7,474	16.0%
Hybrid	930	1,089	17.1%
Discrete	6,557	7,449	13.6%
Optoelectronic	1,634	2,029	24.2%

Source: Dataquest
January 1989

Figure 4

Memory and Micros: The Industry Drivers



* "Other" companies are not included in 1987 and 1988 numbers.

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Source: Dataquest January 1989

Tables 3 through 9 rank the top 20 manufacturers in the categories of total integrated circuit, total bipolar digital, total MOS digital, MOS memory, analog ICs, discrete, and optoelectronic.

In the MOS digital category, the phenomenal growth experienced by Mitsubishi, Samsung, Sharp, and Micron Technology was due to high demand for DRAMs. The extremely high growth experienced by Western Digital (WD) was caused largely by internal demand for microperipherals from the computer storage companies that WD acquired during 1987 and 1988.

In MOS memory, changes in ranking occurred among the top 10 companies, although NEC remained number one. Samsung and Micron Technology both jumped two places. Advanced Micro Devices, number 10 in 1987, dropped to number 15 because of its lack of participation in the DRAM market.

Table 3

1988 World Semiconductor Market Share Ranking
Total Integrated Circuit
(Millions of Dollars)

1988 Rank	1987 Rank	Company	1987 Revenue	1988 Revenue	Percent Change
1	1	NEC	2,795	3,875	38.6%
2	2	Toshiba	2,194	3,223	46.9%
3	4	Hitachi	1,946	2,729	40.2%
4	3	Texas Instruments	2,024	2,637	30.3%
5	7	Intel	1,491	2,350	57.6%
6	5	Motorola	1,755	2,259	28.7%
7	6	Fujitsu	1,660	2,166	30.5%
8	9	Mitsubishi	1,239	1,940	56.6%
9	8	National Semiconductor	1,431	1,625	13.6%
10	11	Matsushita	994	1,335	34.3%
11	10	Philips	1,186	1,302	9.8%
12	12	Advanced Micro Devices	986	1,106	12.2%
13	14	Oki	619	902	45.7%
14	22	Samsung	291	850	192.1%
15	13	SGS-Thomson	646	829	28.3%
16	16	Sanyo	556	813	46.2%
17	17	Sharp	367	752	104.9%
18	15	AT&T	595	688	15.6%
19	18	Sony	364	595	63.5%
20	20	Siemens	354	480	35.6%
		U.S. Companies	12,455	16,323	31.1%
		ROW Companies	500	1,230	146.0%
		Japan Companies	13,795	19,702	42.8%
		Europe Companies	2,818	3,434	21.9%
		Total World Companies	29,568	40,689	37.6%

Source: Dataquest
January 1989

Table 4

1988 World Semiconductor Market Share Ranking
Total Bipolar Digital
(Millions of Dollars)

1988 Rank	1987 Rank	Company	1987 Revenue	1988 Revenue	Percent Change
1	1	Texas Instruments	854	940	10.1%
2	2	National Semiconductor	521	575	10.4%
3	3	Advanced Micro Devices	500	562	12.4%
4	4	Fujitsu	495	561	13.3%
5	5	Hitachi	463	501	8.2%
6	7	Philips	405	442	9.1%
7	6	Motorola	429	435	1.4%
8	8	NEC	247	292	18.2%
9	10	Mitsubishi	122	128	4.9%
10	9	Toshiba	125	108	(13.6%)
11	12	Plessey	68	95	39.7%
12	17	Harris	30	62	106.7%
13	11	AT&T	79	61	(22.8%)
14	14	Raytheon	51	55	7.8%
15	18	Sanyo	29	41	41.4%
16	16	Oki	32	38	18.8%
17	22	Gold Star	21	32	52.4%
18	13	Siemens	63	31	(50.8%)
19	21	Chips & Technologies	25	30	20.0%
20	20	Matsushita	26	30	15.4%
		U.S. Companies	2,583	2,806	8.6%
		ROW Companies	21	32	52.4%
		Japan Companies	1,540	1,700	10.4%
		Europe Companies	586	624	6.5%
		Total World Companies	4,730	5,162	9.1%

Source: Dataquest
January 1989

Table 5

1988 World Semiconductor Market Share Ranking
Total MOS Digital
(Millions of Dollars)

1988 Rank	1987 Rank	Company	1987 Revenue	1988 Revenue	Percent Change
1	1	NEC	2,006	3,114	55.2%
2	2	Toshiba	1,593	2,546	59.8%
3	3	Intel	1,473	2,328	58.0%
4	4	Hitachi	1,173	1,885	60.7%
5	5	Fujitsu	1,014	1,437	41.7%
6	7	Mitsubishi	812	1,408	73.4%
7	6	Motorola	987	1,399	41.7%
8	8	Texas Instruments	784	1,271	62.1%
9	9	Matsushita	592	882	49.0%
10	10	Oki	566	841	48.6%
11	18	Samsung	242	765	216.1%
12	15	Sharp	312	683	118.9%
13	11	National Semiconductor	415	500	20.5%
14	12	Advanced Micro Devices	414	483	16.7%
15	13	SGS-Thomson	344	459	33.4%
16	14	Philips	342	404	18.1%
17	21	Western Digital	187	400	113.9%
18	29	Micron Technology	115	382	232.2%
19	16	AT&T	300	380	26.7%
20	17	LSI Logic	262	370	41.2%
		U.S. Companies	6,924	10,088	45.7%
		ROW Companies	383	1,042	172.1%
		Japan Companies	8,924	14,138	58.4%
		Europe Companies	1,234	1,696	37.4%
		Total World Companies	17,465	26,964	54.4%

Source: Dataquest
January 1989

Table 6

1988 World Semiconductor Market Share Ranking
MOS Memory
(Millions of Dollars)

1988 Rank	1987 Rank	Company	1987 Revenue	1988 Revenue	Percent Change
1	1	NEC	838	1,481	76.7%
2	2	Toshiba	679	1,439	111.9%
3	4	Hitachi	576	1,114	93.4%
4	5	Mitsubishi	492	943	91.7%
5	3	Fujitsu	634	932	47.0%
6	6	Texas Instruments	445	834	87.4%
7	9	Samsung	170	650	282.4%
8	7	Intel	326	392	20.2%
9	12	Micron Technology	115	382	232.2%
10	8	Oki	193	353	82.9%
11	11	Sharp	130	345	165.4%
12	16	Motorola	86	236	174.4%
13	13	NMB	104	218	109.6%
14	15	Matsushita	91	216	137.4%
15	10	Advanced Micro Devices	155	209	34.8%
16	14	SGS-Thomson	95	183	92.6%
17	24	Siemens	52	150	188.5%
18	17	IDT	85	140	64.7%
19	18	Microchip Technology	84	138	64.3%
20	19	National Semiconductor	80	135	68.8%
		U.S. Companies	1,698	2,917	71.8%
		ROW Companies	206	812	294.2%
		Japan Companies	3,909	7,347	88.0%
		Europe Companies	234	479	104.7%
		Total World Companies	6,047	11,555	91.1%

Source: Dataquest
January 1989

Table 7

1988 World Semiconductor Market Share Ranking
Total Analog Integrated Circuits
(Millions of Dollars)

1988 Rank	1987 Rank	Company	1987 Revenue	1988 Revenue	Percent Change
1	3	Toshiba	476	569	19.5%
2	2	National Semiconductor	495	550	11.1%
3	6	Sanyo	377	473	25.5%
4	1	NEC	542	469	(13.5%)
5	4	Philips	439	456	3.9%
6	5	Texas Instruments	386	426	10.4%
7	8	Motorola	339	425	25.4%
8	7	Matsushita	376	423	12.5%
9	10	Mitsubishi	305	404	32.5%
10	11	SGS-Thomson	282	350	24.1%
11	14	Sony	217	345	59.0%
12	9	Hitachi	310	343	10.6%
13	12	Analog Devices	280	340	21.4%
14	13	Rohm	235	264	12.3%
15	15	AT&T	216	247	14.4%
16	16	Fujitsu	151	168	11.3%
17	21	Sanken	119	157	31.9%
18	17	Harris	139	146	5.0%
19	19	Burr-Brown	120	143	19.2%
20	20	Siemens	120	125	4.2%
		U.S. Companies	2,948	3,429	16.3%
		ROW Companies	96	156	62.5%
		Japan Companies	3,331	3,864	16.0%
		Europe Companies	998	1,114	11.6%
		Total World Companies	7,373	8,563	16.1%

Source: Dataquest
January 1989

Table 8

1988 World Semiconductor Market Share Ranking
Discrete
(Millions of Dollars)

1988 Rank	1987 Rank	Company	1987 Revenue	1988 Revenue	Percent Change
1	1	Toshiba	703	864	22.9%
2	2	Motorola	652	752	15.3%
3	3	Hitachi	625	707	13.1%
4	4	NEC	518	571	10.2%
5	5	Philips	390	435	11.5%
6	6	Matsushita	318	369	16.0%
7	7	Mitsubishi	227	311	37.0%
8	9	SGS-Thomson	213	254	19.2%
9	13	Rohm	200	242	21.0%
10	11	Fuji Electric	206	227	10.2%
11	10	Sanyo	210	210	0
12	14	Sanken	162	207	27.8%
13	8	Siemens	218	205	(6.0%)
14	16	International Rectifier	151	200	32.5%
15	18	General Instrument	132	164	24.2%
16	12	AT&T	200	161	(19.5%)
17	15	ITT	160	146	(8.8%)
18	17	General Electric	146	145	(0.7%)
19	19	Powerex	106	115	8.5%
20	23	Sony	72	112	55.6%
		U.S. Companies	2,009	2,140	6.5%
		ROW Companies	92	121	31.5%
		Japan Companies	3,338	3,938	18.0%
		Europe Companies	1,118	1,250	11.8%
		Total World Companies	6,557	7,449	13.6%

Source: Dataquest
January 1989

Table 9

1988 World Semiconductor Market Share Ranking
Optoelectronic
(Millions of Dollars)

1988 Rank	1987 Rank	Company	1987 Revenue	1988 Revenue	Percent Change
1	1	Sharp	223	285	27.8%
2	4	Sony	138	217	57.2%
3	5	Toshiba	132	215	62.9%
4	2	Hewlett-Packard	186	213	14.5%
5	3	Matsushita	145	182	25.5%
6	10	Rohm	70	114	62.9%
7	9	Fujitsu	71	111	56.3%
8	7	Siemens	85	99	16.5%
9	11	NEC	55	88	60.0%
10	8	Telefunken Electronic	77	82	6.5%
11	12	Hitachi	47	70	48.9%
12	6	Sanyo	85	62	(27.1%)
13	14	Texas Instruments	39	41	5.1%
14	19	Oki	25	36	44.0%
15	15	Honeywell	30	30	0
16	17	Mitsubishi	26	27	3.8%
17	18	Philips	26	27	3.8%
18	20	Motorola	24	24	0
19	21	Plessey	17	22	29.4%
20	22	General Electric	16	21	31.3%
		U.S. Companies	373	339	(9.1%)
		ROW Companies	0	0	N/A
		Japan Companies	1,046	1,449	38.5%
		Europe Companies	215	241	12.1%
		Total World Companies	1,634	2,029	24.2%

N/A = Not Applicable

Source: Dataquest
January 1989

DATAQUEST CONCLUSIONS

The Japanese companies have grown from 28.4 percent of the worldwide semiconductor market in 1978 to 50 percent in 1988. Intel reaped the rewards of its sole-sourcing policy on the 80386, which was the microprocessor to have in 1988. Dataquest believes that the tremendous growth of the ROW companies in 1988 was due to the decisions by Hyundai and Samsung to concentrate on DRAMs and SRAMs.

In our opinion, the message from 1988 is clear: those companies that participated in strong growth product areas generally gained market share; among those products, proprietary products gained market share. Although products that experience dynamic growth spurts are also more vulnerable to downturns, we believe that market share gains will continue to be made in the long run.

Patricia S. Cox

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HITACHI AND TI SHARE THE RISK: THE 16Mb DRAM AGREEMENT

SUMMARY

On December 22, Texas Instruments (TI) and Hitachi Ltd. announced that they had entered into an agreement to jointly develop DRAMs. Under the terms of the agreement, the two companies will create a common 16Mb DRAM technology. Implementation of the agreement will allow each company to have access to the other's DRAM technology as it relates to the development of the 16Mb device.

AN INDUSTRY FIRST

The Hitachi/TI agreement marks the first time that leading U.S. and Japanese semiconductor companies have come together to develop a future-generation memory product. The Motorola/Toshiba agreement, although equally significant, involves joint manufacturing and technology exchange related to existing products. In this sense, then, the Hitachi/TI deal has its counterpart more in the "MegaProject" agreement between Philips and Siemens, in which the two European chip manufacturers shared the development costs and technology in producing the 4Mb DRAM (Siemens) and 1Mb fast SRAM (Philips).

The semiconductor industry is certainly familiar with technology exchange as the raison d'etre of alliances. To understand the Hitachi/TI agreement, however, one must also appreciate the risks associated with the increasing capital intensiveness of leading-edge memory development. These risks are probably as great, if not greater, a factor in bringing the two companies together as is any mutual benefit to be obtained through technology swapping.

RISK SHARING

The issue of risk concerning the 16Mb DRAM has to do with cost and timing. From the standpoint of cost, future participants in the high-density memory business face incredible investments in development and production. Equipment and clean room technology required to produce devices based on 0.5-micron linewidths is enormously expensive. At a recent meeting of a semiconductor task force hosted by the American Electronics Association (AEA), a representative of one major U.S. semiconductor manufacturer introduced a cost model that estimated a $250 million capital investment to build a 0.8-micron, 1Mb DRAM factory with throughput capability of 5,000 6-inch wafers a week. This is probably a conservative estimate to begin with.

To Dataquest's knowledge, construction of a prototype 16Mb fab will be started by NEC in Sagamihara, Japan, in the third quarter of 1989. This facility, with a probable capacity of about 5,000 6-inch wafers per four-week period, alone will cost an estimated $160 million. Eventually, companies will have to consider building the next-generation factory--a 0.8- to 0.5-micron, 8-inch wafer fab--that can produce 4Mb as well as 16Mb DRAMs. The cost of such fabs is currently estimated to be about $400 million.

Whatever reductions in development costs their agreement may achieve, both Hitachi and TI will have to build expensive fabs. By working together, however, the two companies have a better chance of coming up with a winning formula for product manufacture and, thereby, overcoming the other demon of DRAM development: timing. Any company that plans to participate in the 16Mb market, which Dataquest believes will reach approximately 2 million units in 1992, must make massive capacity investments during an industry cycle that we have forecast to be weak. If a company stumbles badly in bringing up its 16Mb DRAM production, the penalties will be serious. From this standpoint, then, the Hitachi/TI deal is not so much about sharing costs as it is about sharing expertise and resources and about minimizing individual exposure. Given the stakes in entering the 16Mb DRAM market, failure could be disastrous.

WHAT TI GETS

While risk sharing can be seen as the most powerful common denominator of the alliance, each company has some unique advantages to gain from its partner. In the case of TI, the advantages seem obvious. Hitachi is an acknowledged leader in memory technology, was the first company to introduce the 256K DRAM, and was in the top two in 1Mb DRAM introductions. Furthermore, Dataquest believes that Hitachi is a major contender, along with Toshiba, for the lead in 4Mb DRAMs. As a result of its agreement with Hitachi, TI—the seventh largest producer of 1Mb DRAMs (in units) in 1987--could be one of the leaders in the future DRAM market.

Hitachi is also a leader in BICMOS, which is a critical process for fast SRAMs as well as high-speed DRAMs. In 1987, Hitachi presented a paper at the ISSCC (International Solid State Circuit Conference) on a 35-nanosecond 1Mb DRAM utilizing BICMOS. Dataquest expects to see samples of such a device in 1989, and we further believe that this technology will be a very important process at the 16Mb DRAM density.

In addition to its expertise in memory technology, Hitachi now manufactures in TI's backyard. Hitachi has just finished equipping its Irving, Texas, fab, which is capable of producing 1.3-micron SRAMs. Future production is planned for ASIC devices and microprocessors. Although the Hitachi/TI agreement does not entail joint manufacturing, as is the case with the Motorola/Toshiba alliance, the proximity of the companies' manufacturing sites would at least make such an arrangement logistically convenient.

WHAT HITACHI GETS

With Hitachi's leading position in DRAMs, substantial capital resources, and existing manufacturing presence in the United States, the Hitachi/TI agreement raises the logical question, "What's in it for Hitachi?" Once again, the issue of risk sharing is paramount; but aside from this factor, some other possible motives are worth speculation. These include the following:

- TI's hold on fundamental DRAM patents may be a factor in the joint development effort—Hitachi was one of the Japanese memory manufacturers sued by TI in 1986 over DRAM patent violations. The companies settled out of court in 1987.

- Although the press release from the companies mentions product development beyond DRAMs, a technology swap involving TI DSP (digital signal processing) circuits could certainly be attractive to Hitachi in view of DSP's relevance to the high-definition TV market and Hitachi's growing emphasis on microdevices.

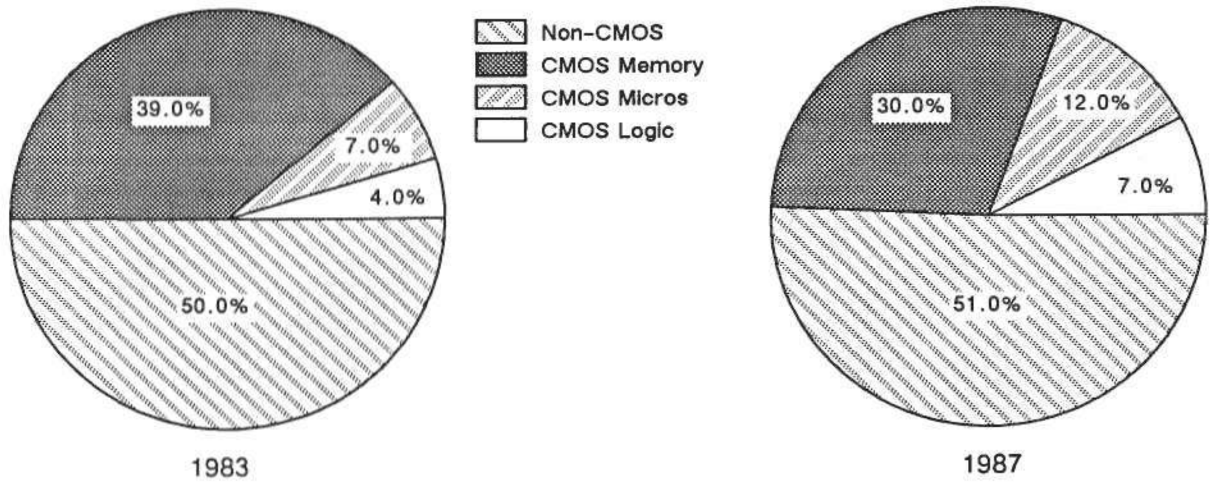
- Not knowing which way the "trade winds" will blow in the future, having a U.S. partner as well as a domestic manufacturing presence certainly cannot hurt Hitachi from a political standpoint.

HITACHI IN TRANSITION

From a more strategic point of view, the agreement with TI is further evidence of Hitachi's broadening market presence. According to Dataquest's Tokyo office, Hitachi's single most important project at this time is the TRON microprocessor—a reflection of Hitachi's focus on logic and micros. Figure 1 shows just how Hitachi's semiconductor product mix has changed in the past five years. While Hitachi's memory business has diminished as a percentage of its total semiconductor revenue, the percentages for logic and microdevices have nearly doubled.

Figure 1

Hitachi CMOS Logic Function Revenue
As a Percentage of Total Semiconductor Revenue
1983 versus 1987
(Based on Millions of Dollars)



Source: Dataquest
October 1988

Contrasted with NEC, one senses the path Hitachi must follow. In 1987, combined microdevice and logic revenue accounted for approximately 19 percent of Hitachi's semiconductor business, compared to 35 percent for NEC. Obviously, Hitachi has no plans to abdicate the memory market. Nevertheless, it will be increasingly difficult for Hitachi to continue along its present path in logic and micros while committing ever greater resources to the MOS memory side of its business.

DATAQUEST CONCLUSIONS

Dataquest has long maintained that the complexities of product mix and the escalating costs of development and manufacture at the leading edge will make it difficult for even the largest broad-based semiconductor suppliers to afford a "go it alone" attitude. Certainly, the Hitachi/TI agreement underscores this point of view. Given the costs and risks of participating in the commodity memory business of the future, it is hard to believe that this agreement will be unique.

For the U.S. electronics systems industry, the Hitachi/TI deal should send a message that the U.S. semiconductor industry is committed to the DRAM market for the long term. While the merits of having a domestic (i.e., United States-owned) supplier base may be debated, it must certainly be reassuring to U.S. computer manufacturers to know that at least one DRAM vendor is not a systems-level competitor.

One issue that may confront the Hitachi/TI agreement is TI's involvement with Sematech, the U.S. manufacturing consortium. There is likely to be some concern about Hitachi's possible access to Sematech-related technology. Inasmuch as the consortium is a beneficiary of its members' intellectual capital as well as a benefactor, it is possible that the technologies developed through the Hitachi/TI agreement could make a positive contribution to the U.S. semiconductor industry as a whole.

As evidenced by the deliberations of U.S. semiconductor companies over reentering the DRAM business, such a commitment cannot be made on the basis of short-term opportunism. Participation in the DRAM market must be a fundamental part of a semiconductor company's long-term strategy. Although the benefits of developing a 0.5-micron manufacturing capability will accrue to other areas of chipmaking beyond the DRAM business, investments in DRAMs cannot preclude the development of other key component areas.

As the cost of capital investment continues to rise, participation in both leading-edge commodity products and higher-margin businesses such as microdevices and ASICs will be more difficult to support. A major reason for this is that these product development paths are becoming increasingly divergent—while future DRAM generations will depend on trench and other 3-D technologies, ASICs will continue to stress CAD technology and multiple metal deposition. In spite of their differing demands, companies will have to have their feet in both worlds if they intend to be major suppliers to the data processing arena. The Hitachi/TI agreement suggests one way of meeting this challenge; and, as such, it follows a direction already indicated by the Motorola/Toshiba alliance.

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BLOCKING INFRINGEMENT AT THE BORDER: THE OMNIBUS TRADE BILL AND THE ITC

SUMMARY

In late November 1988, Intel Corporation announced that the International Trade Commission (ITC) had issued an Initial Determination in Intel's favor regarding its EPROM infringement complaint against All-American Semiconductor Inc., Atmel Corp., Cypress Electronics Inc. (a distributor), General Instrument Corp., Hyundai Electronics Industries Co. Ltd., Microchip Technology Inc., and Pacesetter Electronics Inc. In addition to lodging its complaint with the ITC, Intel had filed a lawsuit over the EPROM issue through the Federal District Court in San Jose, California. Both of these events occurred in September 1987. This newsletter looks at recent actions by the ITC on behalf of U.S. semiconductor suppliers in order to illustrate the power of trade policy in the enforcement of intellectual property law. In addition, this newsletter discusses changes in the scope of that enforcement resulting from the passage of the Omnibus Trade Bill.

THE INTEL EPROM RULING

Although Intel's civil case against Hyundai and the other above-named companies has yet to be tried in court, the ITC in its Initial Determination has already reacted to Intel's allegations with a decision that, if upheld, would result in an exclusion order preventing the future importation of EPROMs that infringe on Intel's patents. Coincidentally, the ITC Initial Determination was made by Janet Saxon, the same judge who had earlier issued an exclusion order against Samsung in Texas Instruments' DRAM patent infringement suit against the Korean supplier.

The ITC will issue its Final Determination in Intel's EPROM case on March 16. In its final ruling, the ITC might either rubber-stamp the Initial Determination, request a further review of the issues, or remand Judge Saxon's initial ruling altogether. If the Initial Determination is upheld, however, Hyundai, as an offshore manufacturer, will be forced to post a bond in order to export infringing EPROMs to the United States. At that point, only a presidential decision could prevent the exclusion order from remaining in effect—or a settlement on Intel's terms involving significant royalty payments.

THE POWER OF THE ITC

The Fast Track to Patent Enforcement

The outcome of the ITC ruling certainly has immediate significance to both Intel and Hyundai. The power of an ITC exclusion order was clearly demonstrated in the DRAM patent suits brought by Texas Instruments (TI). As a result of the ITC's ruling, TI was able to expedite out-of-court settlements with both Samsung, which was immediately affected by the exclusion order, and NEC, which probably saw itself as the next likely target. As the last two companies to settle in TI's sweeping DRAM suit, both Samsung and NEC had initially appeared willing to "go to the mat" on the patent infringement suit. As it was, the ITC offered them a very powerful incentive to soften their positions. In addition, TI was able to claim more than $190 million in royalty revenue in fiscal 1987 as a result of its lawsuit settlements.

Aside from its obvious clout, the ITC offers U.S. patent holders a more expedient avenue of legal recourse than the Federal District Court when dealing with an offshore infringer. Once a complaint is filed with the ITC, the commission has 18 months in which to come up with an Initial Determination. After this ruling has been made, the ITC then has another two months to review the determination and issue a final decision. Compare this process with the many years it has taken to produce a decision through the district court in the Intel/NEC copyright case.

Limitations

Although the legal recourse offered by the ITC looks attractive from the standpoints of expediency and muscle, it has had historical limitations not encountered through the Federal District Courts. Chief among these limitations has been the requirement that a company prove damage to its business as a result of patent infringement by a foreign competitor—and underlying this, the requirement that a company be an active participant in the market associated with the infringed-upon patent. In the case of Intel, this meant that although the company could legitimately file an action through the ITC regarding EPROMs, it was prevented from filing a similar complaint regarding DRAM patent infringement because Intel no longer competes in the DRAM market as a producer of these devices.

THE IMPACT OF THE OMNIBUS TRADE BILL

Enter the Omnibus Trade Bill. This trade bill amends Section 337 of the Tariff Act of 1930 by removing the proof-of-injury requirement noted above. In fact, the amendment minimizes the requirement that a petitioner show investments in R&D, plants and equipment, or employment as evidence of its participation in a market. Also removed is the requirement that the aggrieved company be efficiently and economically operated. Had these amendments been in force when Intel filed its original DRAM patent infringement lawsuit against Hyundai, Intel could have filed an action with the ITC in that case as well. The door is now open for Intel to do just that—in which case, the ITC's Initial Determination regarding Hyundai's violation of Intel's EPROM patents may have been the first shoe to drop.

The larger issue here is not just whether or not Intel succeeds in collecting additional royalties for its earlier memory technology, or even whether Hyundai's competitiveness in DRAMs or EPROMs is compromised by the payment of royalties to an aggrieved U.S. company. The issue is also the impact that Asian memory suppliers may ultimately have on a U.S. end-user market traumatized by the 1988 DRAM shortages. Although DRAM purchasers in U.S. OEM electronics companies could console themselves that the Koreans may soon rescue them from the current supply/price squeeze that their U.S. and Japanese vendors have put them in, it may be too soon to become complacent. Where and how memory technology was obtained may become a key question that users will want answered as they contemplate relationships with Asian suppliers, as any one of a number of former U.S. memory participants may be carefully dusting off its stack of patents in the wake of the Omnibus Trade Bill's passage.

DATAQUEST CONCLUSIONS

The Omnibus Trade Bill raises the level of importance assigned to the source of intellectual property, in effect, since technology is often the bargaining chip in foundry and distribution deals between U.S. start-ups and Asian semiconductor companies. If Goldstar, Hyundai, Samsung, Yamaha, or any other offshore semiconductor competitors plan to "buy" access to a product market through technology swaps with smaller U.S. companies, they will want to be sure that they know the full price up front. The final bill may not be in the hands of a Start-Up Inc., but rather in the hands of an AMD, Intel, or National Semiconductor.

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UNDERSTANDING THE NEC/INTEL DECISION

". . . the more the court is led into the intricacies of dramatic craftsmanship, the less likely it is to stand upon the firmer, if more naive, ground of its considered impressions upon its own perusal." (Judge Learned Hand, Nichols v. Universal Pictures Corp., 1930)

SUMMARY

The above reference, quoted by United States District Judge William P. Gray in reference to an earlier intellectual property lawsuit, says much about the nature of the decision reached last week regarding the microcode copyright trial between NEC Corporation and Intel Corporation. In his decision, which came as the latest development in a dispute that has gone on in one form or another since 1982, Judge Gray declared the following:

- Intel's microcodes for its 8086 and 8088 microprocessors "were proper subjects for protection under United States copyright laws."

- Although its microcode copyright claims were valid, Intel forfeited its copyrights because "more than a relatively small number of copies of product . . . did not contain the copyright notice," and because "Intel failed to make a reasonable effort to cause such notice to be added to those copies after the omission had been discovered."

- NEC's microcode for its V20, V30, V40, and V50 microprocessors did not infringe on Intel's copyrights for its 8086/88 microcodes.

- NEC's V20 and V30 microprocessors could not be considered as "improvements" upon its earlier uPD 8086 and uPD 8088 devices, which were licensed by Intel.

The outcome of the NEC/Intel trial has been long anticipated as a landmark decision on semiconductor intellectual property. This case has rightly been characterized as having implications that go far beyond its impact on the litigants. As a result, this question is often asked: "What effect does the outcome have on NEC/Intel?" Just as often asked is this question: "Does the decision provide any clear guidelines to the industry regarding copyright?"

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The answer to this last question, Dataquest believes, is an emphatic "yes." Judge Gray's decision sends a clear message to the industry regarding the extension of copyright to that form of intellectual property known as microcode; it represents a thorough, well-reasoned consideration of issues that many had considered beyond the competent grasp of a lay jurist. Because of the complexity of the issues involved, which encompass legal, technical, and market share considerations, this newsletter will confine itself to a summary of Judge Gray's decision, with an emphasis on those aspects of the judgment that offer the most insight on the industry's protection of intellectual property.

THE COPYRIGHTABILITY OF MICROCODE

The first part of Judge Gray's decision constitutes what Intel has called "a precedent for our large investments in new products" and "a broad landmark decision for the industry." To begin with, as in the previous decision by Judge William Ingram (which was vacated when the judge disqualified himself from the case due to ownership of a small number of shares of Intel stock), Judge Gray maintains that microcode fits the definition of a computer program as contained in the Copyright Act of 1980. This act defines microcode as "a set of statements or instructions to be used directly or indirectly in a computer in order to bring about a certain result."

The Originality of Microcode

In reaching this decision regarding the copyrightability of microcode, Judge Gray was unconvinced by NEC's arguments that Intel's microcode should not be subject to copyright because many sequences consist of "only a few obvious steps and thus lack the originality required for copyright protection," and that Intel's microcode is in fact "a defining element of the computer itself." To these arguments, Judge Gray replied that "any copyrighted work . . . can be chopped into parts that could be said to have very few creative steps." He further replied that the copyrightability of a work requires only its independent creation by an author and that it contain "a modicum of originality." In the judge's opinion, Intel's microcode meets both of these conditions.

The Relationship of Microcode to Computer

Noting that Intel's microcode falls within the statutory definition of a computer program, Judge Gray used the following quote from a 1983 case involving Apple Computer and Formula Intern, Inc.: "There is nothing in any of the statutory terms which suggest a different result (concerning copyrightability) for different types of computer programs based upon the function they serve within the machine."

The "Merger Doctrine"

The most profound test of the copyrightability of microcode resulting from the NEC/Intel suit, in terms of defining the limits of copyright's domain, has to do with the "merger doctrine." This concept, which on an abstract level seems pointlessly pedantic, is a critical issue from the standpoint of applying copyright to anything that is functional in nature. Since 1879, the courts have allowed that the expression of an idea, not the idea itself, is copyrightable. NEC's chief argument against applying copyright to microcode is that it represents the "merger" of expression and idea.

In the context of the technology being considered, the "merger doctrine" holds that the characteristics of microcode (an expression) cannot be separated from the constraints imposed upon it by the implementation of a macroinstruction set (the idea) in a specific microprocessor architecture. Quoting from a precedent case in 1971, NEC's argument was stated by Judge Gray as follows: "When the 'idea' and its 'expression' are thus inseparable . . . protecting the 'expression' would confer a monopoly of the 'idea' upon the copyright owner free of the conditions and limitations imposed by the patent law." As can be imagined, this is an issue that would inspire a federal circuit judge to rigorous deliberation--and on the outcome of this deliberation, one can trace the trajectory of the final decision.

Judge Gray's answer to the "merger doctrine" is that, while it is "an axiom of copyright law," it should "not be considered on the issue of copyrightability, but . . . be deferred to the discussion of the infringement. Therefore, "the burden of showing such constraints should be left to the alleged infringer." In this manner, the stage was set for NEC to argue technical constraint as the cause of any similarities between its microcode and Intel's, rather than use the merger doctrine as a "preemptive strike" against the copyrightability of microcode itself.

INTEL'S COPYRIGHT FORFEITURE

Judge Gray's ruling on the forfeiture by Intel of its microcode copyright serves as a cautionary tale to the industry and a further clarification of the Copyright Act. The act states that the failure to affix a notice of copyright on distributed copies of a work invalidates the copyright, unless the omission involves "no more than a relatively small number of copies." Otherwise, the copyright owner is expected to make a "reasonable effort" to add notices to all copies that have been distributed or to show that the notices were omitted "in violation of an express requirement in writing that . . . the . . . copies . . . bear the prescribed notice."

Intel has estimated that out of 28,000,000 copies of microcode distributed between May 1978 and May 1986, approximately 10.6 percent did not contain the required copyright notice. Judge Gray first of all noted that nearly 3,000,000 copies of anything, in an absolute sense, seem like more than a "relatively small number." Assuming that this interpretation is based on a relationship between the number of copies without proper notification and the total distributed, Judge Gray examined 20 federal court cases that had considered the same issue. He concluded that, regardless of the absolute numbers involved, none of these cases had considered 10.6 percent to be a "relatively small number."

Concerning Intel's subsequent efforts to correct the omission of copyright notice by its licensees, Judge Gray noted that, "There appears to be no precise authoritative definition as to what constitutes 'a reasonable' effort." More than seven pages of Judge Gray's decision are devoted to a consideration of Intel's efforts to monitor and enforce the affixing of copyright notices on its 8086/88 microprocessors, as well as the adequacy of those efforts. One of Judge Gray's remarks seems to summarize his assessment of Intel's follow-up: "I recognize that Intel's failure to include the requirement of copyright notice does not constitute abandonment of its copyright . . . (however) such an oversight certainly is relevant evidence that protection of its copyright was not high on Intel's list of priorities when the licenses were issued."

THE NONINFRINGEMENT BY NEC'S MICROCODE

Determining infringement in a copyright case boils down to two things: establishing that the accused infringer had "access" to the the original work, and showing that there is "substantial similarity" between the accused work and the original. In regard to the NEC/Intel case, access was a foregone conclusion because NEC had licenses to the 8086/88 microprocessors. The issue of "substantial similarity" was fought concerning about 50 lines of microcode that Intel claimed showed clear evidence of being copied.

Judge Gray stated an important "philosophical" position in approaching this issue. Quoting a UCLA law review article on copyright protection for computer programs, he declared that the court should "not allow the accused work to be dissected into pieces, and the pieces isolated, as if each stood alone." From this perspective, Judge Gray ruled that "the NEC microcode (Rev. 2), when considered as a whole, is not substantially similar to the Intel microcode within the meaning of the copyright laws."

Although this declaration would seem to end the argument, Judge Gray's judgment enumerates the key issues raised by Intel. These issues support the accusation of copying, citing an obligation voiced by a federal judge in another intellectual property case to "make a qualitative, not quantitative, judgment about the character of the work as a whole and the importance of the substantially similar portions of the work." It is to these considerations and their relationship to the final decision that the semiconductor industry should pay close attention, for they reveal much about the application of copyright to situations involving "technical constraint."

To fully appreciate the issues of "similarity" in the NEC/Intel suit, it helps to compare patent and copyright law. With its more rigorous standards of uniqueness and nonobviousness, patent law has no tolerance for similarity. Similarity, in fact, is tantamount to infringement. The intent of copyright, however, is to protect and encourage a multiplicity of expression. Similarity, particularly if it involves expressions related to a common idea, is not in itself proof of plagiarism. What matters is the degree of similarity, which obviously varies with the amount of constraint placed on one's choice of expression.

The crux of Intel's arguments concerning evidence of copying in NEC's microcode revolve around the contention that NEC could have created a microprocessor compatible with Intel's 8086/88 by using "different hardware, different architecture, different specifications, and a different microinstruction format." Thus, from Intel's point of view, because other options were available, any similarity would be the result of copying. To this argument, Judge Gray noted that, because Intel issued a license to NEC to duplicate the 8086/88 hardware, "Intel is in no position to challenge NEC's right to use the aspects of Intel's microcode that are mandated by such hardware."

Enter the "merger doctrine" as a litmus test of whether similarity implies infringement. Having acknowledged NEC's right to duplicate the 8086/88 hardware—not to mention the company's unfettered access to the macroinstruction set (never a matter of contention in the trial)—Judge Gray commented that "if . . . underlying ideas are capable of only a limited range of expression, they "may be protected only against virtually identical copying." He further noted, "NEC properly used the underlying ideas, without virtually identically copying their limited expression."

THE V20/30 ARE NOT "IMPROVEMENTS" ON THE uPD 8086/88

Given the significance of the above decision, the final point in Judge Gray's ruling seems somewhat anticlimactic. As one part of a multiperimeter defense, NEC noted that the license it acquired from Intel in 1983 authorized the copying of Intel's 8086/88 microcode in NEC's uPD 8086 and uPD 8088 microprocessors, as well as in "improvements thereon developed by NEC." NEC argued that, because its V20 and V30 devices were "improvements" upon the uPD 8086 and uPD 8088, they were therefore covered by its existing license from Intel. In reviewing the testimony of NEC's principal license negotiator, Judge Gray observed that NEC's officers never considered the V20 and V30 to be simply "improvements" over the 8088/86, and he concluded that "NEC's contention of 'improvement' was conceived after this litigation began, and it is rejected."

DATAQUEST CONCLUSIONS

In September 1986, Judge William Ingram made his initial decision on the copyrightability of microcode. Then, as now, much was made of the significance of this ruling. In a Research Bulletin written at the time, Dataquest noted the following points:

> "Any major victory celebrations are premature on the part of either Intel or the industry. While the court has decided that microcode does indeed fall within the domain of copyright law, just how effectively it can be protected is difficult to assess until Judge Ingram decides on the infringement issue.
>
> If the infringement criterion is rigidly interpreted to mean literal copying, successfully proving infringement will be very difficult for any copyright holder. With regard to the NEC/Intel trial, similarities between NEC's V-Series microcode and Intel's 8088/8086 code could be judged the result of 'functional constraint' rather than copying. In this case, NEC would very likely be found innocent of infringement."

In reaching his decision, Judge Gray appears to have labored hard to uphold the nature of copyright law in a case that tests its application in a very challenging way. The NEC/Intel trial has at last provided a means by which the industry can assess how the legal system will determine the copyright infringement of microcode. In the aftermath of his decision, however, the industry must now reflect on where it stands.

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RIDING THE MICROCOMMUNICATIONS WAVE: A CLOSER LOOK AT THE AT&T/INTEL AGREEMENT

SUMMARY

Alliances can be seen as concessions to market forces when, for example, companies enter second-source manufacturing relationships in the face of increasing demand or the need to penetrate new regions. Agreements can also create new market forces, as was seen in 1988 with the proliferation of RISC microprocessor agreements. In this sense, then, alliances can at times catch waves and at times create them. Sometimes, as in the case of the recently signed agreement between AT&T Microelectronics and Intel Corporation, they can attempt to do both.

AT&T Microelectronics and Intel have banded together under a five-year agreement to provide original equipment manufacturers (OEMs) with what the two companies have described as "the broadest array of products supporting ISDN (Integrated Services Digital Network) and LANs (Local Area Networks) available from a common source." The agreement will combine Intel's expertise in silicon and marketing with AT&T's understanding of the data transmission and communications market. In what AT&T describes as a "true alliance," the companies will second-source each other on an initial 10 components supporting twisted-pair Ethernet (TPE) LANs and ISDN, jointly develop future ISDN and LAN products, and work together to promote communications standards.

The keys to the ultimate success of this agreement have to do with the following:

- The types of products offered by the two companies and their impact on a market force that Intel refers to as "microcommunications"
- The efforts of AT&T and Intel to both influence and target developing industry standards
- The ability of the two partners to blend their respective strengths through this alliance

This newsletter describes each of these factors and evaluates the importance of this alliance to the strategic horizons of both AT&T Microelectronics and Intel.

TERMS OF ENDEARMENT

In reviewing the AT&T/Intel agreement, analysts in Dataquest's Semiconductor Industry Service (SIS) have noted the following:

- Product and technology exchange does not extend to joint process development. Future products will be created using design rules that have been "developed so that the products will run in both companies' fabs."

- No proprietary packaging technology is involved in the products affected by the agreement, so no packaging information will be exchanged.

- Both companies will sell each other's products through a "private label agreement" (purchase/resale program). No specific comments have been made by either company concerning royalty arrangements.

- The agreement establishes "definite trigger points" that will determine when the purchasing party may become a true second source (i.e., manufacturer) for the other's products. Neither company has disclosed the nature of these triggers.

- With the exception of two AT&T components that will be available late in the first quarter of 1989, the purchase and resale agreement covers products that currently are shipping. The first jointly developed products are not expected to appear this year.

THE PRODUCTS

The cross-reference guide for the 10 ICs to be jointly marketed by AT&T and Intel reveals 4 different LAN products and 6 ISDN products. In the LAN category, each company is contributing 2 existing devices. Intel is the originator of a 16-bit Ethernet LAN controller for high-performance applications (82586) and a CMOS 16-bit LAN controller, introduced in July 1988, which is aimed at lower-cost Ethernet applications (82592). AT&T will contribute a CMOS device that interfaces LAN controllers to twisted-pair Ethernet line drivers and receivers (T 7210) and a VLSI device designed for use in TPE repeater designs.

Among the ISDN devices to be exchanged, AT&T is the originator of 5 out of 6 components. These are a two-chip, 2B1Q (2 "B" channel, 1 "D" channel) "U" transceiver (T 7262/7263); two separate "S" transceiver components (T 7250A, T 7252A); and a single-channel HDLC with 64-byte FIFO register (T 7121). Intel's ISDN contribution is an "S/T" transceiver designed to connect between serial devices, microprocessors, and the ISDN "S/T" interface (29C53).

PROMOTING STANDARDS

AT&T and Intel are throwing their combined weight behind two industry standards that already have some impetus propelling them. In the LAN market, the two companies are supporting current efforts by the IEEE 802.3 committee to develop a new standard that will merge the low-cost benefits of StarLAN with the high-performance features of Ethernet. This new standard, referred to as 10BASE-T, will permit Ethernet data transmission at a rate of 10 Mbps over low-cost, unshielded twisted-pair wires (phone wires). Commonly called Twisted Pair Ethernet (TPE), 10BASE-T is based on the star topology popularized by StarLAN.

In ISDN, AT&T and Intel will support standards promulgated globally by the CCITT. The previously mentioned AT&T "U" interface chips, which will be sampled by the two companies in the second quarter of this year, are designed to meet the 2B1Q standard adopted by ANSI. In addition to participating in the development efforts of existing standards committees, AT&T and Intel also are working toward a common bus structure for all ISDN products (known as the Concentration Highway) and a common software platform that they hope will facilitate the creation of applications for, and by, component end users.

A SHARED VISION

Perhaps as important to the driving of the "microcommunications" market as is the joint product sharing of AT&T and Intel is their acknowledgment of a shared vision--a vision of the integration of the information age with the communications age. This vision calls for the participation of both companies in the continued transformation of communications technology--a transformation that had its beginnings with the digitization of the interoffice trunk lines in the late 1960s and has continued with the replacement of analog switches by digital switches. Now it focuses on the analog-to-digital conversion of the local loop, the link between user and network. It is this final phase of the transformation that is at the heart of ISDN. It is an evolutionary step for communications networks, but it is a revolutionary one for users from the standpoint of moving voice, data, and images through a standard interface and into a single network that already serves them.

Both companies concede that ISDN has not permeated the network as rapidly as initially projected and believe that the lack of network standards, the cost of equipment, and the lack of IC solutions have held back the expansion of ISDN. It is in the digitization of the local loop that AT&T and Intel hope to have a catalytic impact on the ISDN market, hence the significance of their joint offering of "U" interface products in compliance with developing ANSI standards. The companies see the acceptance of these components as laying the silicon foundation for cost-effective provision of basic rate ISDN service.

THE MARKET IMPACT

The AT&T/Intel agreement views the future of ISDN and LANs as being intertwined. As more ISDN lines are installed, greater pressure will be exerted to develop applications that exploit the digital capabilities of these lines. Growth of ISDN is likely to parallel the growth of LANs by networking the networks: linking a variety of equipment and functions together (via local area networks) and giving them a common communications interface. ISDN field tests have allowed companies to consolidate telephone voice services, computers, printers, facsimile machines, and other equipment on one network. As a result, network users get access to multiple computer systems, send facsimile, and share services like electronic directory, voice mail, and conference calling, to name a few.

With a 60 percent share of the LAN market in 1987, Ethernet's origins are in the technical and engineering environments. The high costs associated with the technology and the lack of perceived need for high-speed data transfer within the office environment initially worked against Ethernet applications in the general-business/ PC-oriented segment of the LAN market. Higher-performance microprocessors have changed that environment, driving the need to transfer data at higher-speeds and making a lower-cost Ethernet solution a quest that Intel has decided is well worth undertaking.

AT&T and Intel believe that the trend toward using Ethernet for PC networks could become a wave with the availability of 10-Mbps systems running on less costly twisted-pair cabling. Therefore, both companies are interested in shaping IEEE standards for TPE (10BASE-T) and in jointly developing leading-edge products that conform to those standards.

THE COMPANIES

AT&T Microelectronics: Toward the Merchant Market

The impact on the developing ISDN and LAN markets by two companies of AT&T's and Intel's significance cannot be overlooked as a factor favoring their success. As a communications systems company, AT&T's 1987 equipment revenue included approximately $3.7 billion in public network equipment, giving AT&T 50 percent of the U.S. market. AT&T's customer premises equipment, including LANs, accounted for approximately $2.6 billion in revenue, for a U.S. market share of 25 percent. In addition to its obvious strengths as a telecommunications powerhouse, AT&T has made a corporate commitment to become a more significant factor in the merchant semiconductor industry.

Located in Berkeley Heights, New Jersey, AT&T's chip-producing arm, AT&T Microelectronics, employs 18,900 people and achieved $1.9 billion in 1988 revenue. Dataquest estimates that the merchant portion of AT&T Microelectronics' semiconductor revenue has grown from 1 percent of sales in 1985 to 6 percent in 1987—a compound annual growth rate (CAGR) of 200 percent! Dataquest believes that AT&T Microelectronics' 1988 merchant semiconductor revenue will be in the $100 million range. The company has stated a goal of realizing 50 percent of its semiconductor revenue from merchant sales by 1993. Table 1 shows the company's semiconductor consumption and production for both its captive and merchant operations.

To achieve its goals of greater merchant participation, AT&T has taken several steps. To begin with, as Table 1 indicates, it has increasingly exposed its captive semiconductor operations to competition with merchant suppliers. In order to more closely parallel the decentralized P&L organizations of its competitors, AT&T Microelectronics recently reorganized its component operations into five strategic business units: MOS, lightwave, high-performance, power (such as transformers, power supplies, batteries), and interconnects. Finally, AT&T has pursued strategic agreements that have ranged from obtaining 32-bit microprocessor technology from Sun Microsystems to an alliance with Western Digital that encompasses technology transfer; design support; and fab, assembly, and test of semiconductors. Dataquest believes that AT&T has a goal of establishing partnership arrangements with a total of 25 to 50 OEM companies as a part of its merchant market strategy.

Table 1

AT&T's Estimated Semiconductor Consumption and Production by Captive and Merchant Operations

	1985		1986		1987		CAGR
Semiconductors	$M	%	$M	%	$M	%	1985-1987
Total Consumption	$1,405		$1,188		$1,224		(7%)
Captive Source	1,095	78%	968	81%	757	62%	(17%)
Merchant Source	310	22%	220	19%	467	38%	23%
Total Production	$1,100		$ 983		$ 802		(15%)
Captive Use	1,095	99%	968	98%	757	94%	(17%)
Merchant Sales	5	1%	15	2%	45	6%	200%

Source: Dataquest
March 1989

Intel: Not Just a One-Trick Pony

Intel is certainly no stranger to the communications market, nor is that market ultimately of less strategic importance to a company that has influenced today's data processing market as have few others. Among the significant events in Intel's history of "microcommunications" developments are the following:

- In 1977, Intel introduced the world's first commercially integrated codec chip.
- In 1980, Intel codeveloped Ethernet as a wiring standard for LANs.
- In 1982, Intel announced a high-performance coprocessor for Ethernet LAN control, the 82586.
- In 1984, Intel participated in the move to develop StarLAN as a low-cost PC network and developed the 82588 as a controller for StarLAN.

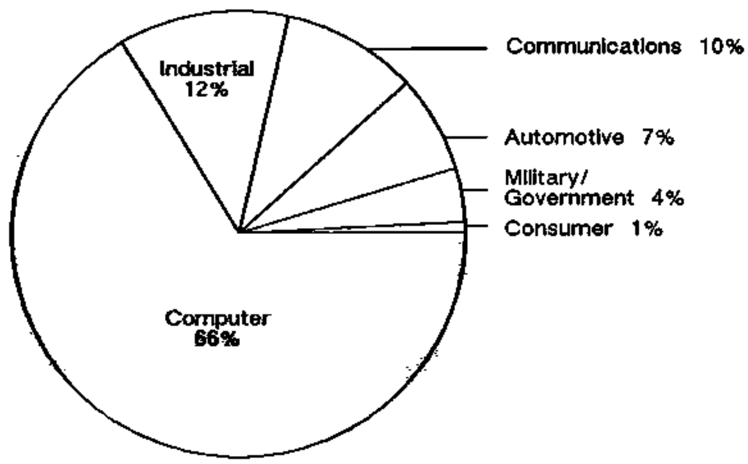
- In 1986, Intel announced its first ISDN chips, development tools, and software.

- In 1988, Intel announced its 82590 family of LAN products for the PC office environment.

Increasing its participation in the communications market is important for Intel if it is to maintain its current position in the pantheon of world-class semiconductor manufacturers. Its current ranking as the seventh largest semiconductor manufacturer in the world is largely owing to the success of its high-end, MS-DOS microprocessor products. As Figure 1 illustrates, Intel depends very heavily on its OEM sales to the computer market.

Figure 1

Intel's Percentage of OEM Sales by Market Segment



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Source: Dataquest March 1989

The past vagaries of the personal computer market aside, Intel cannot allow itself to depend so heavily on a market that is rapidly changing, both in terms of microprocessor platform standards and in terms of operating systems, as the worlds of *he microcomputer and minicomputer converge. Expanding its presence in the communications market, which currently accounts for 10 percent of its OEM sales, provides Intel with an avenue for strategic repositioning, just as when the company rolled out its embedded controller strategy in 1988.

DATAQUEST CONCLUSIONS

Both AT&T and Intel sense a level of critical mass in the microcommunications market. With ISDN standards developing for subscriber loops and the installed base of LANs growing from 333,000 nodes in 1983 to nearly 8 million in 1988, the two companies are looking for a synergy from their strategic alliance that will help them catch the wave. Furthermore, they are in a position to influence the wave's shape. A factor in exerting this influence, as both companies acknowledge, is the formation of strategic alliances between vendors of ISDN and LAN products.

AT&T and Intel are alone in this assessment. The maturing of the ISDN market is a phenomenon that will evolve over the next decade. In spite of its long-term nature, would-be participants must make investments in this market today. Sharing this investment, as well as areas of expertise, has been the impetus for earlier agreements such as the original Ethernet alliance between Xerox, Intel, and Digital Equipment Corporation, along with the Digital/Compaq and Digital/Apple Ethernet alliances.

More recently, systems and components suppliers have come together in such notable alliances as the AMD/Siemens ISDN product agreement and National Semiconductor's alliance with SGS-Thomson. While the above agreements definitely create significant spheres of influence in the European market, the positions held by AT&T and Intel in the U.S. market would seem to give the two companies a powerful domestic edge. In all cases, however, any participants in this market will have to be able to satisfy some deep pocket requirements in order to reap future market growth.

If the AT&T/Intel agreement succeeds in providing OEMs (and, ultimately, the users of telecommunications services) with the solutions that they need, the alliance will have accomplished much for the two companies. Intel will have gained a further inroad into a highly strategic market, while AT&T will have further ensured the invigoration of its merchant semiconductor operations, as well as served the proprietary needs of its systems businesses.

Michael J. Boss

Dataquest
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Research Newsletter

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General
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TRADE ISSUE DEBATED AT DATAQUEST CONFERENCE AS SUPER 301 APPROACHES

OVERVIEW

Super 301 is a provision of the 1988 Omnibus Trade Act passed by the U.S. Congress. According to this provision, the U.S. Trade Representative (USTR) must identify "priority countries" and "priority practices" that inhibit U.S. trade in world markets and then take actions against those countries and practices. The USTR must report on priority practices and countries by May 30, 1989. The Semiconductor Industry Association (SIA) has stated that Japan has not made any progress in opening its markets to foreign suppliers of semiconductor components in the last 10 years. The SIA believes that it is very likely that Japan will be placed on the Super 301 list.

Japan's Ministry of International Trade and Industry (MITI) counters the American claim with an assertion that foreign market share has increased since 1986. MITI further contends that continued low levels of foreign purchases reflect product mismatches, not trade barriers. On April 17, 1989, MITI assembled approximately 160 Japanese companies in Tokyo and instructed them to submit action plans concerning how they would increase semiconductor purchases from foreign suppliers. MITI also introduced an 11-point, step-by-step plan to solve the U.S. complaint of closed markets. Dataquest believes that both sides have a common goal to increase the use of foreign products in Japan; however, the methodology and the time frame for reaching the goal are where the two sides clash.

Both sides of the rapidly intensifying trade dispute between Japan and the United States were presented to a audience of some 350 semiconductor industry managers at Dataquest's Japanese Semiconductor Industry Conference held in Tokyo on April 20 and 21, 1989. Yukio Honda, director of the Industrial Electronics Division of MITI, presented MITI's 11-point plan for improving trade relations. Andrew Procassini, president of the SIA, presented his organization's view that the Japanese markets still remain essentially closed to foreign suppliers.

MITI'S PROPOSAL

MITI's 11-point proposal to encourage expansion of market access for foreign semiconductors as revealed at the Dataquest meeting is as follows:

- Point 1—MITI will encourage major semiconductor users, including Electronic Industry Association of Japan (EIAJ) user's committee members and Japan Auto Parts Industries Association (JAPIAS) members, to adopt market access plans. MITI also will encourage biannual updating of all market access programs and establishment of a special internal committee to increase procurement of products from foreign suppliers as part of their market access programs.

- Point 2—MITI will encourage expansion of efforts to design-in foreign semiconductors.

- Point 3—MITI will encourage automotive parts manufacturers to make qualification and test criteria available to foreign semiconductor suppliers from the early stage of new product development to expedite qualification of foreign semiconductors for current automotive electronics parts production and to commercialize existing joint R&D efforts between Japanese automotive electronics parts manufacturers and foreign semiconductor suppliers.

- Point 4—MITI will encourage Japanese high-definition television (HDTV) manufacturers to hold symposia and/or seminars to provide information about the development of the system and the market and to establish a contact window to facilitate foreign producers' access to the HDTV system producers.

- Point 5—MITI will encourage Japanese manufacturers of consumer electronics to do joint developments with foreign semiconductor suppliers, the objective of which is to increase the foreign semiconductor content in consumer electronics.

- Point 6—MITI will encourage ISDN (Integrated Services Digital Network) equipment makers to aim programs at design-ins of foreign semiconductors.

- Point 7—MITI will encourage Japanese users to make further efforts to expand their qualifications of foreign products.

- Point 8—MITI will encourage Japanese users to engage in long-term relationships with foreign suppliers.

- Point 9—MITI will encourage frequent and timely meetings between EIAJ members and foreign suppliers for the purpose of building relationships and solving problems.

- Point 10—MITI will encourage EIAJ members to hold seminars for foreign semiconductor suppliers to introduce their new products.

- Point 11—MITI will encourage foreign semiconductor suppliers and EIAJ member companies to develop and implement engineering exchange programs.

MITI'S ACTIONS

In order to enforce the proposed 11 points, Mr. Honda stated that MITI will take the following actions:

- MITI will encourage semiconductor user companies to make action plans and to update them biannually. MITI will follow up on their implementations.
- MITI will conduct periodic surveys regarding procurement of foreign semiconductors and will publicize the results in statistical form.
- MITI will survey, when appropriate, the implementation of design-ins and the establishment of long-term relationships.

Mr. Honda's presentation was followed by a spirited question-and-answer session. Surprisingly, all of the questions were from Japanese semiconductor company representatives; the considerable number of American and European representatives remained silent. Most responses were not questions but rather "minispeeches" that expressed the speaker's own view on the trade issue and MITI's approach. Mr. Honda stated that MITI could not make guarantees for the industry and stressed the fact that MITI could only encourage the enactment of the suggested 11 points, not having the power of absolute enforcement.

SIA'S POSITION

MITI's proposal was followed immediately by the presentation by Andrew Procassini, president of the Semiconductor Industry Association. Mr. Procassini quickly recognized Japan as having the world's strongest economy. He suggested, however, that Japan is not recognized as the world's financial leader, and he stressed that the financial leader of the world must be prepared to take on additional responsibilities. Sourcing R.T. Murphy in the March-April 1989 edition of Harvard Business Review, Mr. Procassini listed the following five essential characteristics of a world economic and financial leader:

- Maintains its currency as a store of value
- Allows its currency to function as a global reserve currency
- Acts as an international lender of "last resort"
- Ensures that its domestic and international financial institutions are sound and innovative
- Keeps the trading systems open even at domestic political cost

The United States was the world economic and financial leader for many years. However, with this leadership in question, much of the world is looking to Japan to assume the leadership. Mr. Procassini advised the audience that, in the view of the SIA, Japan at present cannot be counted on for assumption of world economic and financial leadership because of an "adversarial trade mentality." He then presented a series of statistical tables supporting his position.

According to Mr. Procassini, a measure of openness is the "import penetration ratio," which is the ratio of imports to consumption (see Table 1).

Table 1

Import Penetration Rates in All Manufacturing (Imports as a Percentage of Consumption)

	Importing Country					
	United States		Germany		Japan	
Imports From	1975	1986	1975	1986	1975	1986
World	7.0	13.8	24.3	37.2	4.9	4.4
OECD Countries	4.9	9.3	20.5	30.6	2.9	2.6
Developing Countries	2.1	4.2	2.6	4.4	1.8	1.8

Source: ACTN Report

Mr. Procassini argues that, based upon these statistics, Japan's imports have declined since 1975 while the United States and Germany (a nation similar to Japan in the sense of having very few natural resources) have experienced increases of 197 percent and 153 percent, respectively, in their imports. In the total electronics marketplace, Mr. Procassini suggests that Japan's imports are not on par with the United States and Europe (see Table 2).

Table 2

Total 1987 Electronics Production, Export, and Import Ratios

Regions	Production as % of World's Production	Exports as % of Region Production	Imports as % of Region Consumption
Europe	24	18	29
United States	38	20	21
Japan	26	36	6

Source: EIC
SIA

Finally, as illustrated by Table 3, Mr. Procassini compared selected segments of electronic production such as hard disk drives and personal computers. He stressed to the audience that, even though Japan is a minority market-share producer of these products, it nevertheless exports 57 percent and 55 percent, respectively, of its production and imports but 1 percent of its hard disk drives and 17 percent of its personal computers.

Table 3

Electronics—Selected Segments
1987
Production, Foreign Sales, and Foreign Penetration Ratios for U.S. and Japanese Producers and Consumers

	Producers				Consumers	
	Production as a % of World Production		Foreign Sales as a % of Production		Foreign Penetration as a % of Consumption	
Segment	U.S.	Japan	U.S.	Japan	U.S.	Japan
Hard Disks (5-1/4")	63	28	25	57	22	1
Personal Computers	69	18	25	55	13	17
Semiconductors	41	45	39	25	19	10

Source: SIA
Dataquest
May 1989

Mr. Procassini concluded by noting that the American semiconductor industry (SIA) and the Japanese semiconductor industry (EIAJ) are "working very hard" to improve the openness of the Japanese market, but that it was "not an easy task and extraordinary efforts" would be required on both sides.

DATAQUEST ANALYSIS

Taking the SIA's statistics at face value, it is understandable to conclude that Japan has made no progress in opening its semiconductor user markets to foreign suppliers. A fairly thorough sampling of the opinions of Japanese executives regarding the SIA talk produced the following comments:

- No one disputed the statistics presented or construed them to be presented for the purpose of "Japan bashing."

- Virtually all agreed that a problem existed in one degree or another and that Japan must improve its market access to foreigners.

- Many commented that Japan still cannot produce enough foodstuffs to feed its people from independent means. A strong export balance is one way to ensure that Japan will always be able to obtain essential agricultural products.

Dataquest believes that Japan is sincerely concerned about the trade issues. The major Japanese companies and MITI genuinely believe that they are taking the hard steps that will ultimately lead to markets more open to foreign suppliers of semiconductor components, and evidence indicates that this is true. Mr. Procassini praised the five largest Japanese semiconductor consumers for increasing their purchases of semiconductors to 17 percent of total supply from foreign suppliers. We note, however, that the other Japanese companies procure only about 7 to 8 percent of their semiconductor needs from foreign sources.

Nevertheless, key Japanese semiconductor leaders are sensitized to the need for open markets. NEC Electronic Devices executive, Dr. Tsugio Makimoto, stated that "Japanese managers are aware that they may be producing too much, that the share may be too big." He went on to say, "The Japanese industry should realize its important role in the worldwide industry, because a small erroneous decision could result in a serious problem in terms of international economic conflicts." Dataquest agrees. The semiconductor industry has become totally global in nature, with the Japanese being the memory suppliers and the Americans the microcomputer and microprocessor suppliers. The worldwide semiconductor industry will not achieve its intrinsic potential if the two largest participants continue their adversarial trade relationship. It is Dataquest's observation that the two sides are not in substantial disagreement as to the goal. Rather, the contest is over the methods of achieving the goal. The U.S. semiconductor producers have seen their market share eroded more each year and are drawing the line and demanding action now. The Japanese culture dictates change through a step-by-step, albeit slow, methodology. The matter is as much an issue of culture and fundamental approach to life as it is a world-class economic dispute. Japan and the United States must coexist on this planet, which, by virtue of the formidable technology the two nations have created, grows smaller each year. Much of the solution lies in achieving a mutual understanding of the basic differences between the countries and in making concessions to those differences that run deep on both sides. The Japanese have displayed a passion, rarely seen in prior history, for producing goods destined for export. Changing a national agenda so intrinsic to Japan's way of life simply will not occur overnight. On the other hand, the U.S. semiconductor industry executives who are insisting that Japan's markets be opened expeditiously and that Japan take upon the responsibilities commensurate to a world economic leader are of a superior fiber to those who watched with seeming disinterest as America's basic industries moved offshore. These individuals have a deep commitment to and a firm belief in the essentials of strong American participation in the global semiconductor industry. They are resolved in their determination to gain access to Japan's markets.

In Dataquest's opinion, both the MITI 11-point proposal and the EIAJ/SIA commitment to make the electronics marketplace a model for other key industries potentially represent the right solution to this most arduous problem.

David Angel

Dataquest

Conference Schedule

1989

Semiconductor User/ Semiconductor Application Markets	February 27-28	Le Meridien Hotel San Francisco, California
Japanese Components	April 20-21	Tokyo Bay Hilton International Tokyo, Japan
Computer Storage	April 26-28	The Doubletree Hotel Santa Clara, California
Document Processing	May 16-18	Monterey Sheraton Hotel Monterey, California
Copiers	May 16-17	
Printers	May 16-17	
Electronic Publishing	May 18	
Imaging Supplies	May 18	
Color	May 18	
SEMICON/West Seminar	May 24	The Dunfey Hotel San Mateo, California
Telecommunications	June 5-7	Silverado Country Club Napa, California
European Components	June 7-9	Park Hilton Munich, West Germany
Asian Semiconductor and Electronics Technology Seminar	June 28	Radisson Hotel San Jose, California
Financial Services	August 22-23	The Doubletree Hotel Santa Clara, California
Technical Computing and Applications	September 11-13	The Doubletree Hotel Santa Clara, California
European Copying and Duplicating	September 18-19	Majestic Hotel Cannes, France
Western European Printer	September 20-22	Majestic Hotel Cannes, France
Taiwan Conference	September 25-26	Grand Hotel Taipei, Taiwan
Distributed Processing	September 26-28	The Doubletree Hotel Santa Clara, California
SIA/Dataquest Joint Conference	September 27	Santa Clara Marriott Santa Clara, California
Information Systems	October 2-6	Tokyo American Club Tokyo, Japan
Semiconductor	October 16-18	Monterey Sheraton Hotel Monterey, California
Asian Semiconductor and Electronics Technology	November 2-3	Kunlun Hotel Beijing, China
European Telecommunications	November 8-10	Grand Hotel Paris, France
European Personal Computer	December 6-8	Athens, Greece

Dataquest

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May 16, 1989

Dear SIS Client:

Recently, you received a Semiconductor Industry Service newsletter entitled "Trade Issue Debated at Dataquest Conference as Super 301 Approaches." A quotation referenced to NEC Corporation appears on Page 6 of the newsletter. We incorrectly attributed the statement to Dr. Tsugio Makimoto. The statement was made by Mr. Tomihiro Matsumura, Executive Vice President of NEC Corporation. Dr. Makimoto is a representative of Hitachi, Ltd. Dataquest regrets this error and apologizes to both Mr. Matsumura and Dr. Makimoto.

David L. Angel

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Dataquest
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Research Newsletter

SIS Code: Newsletters 1989
General
0003874

1989: THE YEAR OF FORECASTING DANGEROUSLY

SUMMARY

The year 1989 will be a pivotal one for the semiconductor industry---a year that will test the roller coaster curve of industry cyclicality, and challenge or confirm its notorious volatility. If one were to adhere to a strict "past-as-prologue" interpretation of the industry's four-year swings in revenue, a recession would certainly be called for by 1990.

Dataquest's most recent semiconductor industry forecast does, in fact, call for negative quarterly growth for the worldwide market beginning in the third quarter of this year, and continuing through the first quarter of 1990. In the face of continued evidence of the industry's enduring vitality, however, even the mild slowdown predicted by Dataquest may seem unduly pessimistic.

Behind the recent headlines of record bookings and billings in the U.S. semiconductor market, however, the forces of the next recession are in evidence. These forces are:

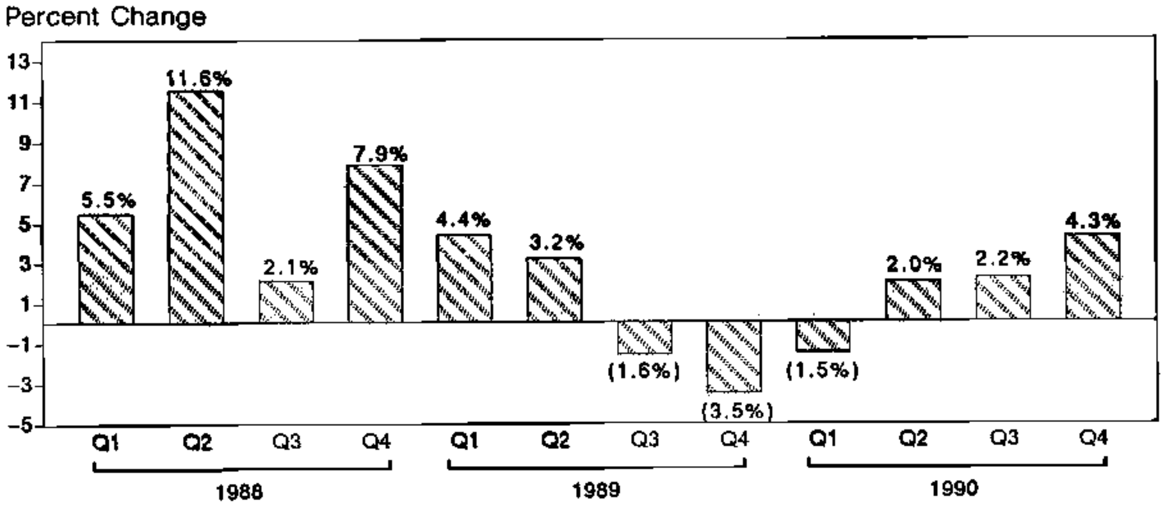
- Slower growth in electronics equipment markets, leading to lessened unit demand for semiconductors.
- The skewing of perceived industry growth caused by strong DRAM pricing.
- Tighter control of inventory by semiconductor end users as a result of a more cautious business outlook and a greater confidence in component availability.
- A decrease in the average selling prices (ASPs) for components, led primarily by lower DRAM pricing as supply surpasses demand later this year.
- The likelihood that macroeconomic influences will negatively affect electronics equipment shipments as the year progresses.

A LESS VOLATILE SEMICONDUCTOR INDUSTRY?

In seeming defiance of history, Dataquest has suggested that the semiconductor market is becoming less volatile, and that following a 15 percent rate of growth in 1989, worldwide negative growth of less than 1 percent will distinguish the industry's next recession in 1990, as shown in Figure 1. Compared with the last major downturn in 1985, during which worldwide revenue declined nearly 15 percent from the previous year, 1990 will be a mere catching of breath before the three years of successively higher double-digit growth that Dataquest has forecast from 1991 through 1993.

Figure 1

Worldwide Semiconductor Consumption
Quarter-to-Quarter Growth Rates
(Percent of Dollars)



0003874-1

Source: Dataquest
May 1989

POSITIVE SIGNS

Not long ago, a presentation of Dataquest's "bust-free" forecast to a group of financial clients was met with some scepticism—and, in fact, our assessment of first quarter 1989 shows a decided slowdown in the U.S. market from the final quarter of 1988. In spite of this, however, the industry is showing a stamina that may cause some to wonder if our present forecast is too conservative. Consider the following indicators:

- On a three-month average basis, semiconductor orders and shipments for the U.S. market reached an all-time industry high for the month of March. Orders booked grew nearly 18 percent over March of last year.

- The World Semiconductor Trade Statistics (WSTS) group noted in April that preliminary 1989 billings for the U.S. market are running 27.1 percent ahead of first quarter 1988, while bookings have grown 8.2 percent over the same period.

- On the whole, U.S. semiconductor companies are reporting positive sales and profits for first quarter 1989. Companies addressing higher margin segments of the memory and logic market, such as Chips & Technologies, Cypress Semiconductor, and LSI Logic, are seeing 60 to 70 percent increases in both revenue and net income compared to 1988.

- Analysts in Dataquest's offshore offices are reporting positive performance in their regional markets. January's "Flash Report" from Japan's Ministry of International Trade and Industry (MITI) showed that, although shipments to the Japanese market had declined approximately 6 percent from December 1988, they had grown 37 percent over December 1987. While production and consumption of semiconductors have been rising fairly steadily since 1987, inventory levels have been declining. The European market has posted several consecutive months of positive book-to-bill ratios, with the March figure at 1.07, and the Asian electronics market has been growing steadily because of the increasing availability of components that were in short supply last year.

In the face of so many signs of vitality, Dataquest's forecast of negative growth occurring in the third quarter of this year and continuing through the first quarter of 1990 may seem unduly pessimistic—particularly in light of the fact that we have forecast that U.S. market recovery in 1990 will lag other world regions by an extra quarter.

This dour outlook, however, is by no means unique to Dataquest. Even the historically optimistic WSTS has noted that "the future outlook for the market is clouded by recent weaknesses in orders from key end markets." Addressing a recent Texas Instruments' shareholders meeting, chairman, president, and CEO Jerry R. Junkins commented that, "The world semiconductor market increased 38 percent in 1988 with about half of this growth coming from unit price increases and movements in exchange rates. The industry growth rate is continuing to moderate from the unsustainably high levels of 1988, and is more closely aligning itself with the growth of end-equipment markets."

DRAMs: THE FORCE BEHIND THE GROWTH

In 1988, removal of MOS memory revenue from the industry's performance would have resulted in market growth of less than 22 percent, in contrast to the nearly 32 percent growth in dollars recorded by Dataquest. The "fulcrum factor" of memories in deciding the current swing of the market is apparent in the observations of Dataquest's most recent forecast newsletter, which showed that if MOS memories were excluded from first quarter revenues, worldwide industry growth would have been only 1 percent. Although we expect the dollar value of the 1989 MOS memory market to grow approximately 47 percent over last year, actual unit growth will be a more modest 10 percent. In this environment, the direction that pricing takes will have a major impact on the overall market. Although first quarter MOS memory pricing has so far stayed firm compared with fourth quarter 1988, Dataquest expects that by the third quarter prices will be much lower. This slowdown will result from lower unit demand, increased supply, and tighter inventory management.

LOWER DEMAND

According to our most recently analyzed Department of Commerce (DOC) data, shipments and bookings growth rates in the computer and office equipment market have flattened on an annualized basis, with February orders slowing to slightly more than 8.0 percent over the previous 12-month period. Quarterly figures, however, are more disturbing: for the three-month period ended February, DOC data shows shipments weakening to a 5.2 percent rate of growth over the same period last year, compared with an 8 percent growth rate noted in January. Quarterly bookings are running at only 2.8 percent ahead of last year, down from a 9.1 percent figure the month before.

The production of PCs still remains critical to the health of the U.S. semiconductor industry. The PC's role in sustaining the current industry expansion is easily realized when one considers that PCs alone account for approximately 11.0 percent of North American semiconductor consumption. Dataquest believes that unit shipments of PCs for the U.S. market will slow to 9.8 percent growth from last year's 13.0 percent annual growth rate. By contrast, unit shipments of PCs in 1987 exceeded those of the previous year by nearly 28 percent. Dataquest expects unit shipments of PCs to further slow in 1990 to less than 9.0 percent over 1989.

TIGHTER INVENTORY CONTROL

While the North American electronic equipment market as a whole decelerates from 8.5 percent growth in 1988 to less than 8.0 percent growth in 1989, availability of last year's shortage components is no longer perceived as a problem. At present, overall component lead times have declined to less than eight weeks for the first time since Dataquest began its monthly poll of original equipment manufacturer (OEM) procurement plans, with half of the companies surveyed noting no difficulty in obtaining semiconductors.

Increasing component availability has had a definite effect on the mentality of end users, who have on average lowered their target inventory levels for the past three months in a row. At the same time that target levels have declined, however, computer OEMs in particular have seen an increase in actual inventory levels. As a result, the difference between target and actual levels has risen to nearly 15 days from the less than 10-day difference noted in March's semiconductor procurement survey.

On the distribution side, the National Electronics Distributors Association (NEDA) reports a recent rebound in distributor orders following the inventory corrections of late 1988, and has forecast distribution business to grow 3 percent in 1989. In a recent market newsletter, however, the NEDA concluded that current order strength "is not enough to evidence aggressive inventory replenishment."

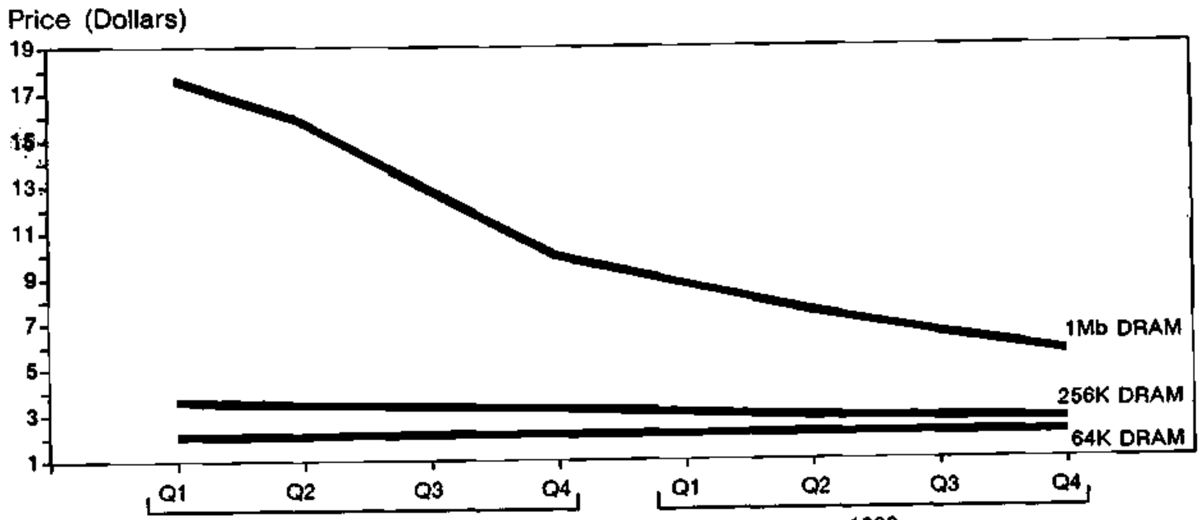
DECLINING ASPs

Analysts in Dataquest's Semiconductor Users Information Service group (SUIS) have noted that if one were to exclude those portions of inventory accounted for by memories and work-in-progress, there would be little difference between target and actual inventory levels. For the moment, then, the prescription for managing inventory is: curtail DRAM orders. This approach is bound to have a downward effect on both price and demand.

Looking ahead at DRAM unit pricing, Figure 2 illustrates the sharp decline that is anticipated for 1Mb DRAMs through the remainder of this year and 1990. From a current volume contract average of $16.75/unit in the U.S. ($14.59/unit in Japan), the cost of 1Mb DRAMs is expected to be at less than $7.00 by the end of 1990.

Figure 2

DRAM Price Trends



Source: Dataquest
May 1989

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The capacity allocated to the manufacturing of DRAMs has had a definite effect on pricing for other memory devices, most notably slow SRAMs, video RAMs, and x4 DRAMs. Suppliers of such devices have had little incentive to increase production at the expense of DRAMs given the volumes and pricing involved in DRAM manufacture. Slow SRAM lead times are expected to remain long and pricing firm during the second quarter of 1989. By the third quarter, however, users can expect an increase in the supply of slow 8Kx8 and 32Kx8 SRAMs.

Declines in ASP are by no means unique to the memory market. Based on procurement surveys by Dataquest's Semiconductor Users Information Service, the following pricing trends emerge in other component sectors:

- Standard logic prices, especially in the more mature product families, have declined since mid-1988 and are expected to continue declining through the first quarter of 1989, even though demand will remain steady because of the increased availability of DRAMs.

- Microprocessor price trends show a softening in the slower 8- and 16-bit devices as the personal computer markets show signs of a leveling of growth. The demand for high-end, 32-bit devices is becoming moderate, but prices remain firm and in line with projected 5-percent-per-quarter price declines. The acceptance of the Intel 80386SX, Motorola 68020, and 80286-16 have caused some price erosion in the 10- and 12-MHz 80286 market, as these new products compete for market share.

- In the ASIC market, gate arrays are declining both in terms of price per gate and nonrecurring engineering (NRE) costs, with the trend most apparent in the 1.5-micron segments. Dataquest notes greater price competition in the CMOS PLD market as well.

As 1989 progresses, lower order rates from end users should continue to cause a decline in both unit and ASP growth for semiconductors. A survey of average bookings by systems manufacturers in the United States has shown a glut of orders occurring in January of this year—perhaps nearly equal to the total of orders in the last quarter of 1988! Since then, each month has shown successive declines in the average, with April orders at a level about half that of January.

MACROECONOMIC INFLUENCES

At present, the semiconductor user mentality is probably as much affected by lessening lead times and price declines as by anticipation of slower business conditions. In an April market newsletter, NEDA noted that distribution inventory continues to be well-managed. Inventories, which peaked during the summer of 1988, have declined in four out of five months since September, and as of February had returned to first quarter 1988 levels. By the second half of this year, however, it is likely that general economic conditions will be the major factor behind dampened demand.

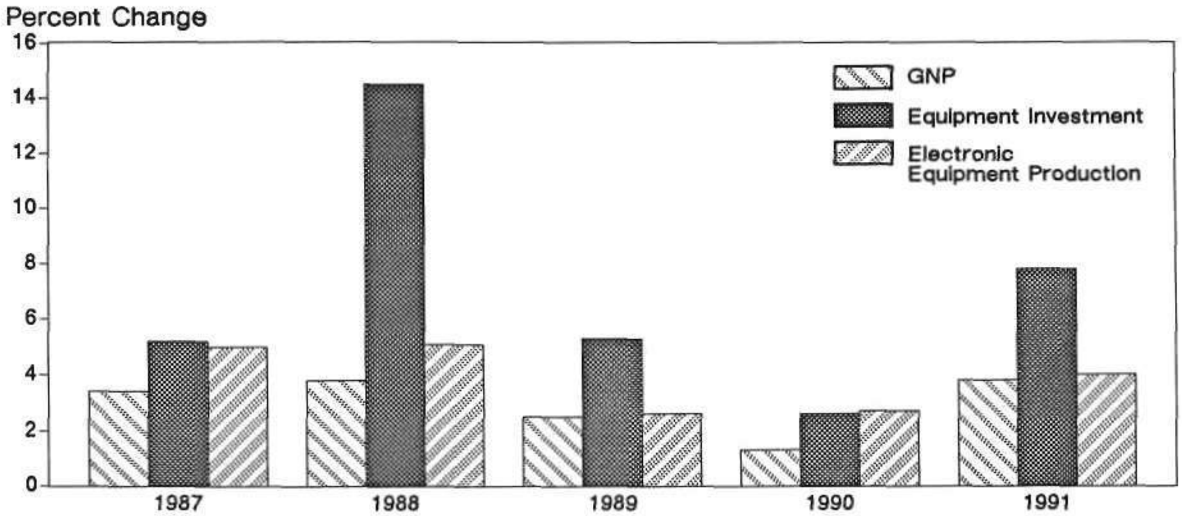
The U.S. economy grew 3.8 percent in terms of real GNP in 1988. Although economic growth was not as strong in 1988 as it was in 1987, real growth in equipment investment for the year was an impressive 14.5 percent compared with 5.2 percent in 1987. This growth in capital spending fueled an increase in 1988 North American electronic equipment production of 5.1 percent over 1987.

A combination of higher short-term interest rates, restrained government spending, and minimal improvement in the trade balance all point to slower economic growth and lower capital equipment spending in the year ahead. Figure 3 shows Dataquest's outlook for GNP, capital spending, and electronic equipment production, based on data from our parent company, Dun & Bradstreet.

Exports were a critical factor in 1988 economic growth. Nevertheless, export activity declined as the year progressed, with real exports at 17 percent annual growth in the first half of 1988, slowing to 11 percent in the second half, and falling to an 8 percent annualized growth rate in the final quarter. In March of this year a survey by the National Association of Purchasing Managers revealed that of the 69 percent of respondents that export, only 22 percent indicated export increases over the previous year. In the previous year's survey, 40 percent of the companies surveyed saw increased exports. While this may be good news on the inflation front, with near-record capacity utilization and low unemployment threatening further interest rate increases by the Federal Reserve Bank, it nonetheless spells lower industrial output and capital investment.

Figure 3

Economic Outlook—Real Growth
Percentage Change 1987–1991



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Source: Dataquest
May 1989

NO CLIFF IN SIGHT

The latest Blue Chip Economic Indicator survey of 54 economists reveals that only 35 percent expect a recession this year, with 30 percent predicting one in 1990, and another 30 percent in 1991. An impressive 80 percent of the economists surveyed, however, believe that whenever the recession does hit, it will not be severe. The Blue Chip Economic Indicator forecast for industrial output growth is a modest 1.7 percent for 1989, with business investment up 1.8 percent.

The good news for the electronics industry, however, is that nearly 50 percent of equipment investment will be for information processing equipment. This outlook is consistent with Dataquest's expectation that the data processing industry will set the pace among the semiconductor application markets with 11.3 percent growth this year—a modest slowdown from the 13.4 percent growth rate achieved by this market in 1988.

Within the semiconductor industry itself, a number of signs indicate that the impending slowdown will not turn into a crashing halt:

- In the distribution business, the average industry inventory turnover rate has improved to nearly 4X—the best rate NEDA has recorded since it began keeping monthly statistics in 1986.
- End-user control of semiconductor inventories promises to soften the transition to slower electronics equipment growth for semiconductor suppliers.
- Industry constraint in capital spending has not led to a situation of overcapacity such as was experienced in 1985 and 1986.

- So far Dataquest does not see any price-cutting catalyst that would drastically affect MOS memories. As Mr. Junkins of Texas Instruments recently expressed it, "Because of the high cost of investment, and the increasing complexity of each new generation of products, there are fewer companies with the resources to participate in the DRAM market. Therefore, we expect price reductions to be more moderate than in the past, with the industry taking into account the need for profitability to sustain investments for the future, as well as passing along cost reductions."

DATAQUEST CONCLUSIONS

The recent spate of positive indicators for the semiconductor industry should be tempered by the knowledge that the industry has a history of comparatively strong second quarters. Dataquest's overall outlook for slower end-equipment growth calls for weakening demand, and more carefully managed inventories. Given the recent impact that memory ASPs have had on industry growth, Dataquest expects their resulting decline to contribute to negative quarterly growth in the latter part of this year. Should the U.S. economy perform more vigorously than our 2.5 percent GNP assumption suggests, of course, the industry could see a higher-than-predicted demand.

Mr. Junkins' remarks on the changed climate of DRAM manufacturing touches on a wild-card factor in the Dataquest forecast: with the regional dominance that now exists in the semiconductor memory business, the action of market forces may no longer play as significant a role in determining the trajectory of ASP declines. The extent to which this new reality is a factor in 1989 may have profound implications for memory manufacturers, end users, and, perhaps, for the future direction of U.S. trade policy.

Michael J. Boss

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Research Bulletin

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0003940

ACER AND TI "PUT THE EYES ON THE DRAGON"

In a traditional Chinese ceremony, Acer Incorporated of Taiwan and Texas Instruments (TI) affixed two 4Mb DRAM chips to the eyes of a mock dragon, symbolizing the creation of a jointly owned memory manufacturing plant that will produce 1Mb and 4Mb DRAMs in Taiwan. Aside from its ritual significance, the ceremony, which included the presentation of a 4Mb DRAM wafer slice to Taiwan's president Lee Deng Huei, proved a fitting allegory for his country's DRAM market in 1988. In the face of last year's memory shortages, Taiwan's electronics industry "dragon" was indeed running blind: Dataquest believes that DRAM shortages in 1988 were responsible for a 25 percent reduction in Taiwanese PC shipments.

With as much as one-half of the production from the Acer/TI joint fab available to satisfy Acer's internal requirements, the decision to expand capacity in Taiwan underscores the growing demand from the Pacific Rim for MOS memory devices. Figure 1 shows the incredible growth in consumption of MOS memories forecast by Dataquest for the Rest of World (ROW) segment (largely Asia/Pacific) as the newly industrialized countries of Asia increase their production of electronic equipment.

The agreement between Acer and TI will create Texas Instruments-Acer Semiconductor Ltd., a jointly owned wafer manufacturing plant. Construction of the facility, which will be located in the Hsinchu Science Park development just outside of Taipei, Taiwan, is scheduled to begin in September of this year, with initial wafer production expected in mid-1991. Details of the agreement, as released by Acer and TI, are as follows:

- Acer will hold a 74 percent equity position in the joint venture, with TI owning 26 percent. TI's share could, however, be increased to 51 percent within five years.

- The cost of the facility is estimated at $250 million to $300 million, with Acer providing most of the required cash.

- TI will provide the joint venture with its 1Mb and 4Mb submicron CMOS technology. The process will be run using 6-inch wafers, with shipment of qualifying samples available as early as the fourth quarter of 1990.

- All production will be sold to TI. Acer will have the option to obtain up to 50 percent of the plant's total output.

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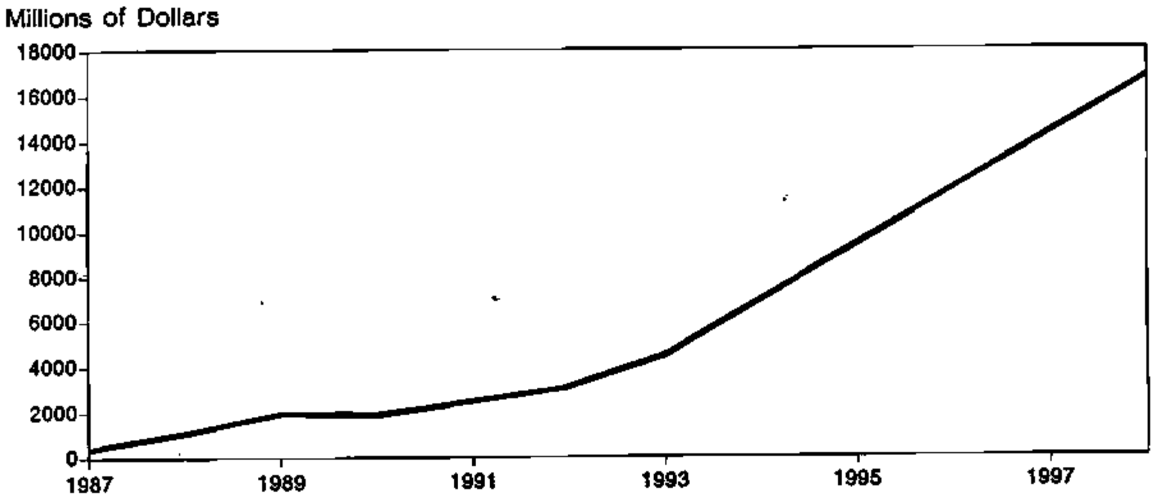
Figure 1

Estimated MOS Memory Consumption by ROW Countries



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Source: Dataquest May 1989

Collaborations between Acer and TI are nothing new. In November 1987, for example, the two companies signed an agreement under which TI's Instruments Data Systems Group in Austin, Texas, would manufacture, assemble, and test all Acer PC AT-compatible computers for distribution in the United States and Canada.

This latest venture with Acer provides TI with its first memory production capacity in the Asia/Pacific region, outside of Japan. With the addition of a plant now under construction in Averzano, Italy, TI's MOS memory fabrication capabilities now will encompass the four major world markets of Asia, Europe, Japan, and the United States. The joint venture with Acer allows TI to expand its memory production capability into the Pacific Rim while limiting the financial burden of this investment. For Acer's part, the joint venture offers an assured source of DRAMs for its personal computer, peripherals, and communications products. As the largest computer company in Taiwan, Acer's consolidated annual sales in 1988 exceeded $500 million.

In addition to DRAMs, TI has stated that its Taiwan plant may eventually manufacture ASICs, and that the facility will incorporate TI's "living fab" philosophy. The plant will be constructed and equipped so that it can produce advanced logic and other integrated circuits in the future.

While the agreement between Acer and TI points to the future, it also marks the 20-year anniversary of TI's presence in the Taiwanese market. As pointed out by the president of TI's Semiconductor Group, Pat Weber, "This dragon eye ceremony is important . . . as a symbol of the beginning of our next 20 years."

Michael J. Boss

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Research Newsletter

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TAIWAN'S AMAZING SCIENCE-BASED INDUSTRIAL PARK

OVERVIEW

According to the Stanford Research Institute, Taiwan has required only 30 years to achieve an economic success comparable with what it took the West 100 years to establish. Agriculture, which contributed 29 percent of Taiwan's GNP in 1960, has been taken over by manufacturing. Today, much of that manufacturing is in the high-technology sector. The Science-Based Industrial Park (SIP), located in Hsinchu, is the Republic of China's high-tech center. Founded in 1980, the SIP had grown to almost 100 companies by the end of 1988, with revenue approaching US$2 billion. Approximately 60 of the SIP companies are locally owned, and of the 40 that are foreign based, 75 percent are U.S. companies. Computer manufacturing represents the majority of the SIP activity; however, production of integrated circuits is the fastest-growing business. Dataquest believes that Taiwan's IC industry is rapidly approaching a capability wherein it is positioned to be a major factor in the worldwide semiconductor industry.

CREATION OF THE SIP

In 1980, the Republic of China (ROC) made a decision to embark upon a course of high technology by establishing an industrial park devoted entirely to high-technology industries. The SIP is the result of this visionary commitment to high technology in Taiwan. By fostering investment and development in high-profile industries, the ROC believes that it will be able to upgrade its industrial structure and stay competitive in the constantly changing worldwide economic environment.

Among the driving elements for the creation of the SIP were:

- The need to establish an infrastructure for creating and attracting high value-added industries in the private sector to Taiwan

- A desire to provide a vehicle that would offer attractive, rewarding employment to expatriates who went abroad for education but wished to return home

- A plan to establish state-of-the-art research and development capabilities by recruiting top-level personnel in the areas of science and technology

- The need to solve common technical problems for local industry, improve the standard of living, and increase industrial productivity

The Science-Based Industrial Park is located in Hsinchu, a rapidly growing city about 50 miles southwest of Taipei. The master plan for the SIP anticipated essentially all future needs. As a result, the SIP currently includes approximately 750 acres (300 hectares) of developed land including industrial, research, manufacturing, and utility zones, as well as residential and educational areas. Single-family dwellings, duplexes, apartments, and dormitory-style accommodations are available. Modern 1,500-square-foot townhouses rent for US$300 a month, apartment rentals range from US$100 to US$250, and dorms rent for less than US$50 per month. The SIP will eventually occupy 5,200 acres (2,100 hectares). One of the distinctive advantages of the Hsinchu location is the number of educational facilities nearby. These include the National Tsinghua University, the National Chiaotung University, and the Industrial Technology Research Institute (ITRI).

FACILITIES, COSTS, AND CAPITAL

Ready-built, multipurpose factory sites are available for companies (start-up or established) that wish to expedite their operations. The rental rate for standard 5,500- to 6,000-square-foot buildings is US$0.19 per square foot per month. Construction cost for new, custom-designed buildings is around US$25 per square foot. Building and land taxes are included in the rental fees or paid by the SIP for custom-built facilities; however, an administration fee of 0.25 percent of annual sales is paid to SIP Administration for management services. Taiwan has a rapidly growing venture capital and investment community that maintains a favorable attitude toward new ventures that are considering operations in the SIP. These investors include the China Development Corporation, ITRI, Multiventure Investment, Inc., Taiwan Cement Corp, Ching Fong Investment Co., China Securities, Kwang Hua Securities, and Hambrecht & Quist (H&Q) Taiwan. Government sources include the Development Fund of the Executive Yuan and the Bank of Communication. Assistance to new entities includes:

- Tax holidays; duty-free import of critical equipment, raw materials, and semifinished goods; and exemption from commodity and business taxes for exported goods

- Government joint venture options (up to 49 percent of the total paid-in capital)

- Low interest (currently 5.25 percent) and R&D matching funds

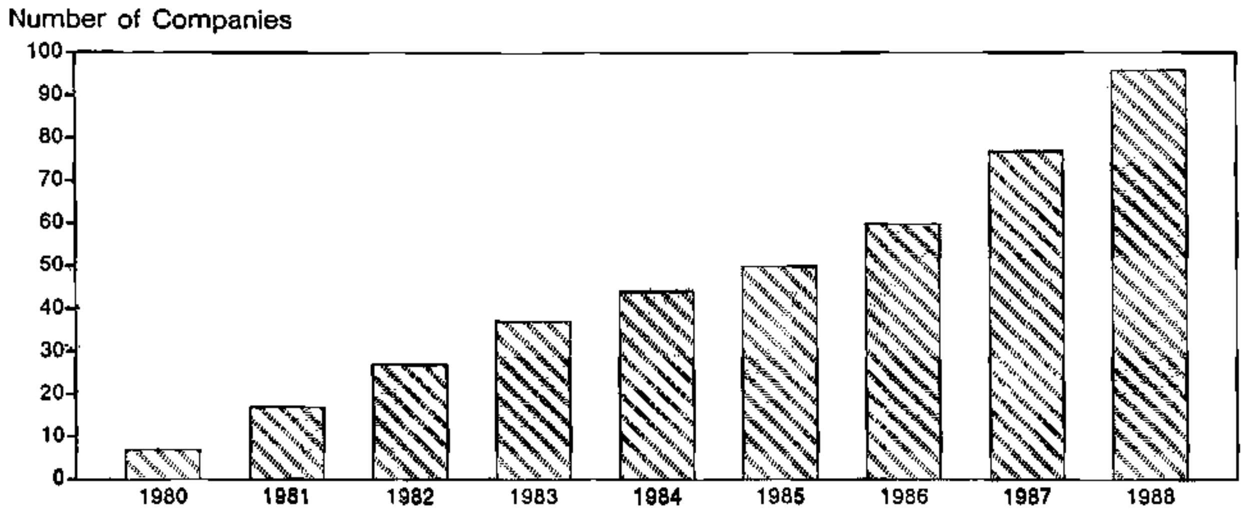
- Technology in trade for equity

SUCCESS AS MEASURED BY THE RESULTS

By virtually any measure, the SIP appears to have achieved a success beyond that realized by any other regional effort. Commencing with 7 companies in 1980, the SIP had grown steadily to 96 companies at the end of 1988. The growth during this period is shown graphically in Figure 1.

Figure 1

Growth in Number of Companies
Hsinchu Science-Based Industrial Park



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Source: SIP
Dataquest
June 1989

Business Types

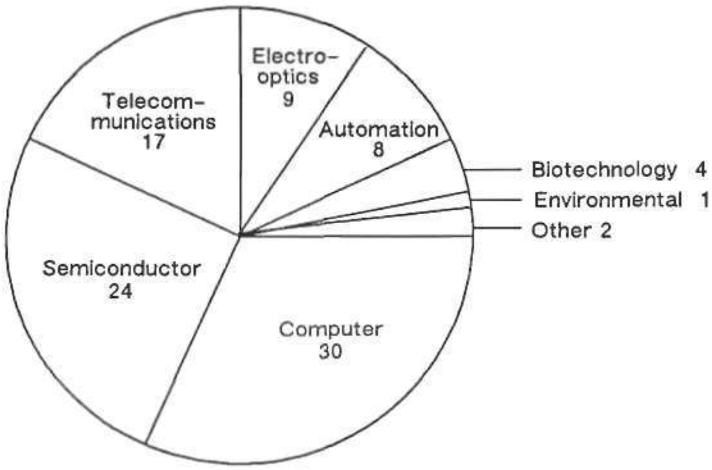
Computers, semiconductors, and telecommunications represent approximately 75 percent of the 96 companies currently in business in the SIP. As indicated in Figure 2, however, there is a reasonable representation of other technologies, including biotechnology, automation, environmental, and optical.

Employment

A central purpose of the regional technology parks based throughout the world is to create employment. SIP's achievement in this area is noteworthy. Starting from a base of 1,200 employees in 1982, employment in the park had grown to more than 16,000 by the end of 1988, a compound annual growth rate (CAGR) of approximately 55 percent (see Figure 3).

Figure 2

SIP Types of Companies by Technology



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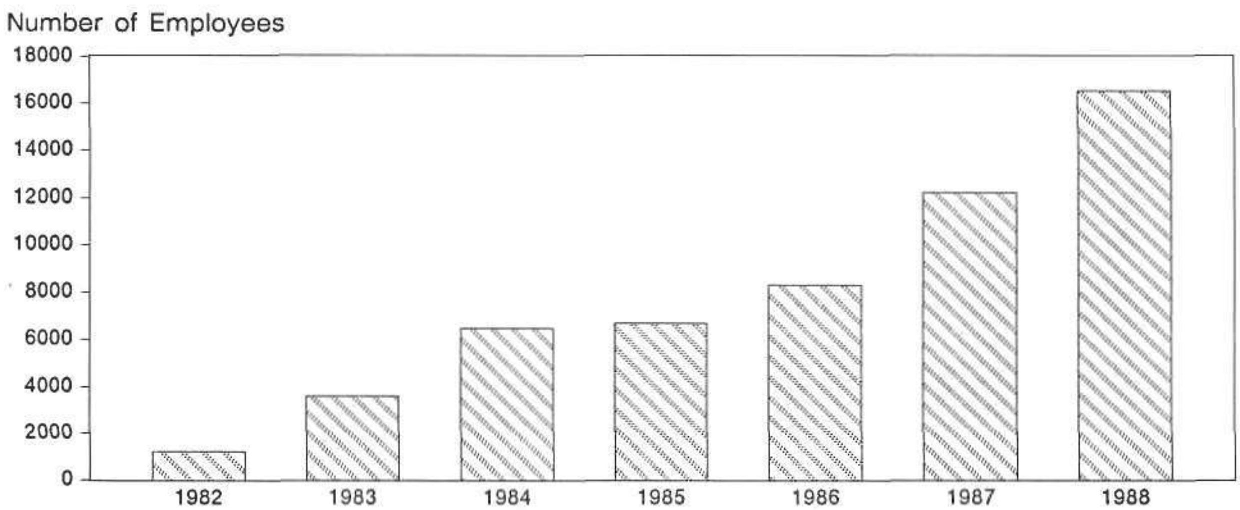
Source: SIP
Dataquest
June 1989

Figure 3

Growth in Number of Employees
Hsinchu Science-Based Industrial Park



0004000-3

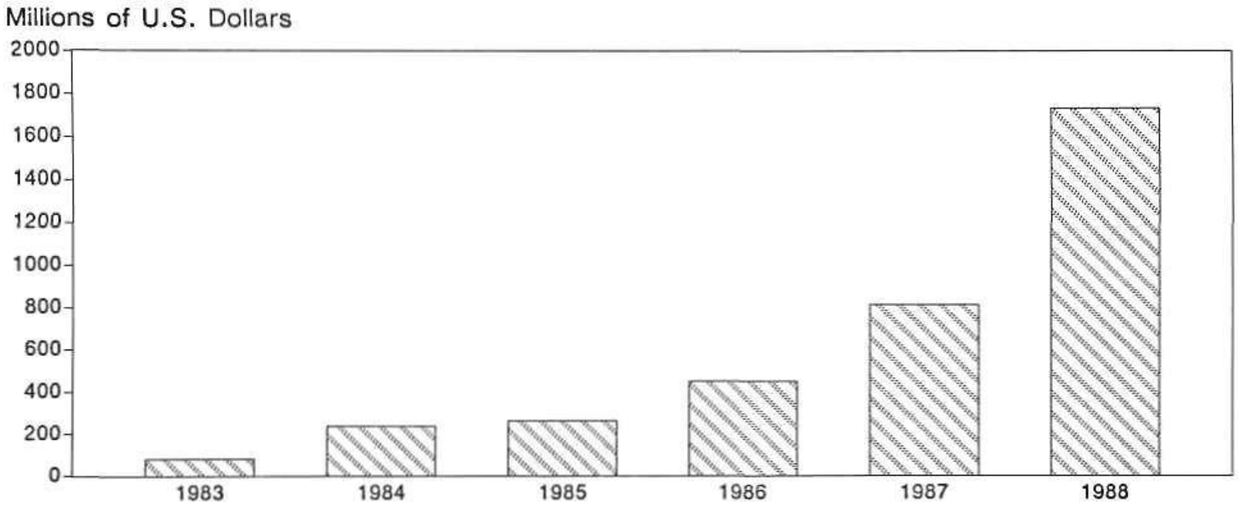
Source: SIP
Dataquest
June 1989

Revenue

The most critical measurement parameter of a regional endeavor such as SIP is its commercial success. Technology acquisition, employment, and a local supply of essential products are all important elements. However, to be competitive on a worldwide basis, the venture must demonstrate its ability to compete on an economic standard. Sales of products produced in the Taiwan's Science-Based Industrial Park have grown from approximately US$82 million in 1983 to more than US$1.7 billion in 1988 (see Figure 4). This is an astounding 85 percent CAGR for the period from 1983 through 1988.

Figure 4

Sales of SIP Companies 1983–1988



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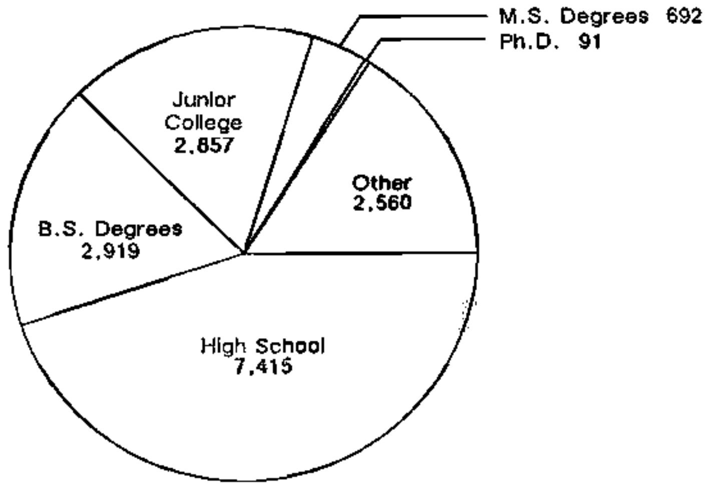
Source: SIP
Dataquest
June 1989

Education

Taiwan is a nation of limited natural resources that might logically be associated with a relatively small island. However, the ROC possesses great strength in the form of its people. Family oriented and hard working, the Taiwanese revere education. This fact is borne out by the SIP employees' educational backgrounds. Approximately 85 percent of the employees working in the SIP have at least high school educations, while nearly 40 percent have junior college or greater educations. Figure 5 provides a breakdown of the educational levels achieved by SIP employees.

Figure 5

Distribution of SIP Employees' Educational Background



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Source: SIP
Dataquest
June 1989

THE SIP SEMICONDUCTOR INDUSTRY

The fastest-growing segment of the SIP appears to be its semiconductor industry. Using the Electronics Research and Service Organization (ERSO) division of ITRI as a nucleus, there are currently six major semiconductor companies operating in the park. The recent announcement of the Acer/Texas Instruments joint venture will create a seventh major entity by the end of 1990. The partnership will occupy 15 acres of land in the SIP and expects to ship sample quantities of DRAMs in the fourth quarter of 1990. All of the six operating companies have construction under way or have plans for major wafer fabrication capacity expansion in 1989 and/or 1990. Dataquest believes that the ROC will consume approximately US$4 billion of MOS memories in 1993 and more than US$16 billion by 1997. Virtually all of the semiconductor companies in the SIP are moving quickly to incorporate SRAMs, EPROMs, and other MOS memory devices into their product portfolios.

DATAQUEST ANALYSIS

In a few short years, the Hsinchu Science-Based Industrial Park has been able to establish the ROC as a world-class player in the electronic equipment industry. In five years, SIP company revenue has grown to nearly US$ 2 billion. By way of comparison, it took the Japanese semiconductor industry ten years to increase revenue from approximately US$100 million to US$1.7 billion.

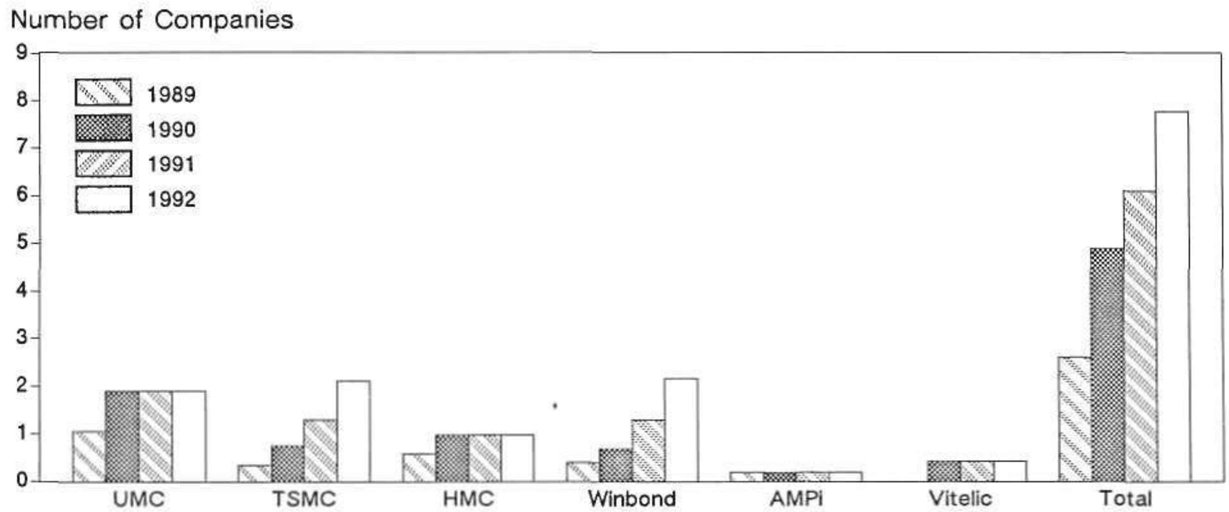
Dataquest believes that in the next few years, the SIP semiconductor industry will emerge as the leading growth and revenue entity in the park. All six of the semiconductor companies in the park are currently operating at full capacity. All are planning or are in the process of completing significant capacity expansions.

Dataquest has an extensive data base that closely correlates square inches of silicon started (not including test wafers) to revenue produced throughout the worldwide semiconductor industry. In 1988, these data were $48 per square inch of silicon fabricated for U.S. IC producers, $40 for Japanese producers, $36 for European producers, and $22 for ROW producers. Dataquest believes that given the recent increase in product value added, the revenue produced per square inch of silicon started in the SIP in the 1989 to 1992 time frame will be in the $25 to $30 range.

On this basis, an estimate of the revenue potential of the SIP IC companies can be calculated. Figure 6 compares the silicon start capacity in millions of square inches per month of the six major IC companies in the SIP on the basis of installed and forecast capacity for the years 1989, 1990, 1991, and 1992. (An apparent leveling of capacity by some companies simply reflects that that company did not provide a firm forecast for capacity expansion beyond the year(s) in which leveling occurs.)

Figure 6

SIP Wafer Start Capacity (Millions of Square Inches per Month)



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Source: SIP

In 1989, the six companies have a potential annual revenue of approximately US$772 million on the basis of the installed capacity. This figure rises to US$1.6 billion in 1990, US$2.2 billion in 1991, and US$3.1 billion in 1992. Table 1 shows Dataquest's forecast for the total value of semiconductors produced in the ROW for the period 1989 to 1992.

Table 1

Estimated Value of ROW-Produced Semiconductors
(Billions of U.S. Dollars)

	1989	1990	1991	1992
Value	$5.8	$7.3	$8.6	$8.9

Source: Dataquest
June 1989

Considering all of the above information, we suggest that the companies in the SIP are at least positioned, on the basis of installed capacity, to capture 13 to 35 percent of the forecast ROW semiconductor production during the period from 1989 to 1992. This simple analysis does not take into account the value of the products produced from the Acer/TI partnership, nor does it assume that capacity beyond that forecast will be added during the subject period. Hence, the model is conservative and may further understate the significant capability that is now forming in the SIP.

A conclusion that one can draw is that Taiwan's semiconductor industry is rapidly becoming a world-class player. With submicron technology and large-volume capacity virtually in place by the end of 1989, combined with product offerings that include SRAMs, EPROMs, and soon DRAMs, Dataquest believes that the SIP-based IC suppliers will soon begin to compete aggressively in the Pacific Rim. The SIP administration seems to agree with the potential of the SIP IC industry. On May 18, 1989, the Hsinchu Science-Based Industrial Park announced that it has decided to offer integrated circuits producers first priority on the remaining land in the park.

David Angel

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Research Newsletter

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General
0004092

INTERNATIONAL SEMICONDUCTOR TRADE ISSUES—DOMINANCE, DEPENDENCE, AND FUTURE STRATEGIES

OVERVIEW

Trade issues have been a major concern throughout the world thus far in 1989. The Japanese semiconductor manufacturers have achieved dominance of the worldwide DRAM market, while U.S. manufacturers still hold a comfortable lead in high-end microprocessors. The European semiconductor producers, particularly in view of the forthcoming 1992 combined-market scenario, have pledged that they will be in a position to supply Europe's semiconductor needs. Finally, substantial growth is being seen throughout the Asia/Pacific region as Taiwan, Korea, and Singapore rapidly expand their semiconductor production base.

Dataquest forecasts a global semiconductor industry taking shape by the mid-1990s, with a more balanced distribution of products and technologies than we witnessed in the 1970s and 1980s. However, with the trade press burgeoning with weekly—if not daily—statistics regarding export balances, threats of protectionism, and national agendas for critical electronic components, it is difficult to sort out the true current situation in the worldwide market. Dataquest has taken an alternate perspective on current worldwide production/consumption of semiconductor components and has classified each region as to whether it consumes more ICs than it produces or has a sufficiency for export after satisfying domestic needs. This net difference for each region, presented by major product category, is a measure of the self-sufficiency profile for each region. By understanding the net consumer or net producer profile of each region, we can anticipate strategic moves that the IC producers in these regions may make in the international marketplace.

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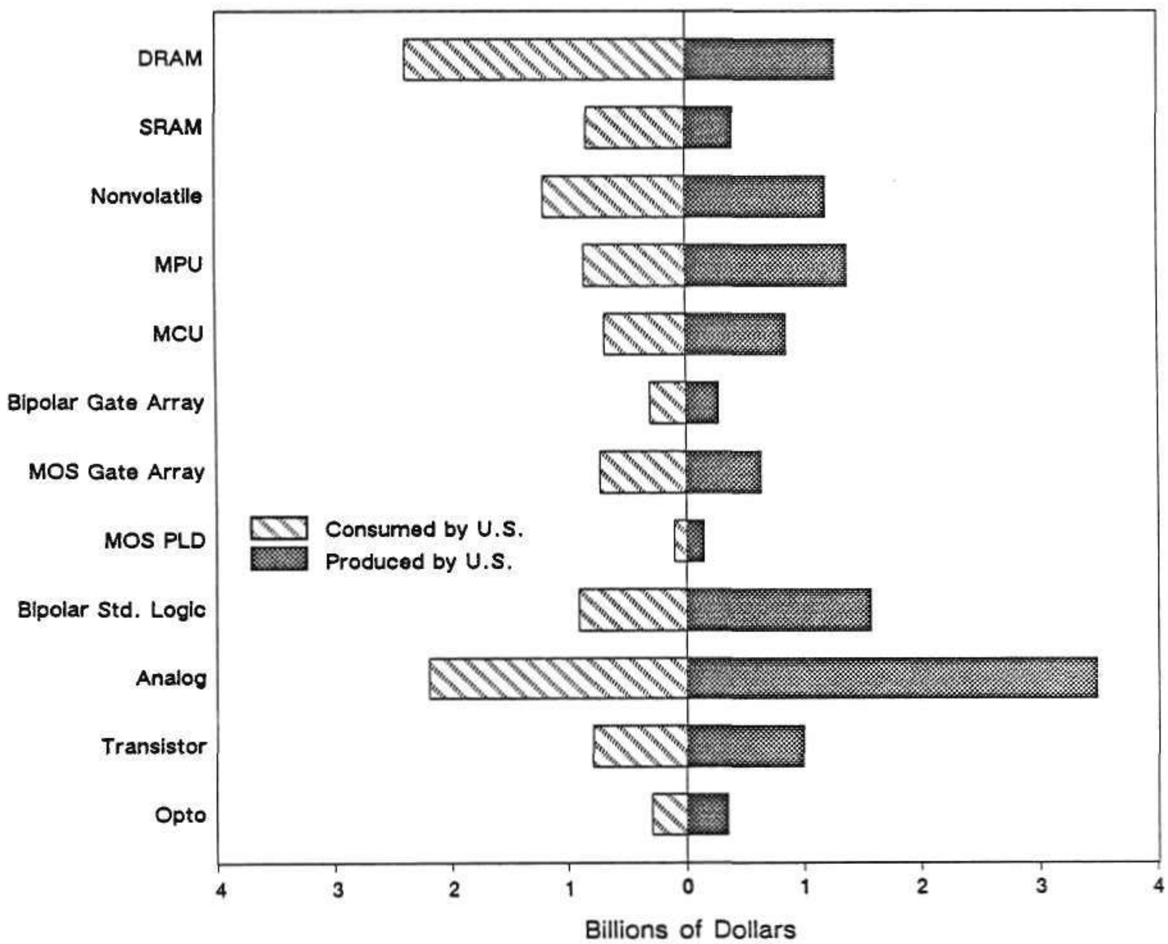
PROFILES BY REGION

U.S. Companies

We begin our analysis of worldwide production and consumption of ICs with a look at the U.S. semiconductor consumption/production profile. Figure 1 illustrates that the United States has a relatively symmetrical consumption/production profile, except for DRAMs and analog ICs. Figure 2 presents a better picture of the United States' position as a net consumer or net producer of ICs. From it, we can see that the United States is a net producer of both microprocessors and microcontrollers of bipolar standard logic, analog ICs, and discrete transistors. However, as expected, the United States also is a net consumer of DRAMs, a net consumer of SRAMs, and, surprisingly, a net consumer of both bipolar and MOS gate arrays.

Figure 1

Semiconductor Consumption/Production Profile
United States



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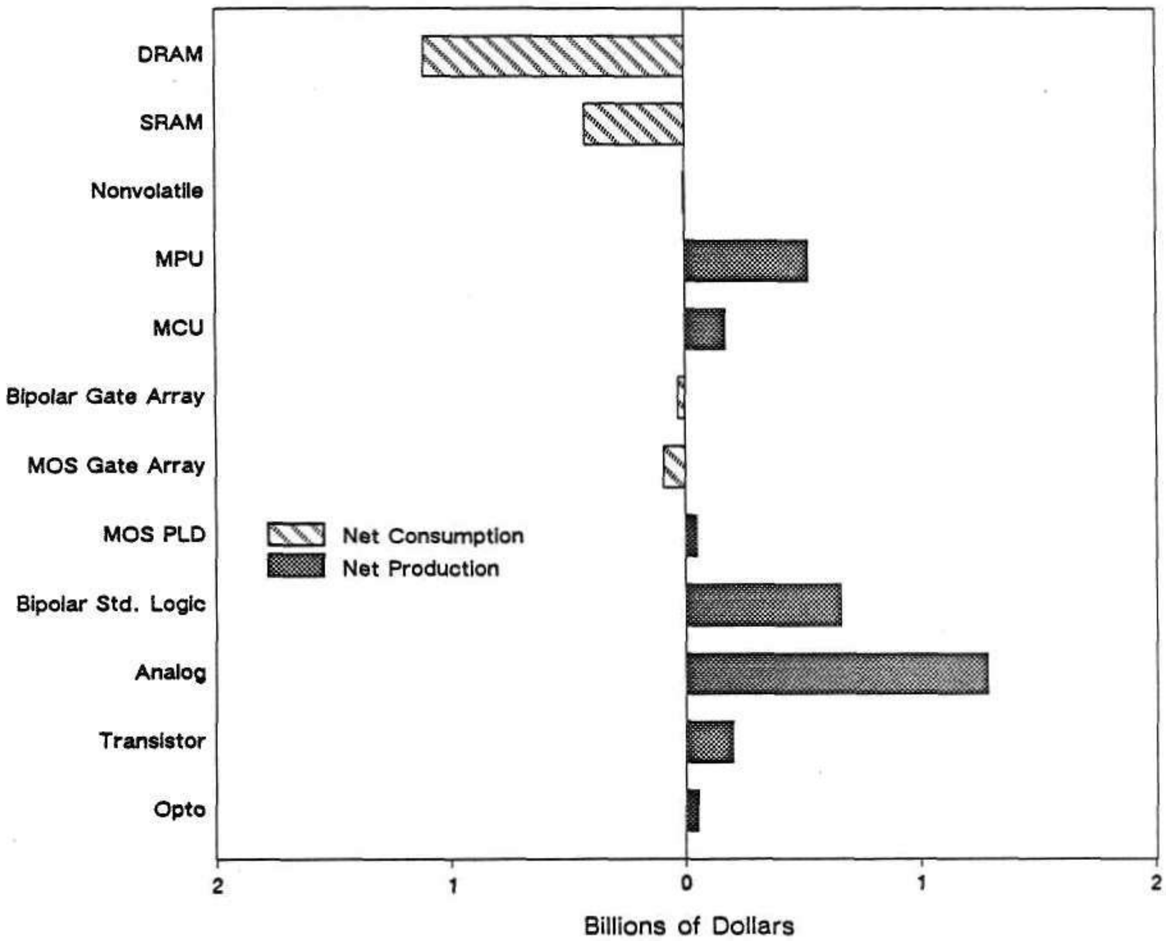
Source: Dataquest
June 1989

Figure 2

Difference between Semiconductor Consumption and Production
United States



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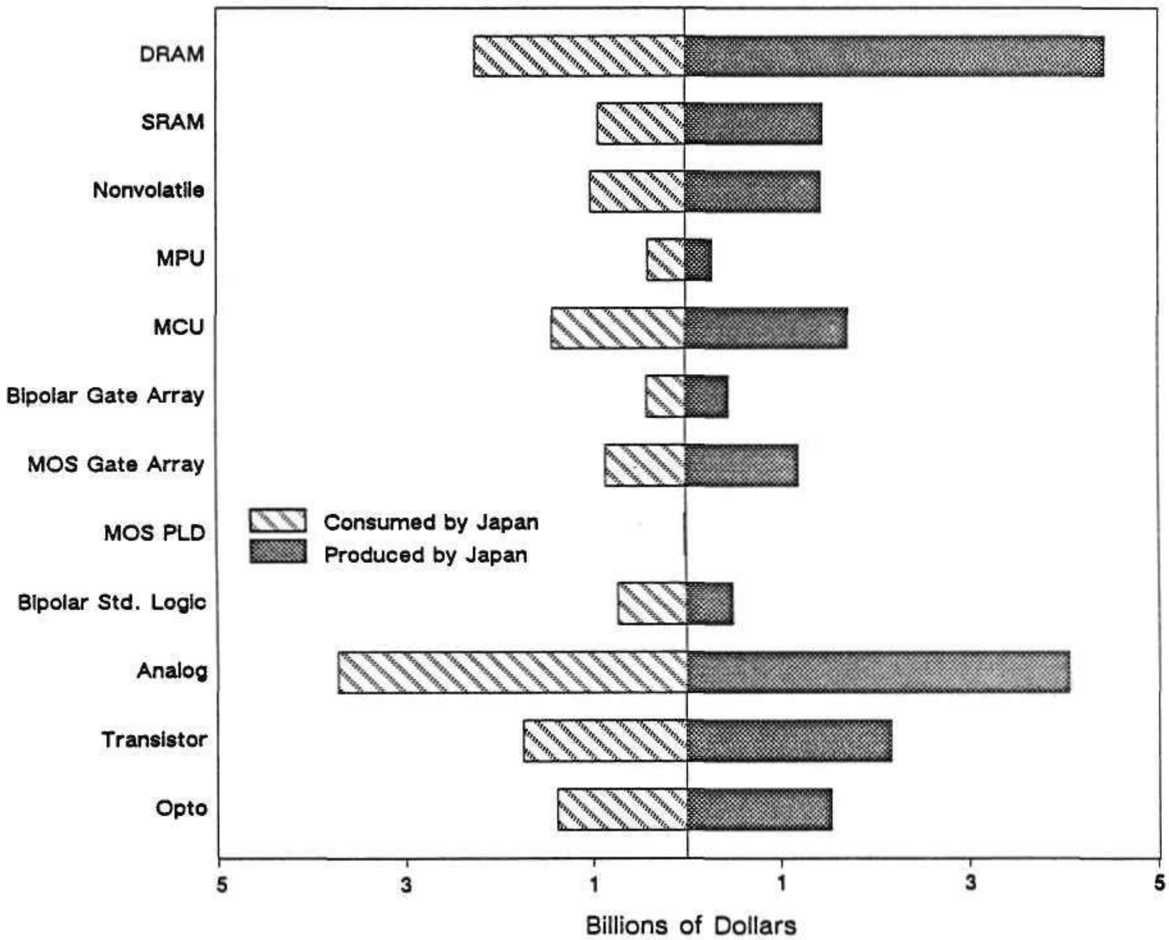
Source: Dataquest
June 1989

Japanese Companies

Figure 3 presents the overlay of Japanese semiconductor consumption, and Figure 4 presents the net consumption/production chart as it relates to Japan. These figures illustrate that Japan is overwhelmingly a net producer of ICs and that it consumes only microprocessor units, MOS PLDs, and bipolar standard logic from foreign sources.

Figure 3

Semiconductor Consumption/Production Profile Japan



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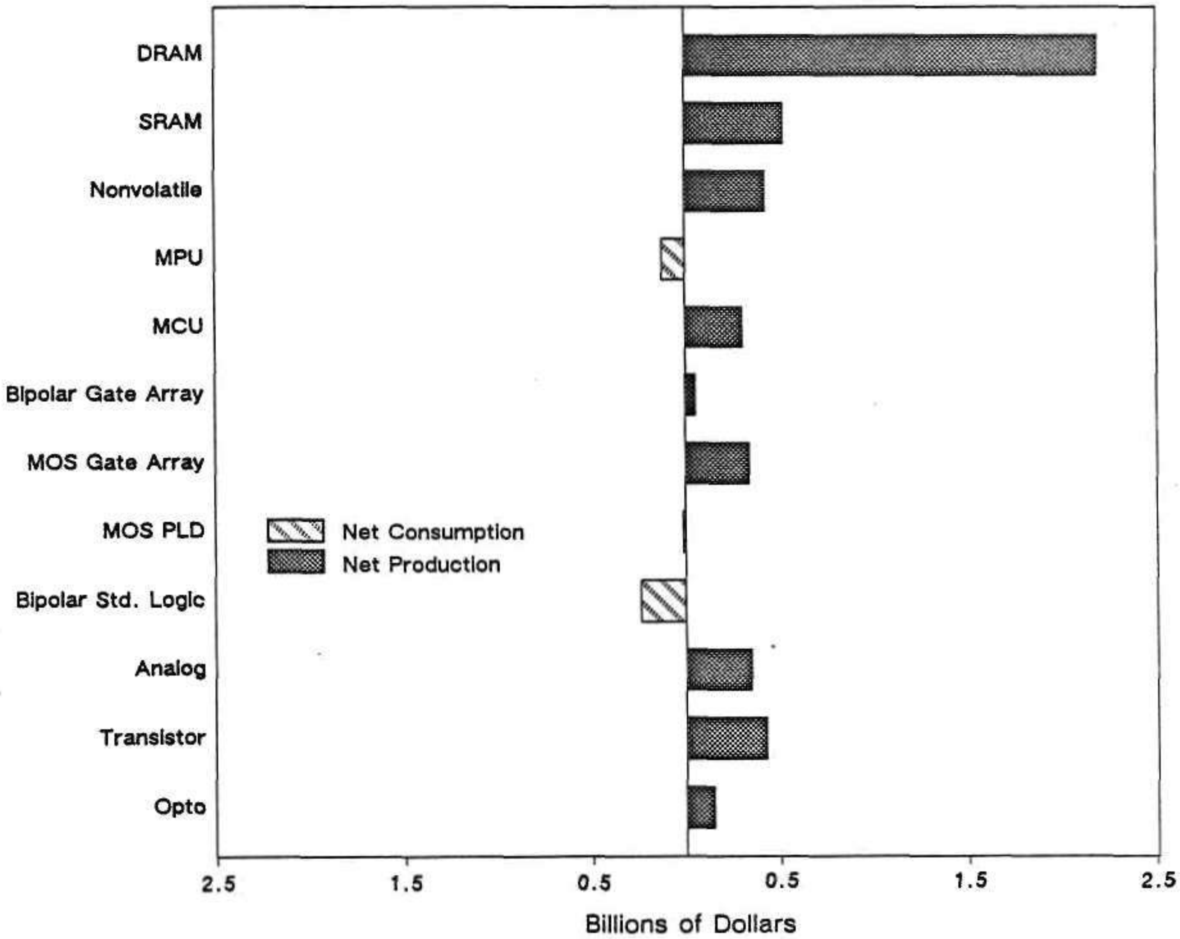
Source: Dataquest June 1989

Figure 4

Difference between Semiconductor Consumption and Production
Japan



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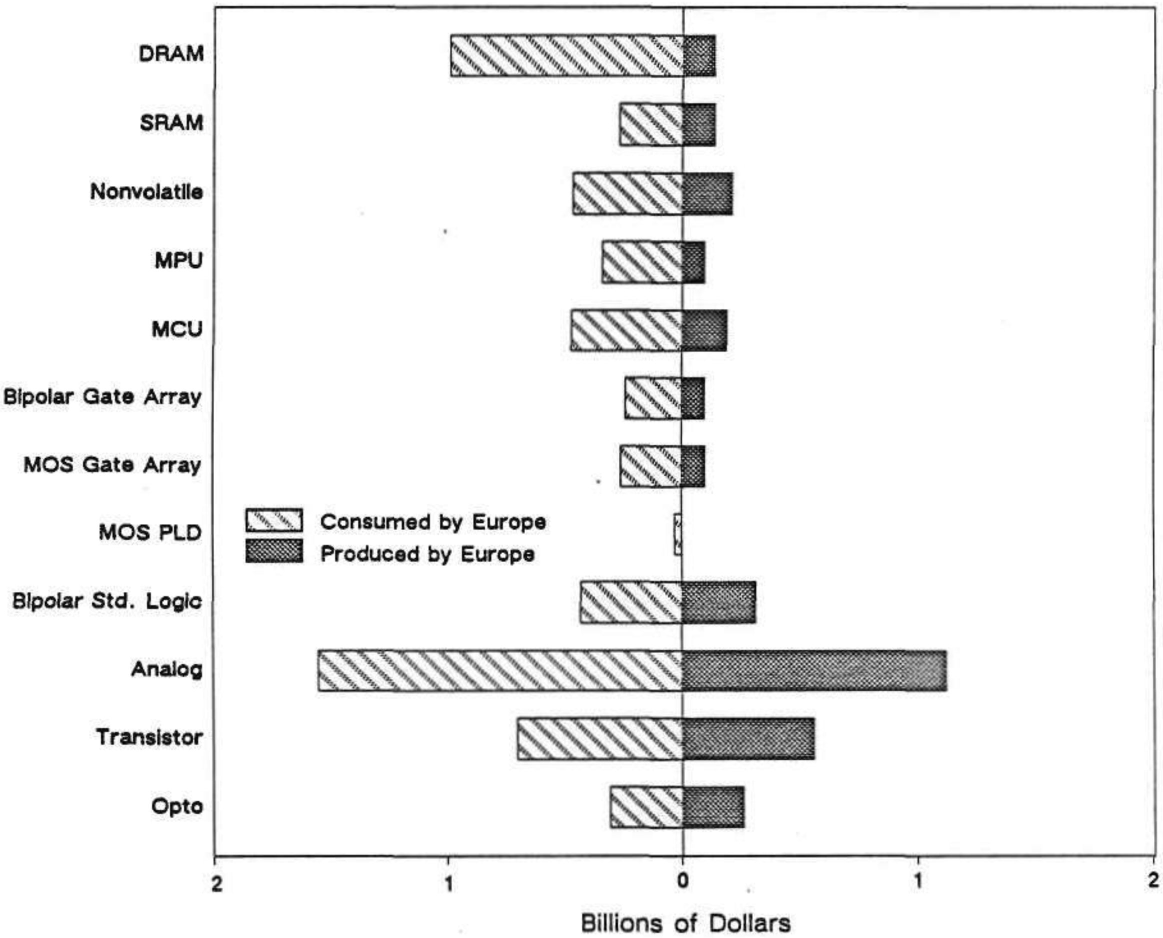
Source: Dataquest
June 1989

European Companies

Figures 5 and 6 depict the consumption/production scenario for Europe. As seen in Figure 6, Europe is a net consumer of foreign semiconductors in all categories.

Figure 5

Semiconductor Consumption/Production Profile Europe



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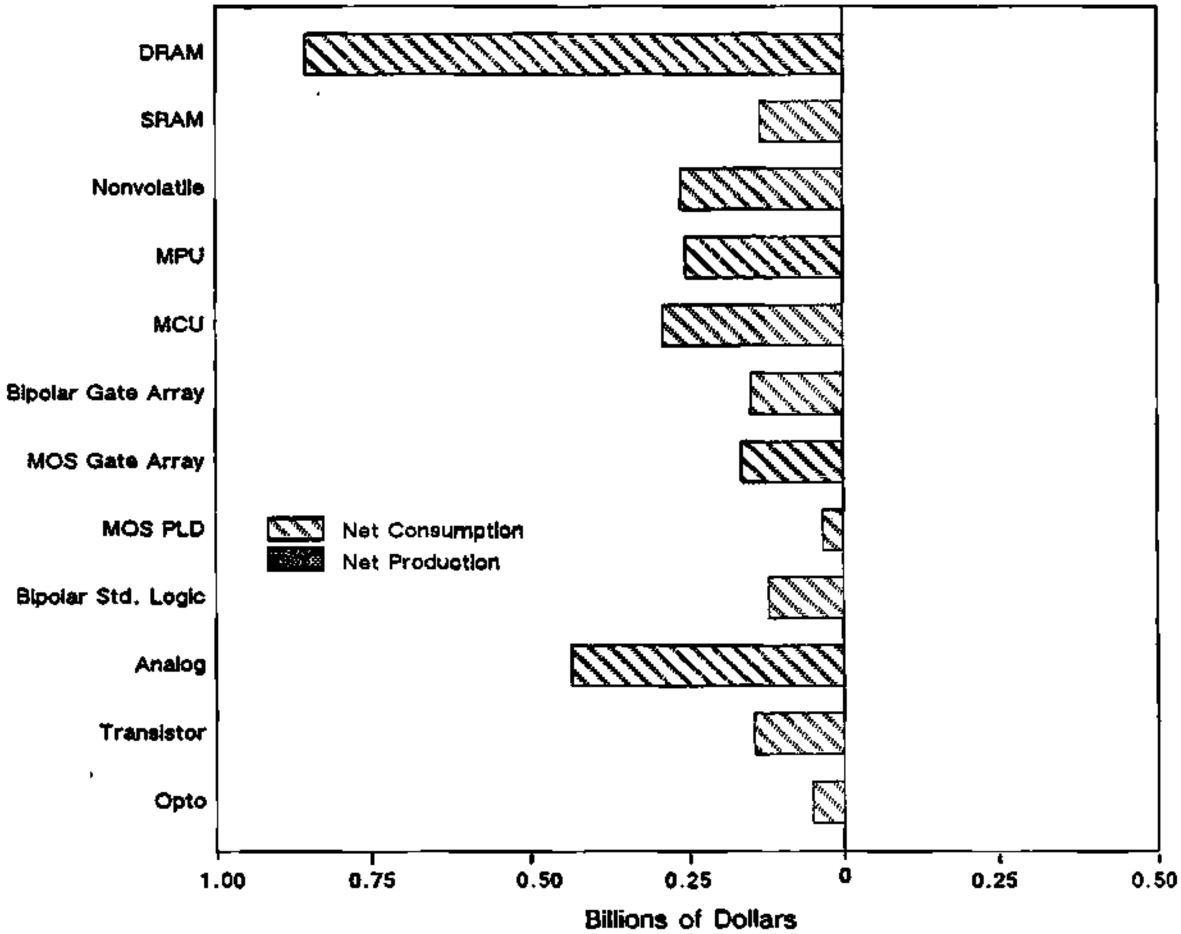
Source: Dataquest June 1989

Figure 6

Difference between Semiconductor Consumption and Production
Europe



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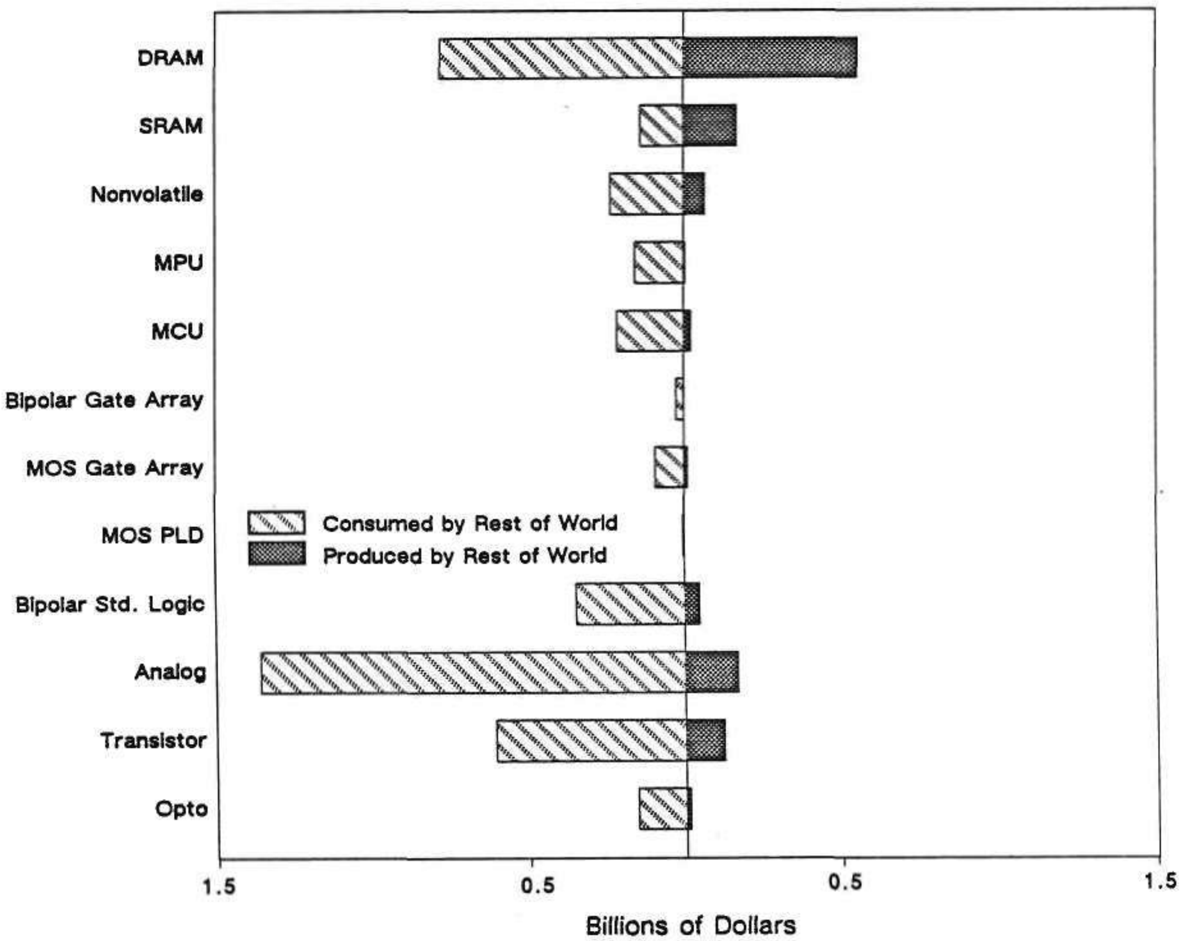
Source: Dataquest
June 1989

Asia/Pacific and ROW Companies

Figures 7 and 8 depict the consumption/production profile for the rest of the world, which is essentially Asia/Pacific. As seen in these figures, ROW is a net consumer of foreign ICs, with the exception of SRAMs.

Figure 7

Semiconductor Consumption/Production Profile Rest of World



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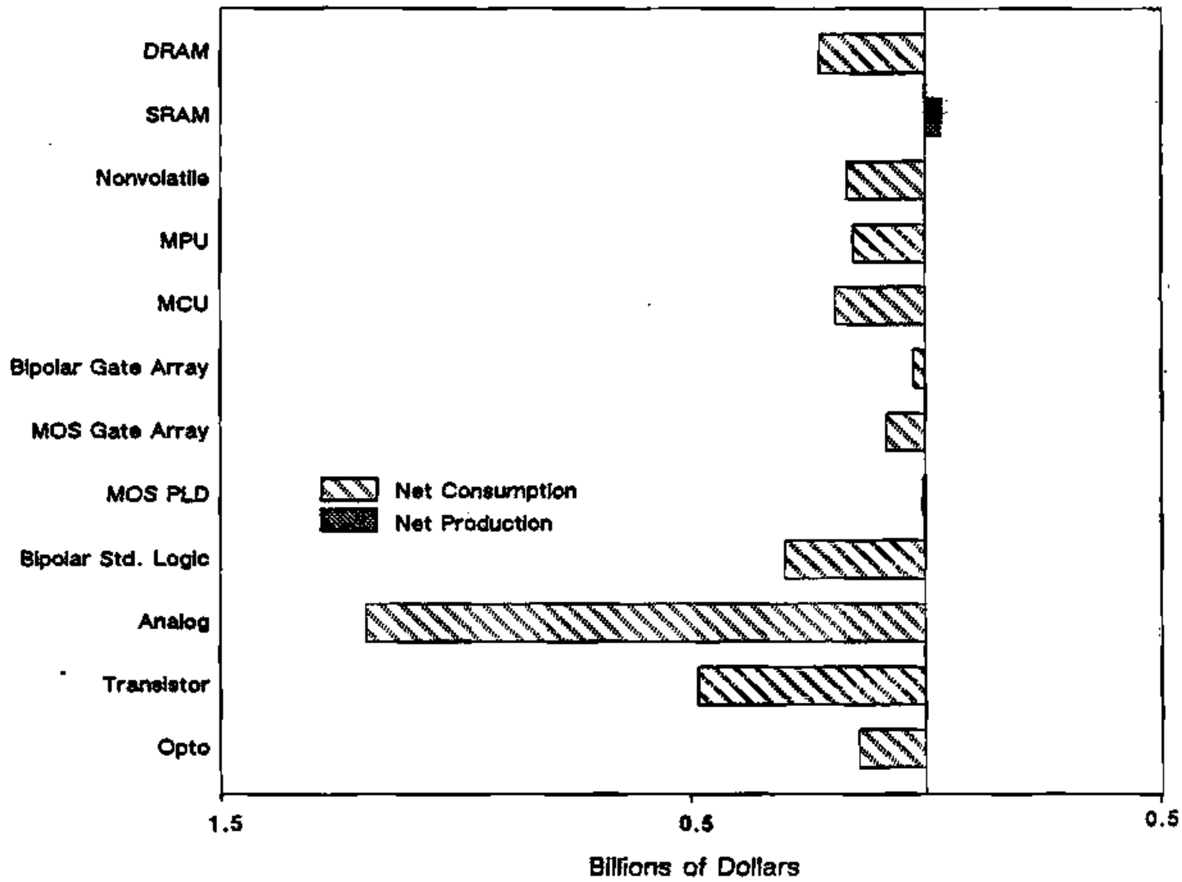
Source: Dataquest June 1989

Figure 8

**Difference between Semiconductor Consumption and Production
Rest of World**



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Source: Dataquest
June 1989

DATAQUEST ANALYSIS

Viewing the information in the net consumer/producer format allows one to quickly assess the characteristics of a certain region and also allows one to anticipate strategic moves that the semiconductor producers and system manufacturers in the region may make to defend markets or to obtain a better balance between consumption and production. Viewing the U.S. consumption/production profile, Dataquest believes that the United States will become a larger producer of both DRAMs and SRAMs and may become a net exporter of SRAMs in the next four to five years. Most of the semiconductor start-up companies that have begun operations in the United States in the last four years have some plans in place to produce SRAMs and specialty memories. Therefore, we believe that the United States will take a stronger position in SRAMs in the 1990s.

Dataquest believes that U.S. producers will continue to exercise dominance in microprocessors, given their superiority in complex design and software expertise; however, we also believe that the United States will become a net consumer of microcontrollers as Japanese companies gain expertise in this technology. This is particularly true for the less complex microcontrollers, which are embedded into a vast array of consumer electronic products and office equipment.

The U.S. companies' position in gate arrays, both bipolar and MOS, is surprising. Already, in this relatively young market, the United States does not produce enough to satisfy its own needs, suggesting underinvestment in this important and growing market. Unless dramatic changes occur, and occur very soon, we believe that non-U.S. suppliers will gain dominance in MOS gate arrays and that the U.S. electronics industry will continue to consume more gate arrays than it produces in the 1990s. Finally, although the U.S. IC producers appear to have a strong position in analog ICs, we believe that this strength will diminish somewhat in the 1990s, resulting from the lack of an indigenous consumer electronics industry.

To no one's surprise, the Japanese IC suppliers are the world's leaders in DRAMs. Dataquest believes that the Japanese companies will continue in their dominance of these markets and will be substantial net producers of DRAMs in the 1990s. Numerous Japanese companies are well positioned in 4Mb DRAMs already and are beginning to focus their attention on the 16 and 64Mb DRAMs. With this much inertial energy, we believe that it will be difficult for anyone to dislodge the Japanese IC producers from this number one status. We believe that the Japanese semiconductor producers will continue to strengthen their position in gate arrays and soon will begin to focus their energies on the MOS programmable logic device (PLD) area. Although it is purely speculation at this point, we believe that in the light of increasing trade friction, the Japanese suppliers may pursue microprocessor devices with less intensity and that the Japanese electronics industry will continue to be a net importer of MPUs, particularly 32- and 64-bit MPUs.

The European region forecast is less clear. The European electronics industry, at this time, is substantially dependent upon non-European sources for its critical semiconductor devices. We will have to wait to see if the "1992 Effect" and the recent consolidation of several European IC manufacturers will have a positive impact upon this profile as we head into the 1990s.

Dataquest believes that the area wherein the greatest change in profile could occur will be ROW—principally, Taiwan, Korea, Singapore, and Malaysia. Taiwanese and Korean companies are making substantial increases in semiconductor manufacturing capacity. In the last year alone, Taiwan has witnessed several new IC start-ups focused on the SRAM market as well as incorporation of SRAMs into the product profiles of many of the existing Taiwanese companies. Korean companies are well positioned to gain a major role in DRAMs. Singapore, Malaysia, and Taiwan, to some extent, have large amounts of installed foundry capacity. Dataquest believes that several of these foundries may begin to run SRAM-type products as technology drivers and as capacity balancers, further enhancing the region's image as a net producer of SRAM-type products. We also believe that there will be increased activity in both microprocessor- and microcontroller-type products, especially in Taiwan and Korea, as these regions' technical competency increases in high-end personal computers and workstations.

Dataquest anticipates an era of greater interdependence among geographic regions, beginning in the early 1990s. We believe that this will be especially true among the electronic IC companies of the United States, Japan, and Asia/Pacific, as all of these regions attempt to arrive at an amenable trade balance. We further believe that European industry will first focus on meeting a greater share of its own internal needs in the early 1990s and then join the other regions of the world in the mid- to late 1990s as the electronics industry becomes truly global in nature, with virtually no geographical boundaries.

David Angel
Mel Thomsen

Dataquest
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WAFER FAB IN THE 1990s: ASIA COMES ON STRONG

SUMMARY

The worldwide semiconductor industry recently has undergone one of its cyclical conjunctions of high demand and limited capacity--at least where leading-edge products are concerned. The recent effects of this coincidence are only too evident to procurement managers at U.S. electronics companies. As the industry heads for a downturn, however, Dataquest maintains that the severity of the coming recession will be mitigated by the overall constraint shown by U.S. and Japanese semiconductor companies in constructing new fab facilities--particularly when compared with the halcyon capital spending period between 1983 and 1985. Nevertheless, based on the current wafer fab trends that Dataquest analysts are observing in Asia, the industry may face another serious overcapacity situation by 1994.

This newsletter provides a look at Asian fab trends by drawing on the recent and extensive fab data base work done by analysts in Dataquest's Semiconductor Equipment and Materials Service (SEMS) and Asian Semiconductor and Electronics Technology Service (ASETS). Dataquest believes that the massive investments in capacity now being undertaken by the newly industrialized countries (NICs) of Asia, combined with major shifts in Japan's fab strategy, could lead to tremendous competitive pressures in the next five years--not only in commodity memories, but in the microcomponent and ASIC markets as well.

ENTERING THE ASIAN AGE

At the beginning of this year, Dataquest's ASETS analysts observed that the rapid growth in personal computer, office automation, and consumer electronics production was resulting in the construction of 39 new semiconductor plants in Asia (see Table 1). Although most of this activity is centered in South Korea and Taiwan, the countries of Australia, China, Hong Kong, Malaysia, Singapore, and Thailand also are seeing fast growth. Some of the regional factors behind the rush of new semiconductor investment in Asia include the following:

- Dynamic growth in Taiwan's PC clone, consumer, and industrial electronics sectors has resulted in the opening of 40 ASIC design centers. These factors have prompted government interest in expanded semiconductor production capacity—particularly in memory ICs.

- South Korean conglomerates are investing heavily in new semiconductor plants to achieve self-sufficiency and to respond to the huge demand for memory chips. The capital spending levels of both Samsung and Hyundai, for example, have reached parity with Toshiba, which will spend in excess of $600 million this year.

- Foreign companies are opening plants in the People's Republic of China to take advantage of the growing demand there for semiconductors.

- The Singapore government pays 100 percent of new plant investments and, by doing so, has attracted Chartered Semiconductor, Hewlett-Packard, and NEC assembly plants.

- Thailand is experiencing massive investments by Japanese companies. Japan's Ministry of International Trade and Industry (MITI) estimates that 277 Japanese companies in all sectors opened their doors in Thailand in 1987, and 670 opened in the first nine months of 1988 alone.

- Malaysia has 16 U.S. semiconductor companies and offers tax breaks and duty-free imports of equipment, materials, and technologies.

Table 1 summarizes all semiconductor facility plans for Asia known to Dataquest as of the beginning of this year.

Table 1

Asian Semiconductor Facilities
Known Plans for 1988–1996
(Exchange Rates: US$1 = ¥120, W680, Y3.73)

Company	Location	Cost (US$M)	Start Mfg.	Plant Type*	Initial Products	Wafer Size	Wafers/ Month**
			South Korea				
Daewoo	Guro	N/A	Q3/88	Fab	Zymos chip sets	4"	10,000
Goldstar #1	Woomyun	135.0	1988	Fab	CMOS memory	6"	18,000
Goldstar #2	Chongju	2,200#	Q4/90	Fab	1Mb DRAM,256K SRAM	6"	45,000
Goldstar #3	Chongju	above	1993	Fab	4Mb DRAM,1Mb SRAM	6"/8"	90,000
Goldstar #4	Chongju	above	1996	Fab	16Mb DRAM,4Mb SRAM	6"/8"	135,000
Hanil	N/A	7.0	1989	Fab	GaAs laser diodes	N/A	N/A
Hyundai #4	Ichon	N/A	Q1/90	Fab	1Mb DRAM	6"	40,000
Hyundai #5	Ichon	450.0	Q4/90	Fab	4Mb DRAM	6"	20,000
Sammi	N/A	7.0	1989	Fab	GaAs laser diodes	N/A	N/A
Samsung #3	Suwan	N/A	Q1/88	Fab	1Mb DRAM	6"	22,400
Samsung #4	Kiheung	N/A	Q1/89	Fab	1Mb DRAM	6"	18,000
Samsung #5	Kiheung	514.7	Q4/89	Fab	4Mb DRAM	6"	30,000
			Taiwan				
AMPI	Hsinchu	5.3	Q3/88	Fab	Power & consumer ICs	4"	8,000
Diodes Inc.	Taipei	N/A	1989	Fab	Diodes	N/A	N/A
HMC	N/A	N/A	Q4/89	Fab	Memory,telecom ICs	5"	30,000
Hualon	Hsinchu	200.0	Q3/88	Fab	Memory, consumer	5"	25,000
TSMC(ERSO)	Hsinchu	32.5	Q2/88	Fab	Memory, telecom ICs	6"	10,000
TSMC	Hsinchu	220.0	Q4/89	Fab	CMOS foundry	6"/8"	30,000
UMC(Phase I)	Hsinchu	140.0	Q1/89	Fab	Memory,MCU, graphics	6"	30,000
Vitelic	Hsinchu	80.0	Q3/90	Fab	Memory	6"	10,000
Winbond	Hsinchu	50.0	Q4/88	Fab	SRAM, ASIC, consumer, telecom	5"	20,000
			China				
Wuxi	Wuxi	N/A	1991	Fab	Integrated circuits	N/A	100MU/yr##
Motorola	Tianjin	N/A	1990	Fab	Discrete, ICs	6"	N/A
Philips	Shanghai	N/A	Q4/89	Fab	TV/VCR ICs	N/A	70MU/yr
Shanghai #17	Shanghai	N/A	Q3/88	Fab	Consumer	N/A	N/A
			Hong Kong				
Motorola	Hong Kong	50.0	Q3/89	A/T	Analog, memory, MPR, ASIC	N/A	N/A

(Continued)

Table 1 (Continued)

New Semiconductor Plants Planned for Asia, 1988–1996
(Exchange Rates: US$1 = ¥120, W 680, Y 3.73)

Company	Location	Cost (US$M)	Start Mfg.	Plant Type*	Initial Products	Wafer Size	Wafers/ Month**
			Singapore				
Chartered	Singapore	50.0	Q2/89	Fab	CMOS ASICs	6"	5,000
HP	Singapore	N/A	N/A	Fab	GaAs	N/A	N/A
Matsushita	Singapore	N/A	1988	A/T	N/A	N/A	N/A
NEC	Singapore	12.5	1989	A	256K/1Mb DRAM	N/A	1.5MU
					Linear	N/A	500KU##
			Malaysia				
Fujitsu	Kuala Lumpur	25.8	Q1/89	A/T	CMOS memory, logic and linear ICs	N/A	N/A
Hitachi	N/A	N/A	Q3/87	A	1Mb DRAM	N/A	10KU
Motorola	Seremban	48.0	Q3/88	Fab	Small signal trans.	N/A	N/A
			Thailand				
Shindengen	N/A	N/A	Q3/89	A/T	Car electronics	N/A	N/A
Sony	AMD Thai.	N/A	1989	Fab	Bipolar	N/A	3.0MU
Sony	Bangkok	21.7	Q3/90	Fab	Bipolar	N/A	10.0MU
			Australia				
AWA Ltd.	Sydney	52.0	Q1/89	Fab	CMOS ASIC	6"	N/A
Ramax	Melbourne	45.0	1989	Fab	Ferroelectric ICs	N/A	N/A
University of Adelaide	Adelaide	N/A	1988	R&D	GaAs	N/A	N/A

*Type of plant: Fab = fabrication, A = assembly, T = testing
**Total available capacity, not current capacity utilization
#$2.2 billion Goldstar investment will cover three new plants
##MU = million device units per month; KU = thousand device units per month
N/A = Not Available

Source: Dataquest
July 1989

JAPAN'S CONSISTENT CAPACITY EXPANSIONS

Compared with the United States, Japan has been very consistent about its additions of semiconductor fab capacity. Japan has brought up new production and pilot-based silicon fab lines at a rate of approximately 12 per year since 1984—and we believe that this rate will continue, at least through 1990. By comparison, U.S. fab additions fluctuated between 8 and 21 per year during the same time period. Dataquest believes that most new Japanese fabs that have or will come on-line during industry downturns begin production with a small fraction of the equipment that they will ultimately contain. The companies that own these fabs therefore are well-positioned to handle the next upturn by quickly adding equipment to their partially utilized floor space.

JAPANESE VERSUS U.S. FABS

The fab data base currently maintained by Dataquest's SEMS analysts reveals that the United States boasts 216 silicon-based wafer fabs compared with 168 in Japan. On the average, however, Japanese fabs are larger and newer. Although the average maximum wafer start capacity for U.S. companies is 16,000 wafers per month for production facilities and 4,000 per month for pilot lines, the comparable figures for Japan are 23,000 and 8,000, respectively. The average age for Japanese fabs is four years, compared with six years for U.S. fabs. On the average, Japanese fabs are running 5-inch wafers, while the average wafer size for U.S. fabs is 4 inches.

Japanese and U.S. fab capacities also differ in terms of both product and micron mix, as shown in Table 2.

Table 2

Comparison of U.S. and Japanese Fabs

	Differences in Product Mix				
Country	Memory	MPU	Logic	ASIC	Other
Japan	39%	7%	6%	14%	34%
United States	25%	14%	8%	26%	27%

	Differences in Micron Mix					
	≤1u	≤1.1-1.5u	≤1.6-2u	≤2.1-2.5u	≤2.6-3u	≥3u
Japan	22%	30%	28%	0	14%	5%
United States	17%	31%	19%	3%	13%	19%

Source: Dataquest
July 1989

Looking more closely at the Japanese fab data base, SEMS data show that 13 production and pilot-based silicon fabs went into operation in Japan during 1988. In 1989, 14 will go into production, and 12 more are expected to come on-line in 1990. Eight other gallium arsenide and R&D lines should come on-line between 1988 and 1990. Dataquest also knows of 13 more fab lines that are scheduled to go into production after 1990. Out of this activity, the following details emerge:

- Nine of the 13 production and pilot-based silicon fabs that began operations during 1988 produce advanced DRAMs and SRAMs.

- Ten of the 14 fabs begun during 1989 and 9 of the 12 during 1990 are also expected to produce advanced DRAMs and SRAMs.

- Approximately 75 percent of these new fabs will produce advanced 1Mb or 4Mb DRAMs and, with few exceptions, all will process linewidths at 1 micron or less on 6-inch or 8-inch wafers.

- The average wafer-start capacity for future DRAM production-based lines is 21,133 wafers per four-week period, while the average wafer-start capacity for future DRAM pilot lines is 8,500 wafers per four-week period.

JAPAN'S SHIFTING FAB STRATEGY

As interesting as these comparisons may be, SEMS analysts have uncovered a far more profound competitive trend in Japanese wafer fab production. Historically, an advanced fab in Japan has produced two generations of DRAMs. It has been logical to try to produce as many generations of a DRAM as possible from the same fab because DRAMs have represented the clear majority of Japanese production. Traditionally, these fabs have upgraded or replaced some of the installed equipment in order to produce the second DRAM generation through its die shrink. Dataquest now believes that more of Japan's new and future DRAM fabs will produce one, or perhaps one and a half, DRAM generations. Rather than retool existing fabs for next-generation DRAMs, we believe that Japanese suppliers will shift production down the "product food chain" in the following sequence: DRAMs/SRAMs—>gate arrays—>CBICs—>MCUs/MPUs—>opto devices—>standard logic—>analog—>power ICs—>discretes.

Dataquest already has observed the beginning of this movement toward single-generation DRAM fabs, with some companies bringing up dedicated 1Mb fab lines that are not expected to be upgraded to 4Mb DRAM production. Although 4Mb DRAMs have been sampled out of these 1Mb fabs, Dataquest has noted that, so far, all Japanese manufacturers have plans to do volume production in new, dedicated 4Mb lines. Factors that may influence this move toward a single-generation DRAM fab concept, with subsequent production of other types of products, include the following:

- The implementation of common "core" manufacturing processes for all product divisions—Under ideal conditions, this would require that only the mask set be changed for manufacturing a different product while using the same "core" process recipe.

- Conversion to 8-inch wafers for volume production of next-generation DRAMs--Most of the companies that do not adopt 8-inch production during the 4Mb generation will do so at the 16Mb level.

- Required purity improvements in DI water and gas-handling systems for next-generation DRAM manufacturing--The move to 4Mb production appears to require new fabs and support facilities as opposed to upgrading existing fabs. In turn, there is a chance that 16Mb production will be better addressed with new fabs and support facilities instead of upgraded 4Mb lines.

- The reduction of process capability overlap for semiconductor processing equipment when moving from one DRAM generation to the next--This is particularly true in regard to lithography limits.

  - New 4Mb fabs brought up on high numerical aperture g-line steppers could, at best, make the final die shrink of the 4Mb DRAM.

  - For new 4Mb fabs brought up on i-line steppers, this shift will mark the beginning of a rather short transition phase in Japan, most likely beginning and ending with the 4Mb DRAM.

FUTURE SHOCK

Not coincidentally, the trend toward shifting fab production down the product food chain comes at a time when Japan is making gains in ASICs, microcomponents, and other ICs for consumer, computer, and automotive applications. If Japan rapidly adopts the single-generation DRAM fab strategy, a large bubble of advanced and low-cost capacity would begin to move into ASIC and microcomponent production. The first such capacity bubble would begin to come in after the 1Mb production peak during 1992, and the second capacity bubble would begin to come in after the 4Mb production peak during 1995.

By 1992, Japanese companies should be enjoying the fruits of their current ASIC and microcomponent efforts that include many technology exchange agreements and joint development projects being conducted on- and offshore. At the same time, DRAM capacity that is very low in cost and advanced will become available to the Japanese. This equipment will be close to being written off the books and should already have provided a minimum of three good years of DRAM profits.

DATAQUEST CONCLUSIONS

At present, Dataquest foresees worldwide semiconductor capacity utilization levels remaining at or above 80 percent through 1993. However, there are some ominous signs that the industry could face an overcapacity situation in 1994. These signs include the following:

- Rest of World (ROW) markets are making enormous investments in semiconductor wafer fab facilities. Korean companies Goldstar, Hyundai, and Samsung all are adding 4Mb DRAM lines between 1989 and 1992 and expect to sample 16Mb DRAMs in 1993.

- In addition to the more visible "Four Tigers" of Asia (Hong Kong, Korea, Singapore, and Taiwan), the Southeast Asian nations of Indonesia, Malaysia, the Philippines, and Thailand are poised to be the next major wave of electronics producers. China and India may not be far behind.

- The forces of trade and end-user demand are requiring semiconductor companies to invest more heavily in producing where they do business. Regarding Japan, companies that would have been content to supply their world markets from Japan-based factories are announcing that they will expand capacity in other regions--particularly in Europe and the United States.

- In response to stronger competition from Korea and the United States in the memory market, it appears that Japan's changing fab strategy will shift future production capacity into nonmemory markets such as ASICs and microcomponents.

A final, although more speculative, caution comes in the form of past industry cycles. If the past serves as prologue, the industry's 10-year cycle of major booms and busts indicates that a serious recession might be due in 1994--just in time for much of the capacity additions that we foresee in the early 1990s to come up to full production. Like it or not, participation in the semiconductor industry has become an imperative for almost every world economy that seeks to be globally competitive in the 21st century. Before the economies of China, India, and Southeast Asia learn firsthand about industry cyclicality, the semiconductor market may yet be in for some heavy weather.

Michael J. Boss
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MOTOROLA AFFIRMS ITS COMMITMENT TO BROAD-BASED SUPPLY

INTRODUCTION

The year 1988 marked Motorola's sixtieth anniversary. Founded in September 1928 as the Galvin Manufacturing Corporation to produce battery eliminators, the company barely survived the stock market crash in 1929. Today, the company is an approximately $8 billion supplier of electronic equipment, systems, and components.

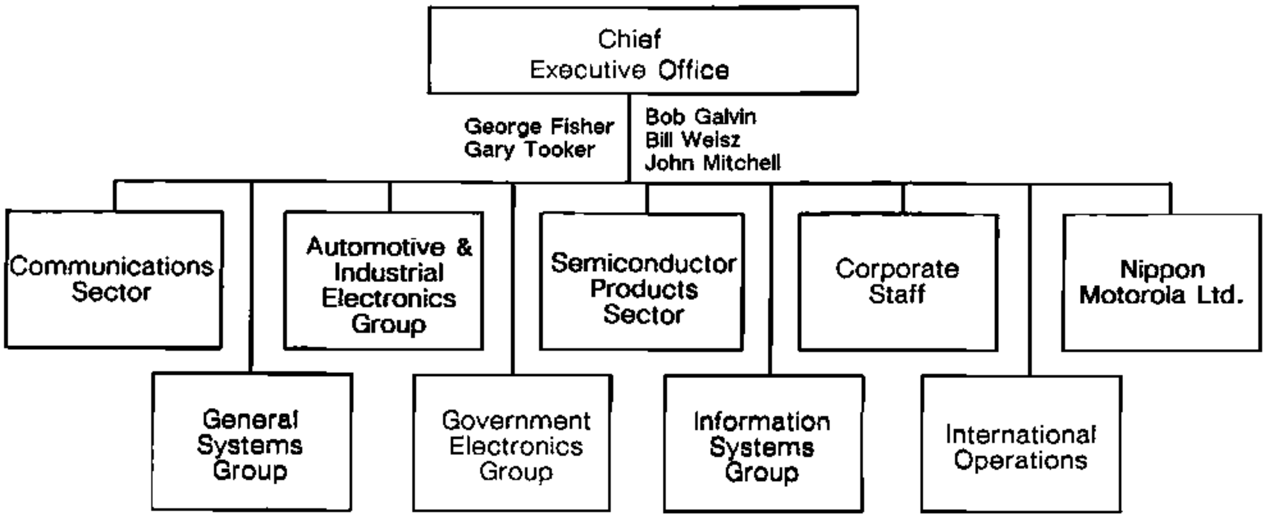
In an era of increasing specialization and niche-market-oriented companies, Motorola represents an unusual breed of U.S. semiconductor manufacturers. Motorola, the largest U.S. chipmaker, continues to be one of the few remaining broad-based semiconductor suppliers in the nation. The company considers its wide breadth of products to be critical to its semiconductor strategy and has charted a course that provides an extensive rather than an intensive product portfolio. This newsletter focuses on Motorola's broad-based supplier strategy, the challenges of maintaining this position in the future, and, more specifically, how the company's semiconductor operations are changing to meet these challenges.

MOTOROLA—THE COMPANY

In 1947, the company name was changed from Galvin Manufacturing Corporation to Motorola, the name of a car radio produced by Galvin Manufacturing. Corporate headquarters are located in Schaumburg, Illinois. Figure 1 details the company's organizational structure, and Table 1 shows Motorola's revenue by sector since 1980. It is interesting to see how consistent a percentage share of revenue has been represented by Motorola's two largest sectors, Communications and Semiconductors. The composition of Motorola's business generally can be characterized as balanced. Each business segment has experienced either strong or exceptional growth over the past five years, with the exception of the Information Systems business, where Motorola has apparently met with little success.

Figure 1

Motorola's Corporate Structure



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Source: Motorola Inc.

Table 1

Motorola's Revenue by Sector (1980-1988)

	1980	1981	1982	1983	1984
Communications	38.3%	40.4%	40.3%	37.4%	33.7%
Semiconductors	36.8%	35.8%	34.3%	37.2%	40.5%
General Systems	-	-	-	-	-
Information Systems	10.0%	11.5%	12.8%	11.9%	8.7%
Government Electronics	-	-	-	8.5%	8.0%
Other Products	16.9%	14.5%	14.9%	7.5%	12.6%
Adjustments	(2.0%)	(2.3%)	(2.3%)	(2.6%)	(3.4%)
Total Revenue (Millions of $)	$3,283	$3,570	$3,786	$4,328	$5,534

(Continued)

Table 1 (Continued)

Motorola's Revenue by Sector (1980–1988)

	1985	1986	1987	1988
Communications	37.0%	38.1%	36.6%	36.6%
Semiconductors	30.6%	30.7%	32.6%	33.2%
General Systems	-	-	11.9%	13.4%
Information Systems	7.9%	7.9%	7.8%	6.9%
Government Electronics	9.1%	8.9%	8.0%	7.9%
Other Products	18.3%	17.5%	6.2%	5.8%
Adjustments	(2.9%)	(3.1%)	(3.1%)	(3.7%)
Total Revenue (Millions of $)	$5,443	$5,888	$6,727*	$8,250

*1987 restated to show reclassification of products from Communications products to Other Products and General Systems products presented separately from Other Products

Source: Motorola Annual Reports

FINANCIAL PERFORMANCE

One way of attempting to assess Motorola's financial performance in relation to its industry peers is to compare the company's ratios of net income to sales and net income to shareholders' equity with those of its competitors (see Table 2). In the United States, however, from the point of view of size and scope of operations, only one other U.S. company, Texas Instruments (TI), has a profile that approximates Motorola's. In fact, Motorola's international competitors are typically much larger companies, frequently encompassing extensive nonelectronic businesses; therefore, relating these statistics to them is not helpful. However, NEC, although considerably larger than Motorola, is engaged primarily in the electronics businesses and so is included for the purposes of comparison. According to this data, Motorola has evidenced superior financial performance.

Table 2

Ratio of Net Income to Sales and Shareholders' Equity
Motorola, TI, and NEC
(1984–1988)

	1984	1985	1986	1987	1988	Average 1984-1988
Motorola Net Sales ($M)	$5,534	$5,443	$5,888	$6,727	$8,250	
Net Income as Percent of Sales	7.0%	1.3%	3.3%	4.6%	5.4%	4.4%
Net Income as Percent of Shareholders' Equity	17.0%	3.2%	7.0%	10.2%	13.2%	10.3%
TI Net Sales ($M)	$5,742	$4,925	$4,974	$5,595	$6,295	
Net Income as Percent of Sales	5.5%	(2.4%)	0.6%	5.7%	5.8%	3.3%
Net Income as Percent of Shareholders' Equity	20.5%	(8.3%)	1.7%	17.0%	16.3%	10.4%
NEC Net Sales* (¥B)	¥2,258	¥2,335	¥2,450	¥2,715	¥3,083	
Net Income as a Percent of Sales	3.0%	1.2%	0.6%	0.9%	2.1%	1.6%
Net Income as Percent of Shareholders' Equity	14.1%	5.5%	2.9%	4.3%	9.3%	7.2%

*NEC's fiscal year ends in March; therefore, in an effort to approximate the time frame for competitors' data, the 1984 column contains data for fiscal year 1985, the 1985 column contains fiscal year 1986 data, and so on.

Source: Motorola, TI, and NEC Annual Reports

SEMICONDUCTOR PRODUCTS SECTOR

Extensive Product Portfolio

Motorola offers one of the industry's broadest semiconductor product portfolios. A review of Motorola's product portfolio (see Table 3) shows that the company is manifestly strong in the areas of discrete devices, logic, and microcomponent products. It is investing to establish a future position in memory through a strategic alliance with Toshiba. Analog is another area where a strategy is being put in place to enhance the company's position and achieve higher penetration in Japan by targeting integrated services digital network (ISDN) and consumer markets.

Table 3

Motorola's Estimated Semiconductor Revenue and Ranking by Product Area (Millions of Dollars)

	1987 Rank	1988 Rank	1988 Revenue	Percent of Semiconductor Revenue	1987-1988 Revenue Percent Change	1987-1988 Industry Percent Change
Total Semiconductor	4	4	$3,035	100.0%	24.8%	31.9%
Integrated Circuits	5	7	$2,259	74.4%	28.7%	36.5%
Bipolar (Technology)	6	6	$ 435	14.3%	1.4%	9.2%
Digital Memory	9	9	$ 7	0.2%	(30.0%)	7.9%
Digital Logic	3	4	$ 428	14.1%	2.1%	9.4%
MOS (Technology)	6	7	$1,399	46.1%	41.7%	53.1%
Memory	16	12	$ 236	7.8%	17.4%	90.1%
Microcomponents	3	3	$ 699	23.0%	34.4%	42.7%
Logic	3	3	$ 464	15.3%	21.8%	28.2%
Analog	8	7	$ 425	14.0%	25.4%	15.3%
Total Discrete	2	2	$ 752	24.8%	15.3%	13.2%
Total Optoelectronic	20	20	$ 24	0.8%	0	25.4%

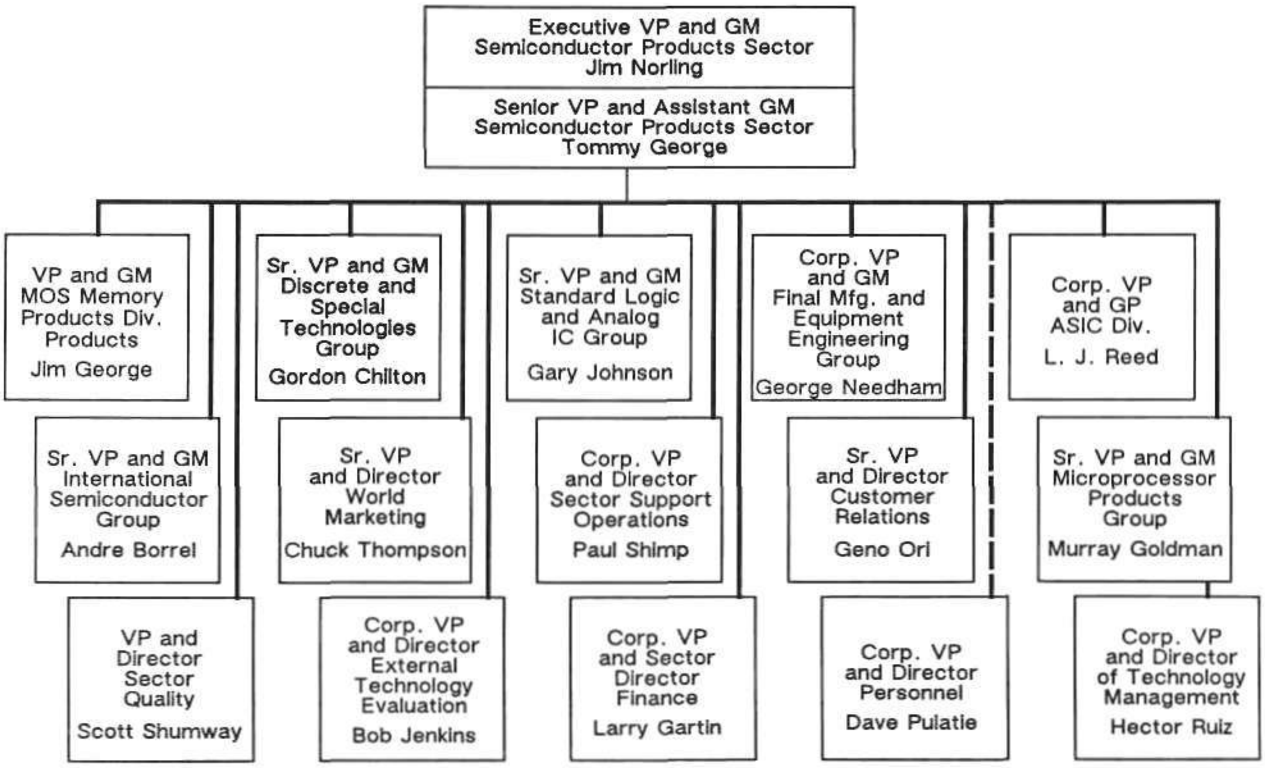
Source: Dataquest July 1989

Product Operations

Motorola's Semiconductor Products Sector, headquartered in Phoenix, Arizona, is organized as shown in Figure 2.

Figure 2

Motorola's Semiconductor Products Sector



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Source: Motorola Inc.

STRATEGIC GOALS

The cornerstone of Motorola's vision is providing total customer satisfaction. This newsletter focuses on the following areas that Dataquest considers to be essential in Motorola's strategy to achieve its goal of total customer satisfaction within the Semiconductor Products Sector:

- Service strategy
- Increasing end-use focus
- Reentry into the DRAM market
- Microcomponent strategy
- Continuing investment in process and product technology
- Globalization

Service Strategy

In Motorola's terms, customer service is the "third wave" in the semiconductor industry, which has progressed from a technology focus to manufacturing excellence to customer service. Three elements of the company's service strategy bear further inspection:

- Corporate program
- Connectivity
- Marketing structure

Corporate Program

Motorola's corporate program has taken a structured approach to service strategy. Its goal is to achieve economies of scale and share efficiencies with the customer.

In 1987, a task force of eight senior people was assembled for a three-month period of full-time concentration on recommendations for achievement of superior customer service. Based on approximately 40 interviews with customers and input from company employees, more than 50 recommendations were made.

Motorola has achieved substantial progress toward the implementation of these recommendations. Already, much more accurate customer delivery commitments have resulted from some portions of a demand-driven manufacturing system that was subsequently put in place. As Motorola addresses its channels-to-market strategy, just-in-time (JIT) manufacturing is a key element. The implementation of a successful JIT strategy could add as much as 13 to 15 percent to its profits, according to Motorola.

Connectivity

Motorola has invested $6 million to $7 million on new software communications systems to support a worldwide customer network. The following milestones have been reached to date:

- The Electronic Data Interchange program, started in 1978, now processes more than 1.5 million transactions weekly in host-to-host processing of daily orders; the system handles all distributors worldwide, plus 35 U.S. customers and 2 Japanese customers.

- Two years ago, Motorola moved to centralized tracking of its transaction processing through six regional locations, permitting a customer to call a toll-free number to reach his or her account representative, who has worldwide responsibility for the customer's company account at the regional office.

Marketing Structure

As befits the top U.S. semiconductor manufacturer, Motorola derives major strength from its worldwide marketing operations of a wide range of products. Motorola is able to serve its customers on a global basis in response to the changing environment because of the following:

- The company employs approximately 2,000 people in 80 sales offices worldwide, providing both sales and engineering support.
- With customers reducing their vendor bases, Motorola has an advantage in its breadth of product offerings. According to the company, all of its customers buy a range of its products.
- A worldwide distribution network is in place.
- Motorola has local design centers.
- The company's worldwide MIS system allows worldwide order entry and shipment.

Increasing End-Use Focus

With the rapidly evolving pace of technology and accelerating product life cycles, companies are being forced to respond to new markets more quickly. The need for closer customer-vendor relationships becomes more critical as a company plans to introduce products of a higher value-added nature. In this environment, a company can bring application-specific products to market by using better technology. We see this approach manifesting itself through several avenues in Motorola's case. These avenues include the following:

- CAD standards—Motorola will develop an integrated open-architecture CAD system and actively drive industry standards for CAD to accelerate availability.
- Cell-based design methodology—Motorola decided in 1988 not to operate a standard cell group as a standalone unit but rather to disperse this technology throughout the semiconductor sector to enable customers to get customized versions of standard products.
- Application-specific logic products (ASLPs)—One of Motorola's thrusts is to offer application-specific logic products, which are standard products directed at an end-use market. The company is witnessing phenomenal growth in this business, and its strategy depends on being close to the customer and providing a systems solution.

- Standard logic—Motorola proposes to base a standard logic line on its new ECLinPS and design an array that will provide sufficient functionality to form a core of standard logic functions. This approach will speed time to market, and Motorola plans to incorporate a high level of customer involvement in defining the family.

- Vertical integration—Motorola derives considerable synergy between semiconductors, its technology engine, and the other parts of its business in communications, computer, automotive, military, industrial, and consumer products. This gives the company a competitive advantage when providing end-user solutions.

- Marketing—Motorola's worldwide marketing organization is designated by end-use segment as well as by region, which the company believes is advantageous in providing solutions.

Reentry into the DRAM Market

The U.S.-Japan Semiconductor Trade Arrangement provided the necessary framework for Motorola to reconsider entering the memory market. The combination of internal Motorola programs, the Toshiba agreement, and the advent of Sematech will support its reentry into this market. Motorola considers its participation in this market to be of strategic importance. Although tough to operate in, the memory market's value is in driving both technology and manufacturing, as well as addressing a major deficiency in Motorola's product portfolio. Not only is this a difficult market from a competitive viewpoint, but also the sustained investment necessary to pursue a memory strategy is enormous. The risks associated with the increasing capital-intensiveness of leading-edge memory technology development are driving semiconductor manufacturers more and more toward alliances in order to share the costs and the risks involved. The technology road map shown in Table 4 indicates the lengthy lead times involved from commodity development start date to product introduction date.

Motorola/Toshiba Alliance Crucial

Motorola was once a significant participant in the memory market, consistently ranking among the top ten producers worldwide. Although Motorola withdrew from the DRAM market in early 1985, DRAMs remain the company's largest revenue-producing memory product, as Motorola packages and markets DRAM dice manufactured by Toshiba.

If being a major DRAM manufacturer (and making them in Japan) is important to maintain a place in the top echelons of the semiconductor business, Motorola may achieve this through its relationship with Toshiba. Through a joint venture with Toshiba (called Tohoku), Motorola has acquired memory technology to produce 256K, 1Mb, and 4Mb DRAMs and 256K and 1Mb SRAMs. Currently, Motorola is manufacturing 1Mb DRAMs in Japan and East Kilbride, Scotland, and has successfully transferred the process to MOS 6 in Mesa, Arizona. Toshiba, in turn, is to receive 8-, 16- and 32-bit microprocessor technology from Motorola.

Table 4

MOS Memory Technology Road Map

Technology	Commodity Product SRAM	Commodity Product DRAM	Commodity Product Introduction Date	Commodity Development Start Date
1.8u-2.0u	64K	256K	1982-1983	1978
1.2u	256K	1Mb	1985-1986	1980
0.8u	1Mb	4Mb	1988-1989	1983
0.5u	4Mb	16Mb	1991-1992	1986
0.35u	16Mb	64Mb	1994-1995	1989
0.25u	64Mb	256Mb	1997-1998	1992
0.15u	256Mb	1GB	2000-2001	1995

Source: Motorola Inc.

Microcomponents: a Pivotal Strategy

The microcomponents market segment is extremely important for Motorola; the company has consistently ranked as the number three microcomponents supplier worldwide. The need for considerable resources required to maintain a leading position in this segment leads the company to reason that only the strong will survive.

Microprocessors

Companies that base their equipment on a particular microprocessor architecture are concerned about the long-term viability of the supplier and the future availability of hardware and software support and upgrades. The escalating costs for users in maintaining their software investments make the choice of a microprocessor architecture a very strategic one.

The strategic importance of Motorola's microprocessor product line is highlighted by the fact that it is this line that Motorola traded in exchange for Toshiba's DRAM technology. Microprocessors are being targeted by the Japanese, who, rather than be dependent on U.S. technology, are developing their own proprietary microprocessors to support their growing electronics systems' needs. High-end microprocessors represent one of the few remaining strongholds in component technology for U.S. manufacturers. How Motorola manages its relationship with Toshiba without jeopardizing its prominent position in this market will be key to the companies deriving mutual benefit from the agreement.

Today's performance-driven microprocessor market obliges Motorola to continue to introduce enhanced next-generation products that remain upwardly compatible with their microprocessor architecture. It requires large ongoing investment to maintain one's presence at the forefront of this market. Motorola has consistently shown its willingness to do this, as is evidenced by the following:

- A product such as the 68020 is used as a CMOS process driver. Currently, Motorola's production fab in Austin, Texas, MOS 8, is running CMOS at 1-, 1.2-, and 1.5-micron linewidths.
- Currently, the 68020 is offered in speed grades from 12.5 to 33 MHz.
- More integration is on the 68030 microprocessor, which incorporates such functions as a paged memory management unit (MMU), an instruction cache, and data cache on-chip.
- Introduction of the next-generation 68040 is anticipated in late 1989.
- A 50-MHz version of the 68030 has been announced with volume production in the third quarter.
- Upward compatibility saves the customer's investment in software.

Performance: the Driving Factor

The quest for ever-increasing performance has spawned another performance solution in the market: RISC microprocessors. Currently, the RISC market is in its immature phase and is crowded with contenders, many of which are targeting Motorola's traditional area of strength, the workstation market. It is a battle that Motorola cannot afford to lose. The company has responded by doing the following:

- Unveiling its contender in the 32-bit RISC microprocessor market, the 88000, in 1988
- Making an agreement with Data General to create an ECL version of the 88000 microprocessor that the companies claim will achieve 100-mips performance by 1991 and bring mainframe computer power to users at personal computer price/performance levels
- Spending in the neighborhood of $20 million to date in software support alone to launch this architecture
- Promoting the creation of a consortium of computer hardware and software vendors, the 88open Consortium, to drive standards for the 88000 architecture prior to implementation (This is expected to be a more cost-effective approach as vendors share technological innovations and save porting and R&D costs.)

Digital Signal Processing (DSP)

Motorola's DSP device was defined by the company's experience with its communications sector. As people relate more and more to computers, significant benefits derive from the incorporation of advanced DSP devices. The selection of Motorola's 56001 DSP chip in Steve Job's NeXT computer was significant. The NeXT computer system also incorporated Motorola's 25-MHz 68030 and the 68882 floating-point coprocessor. The DSP device was designed directly onto the motherboard to provide sound and speech synthesis, a high-speed modem, facsimile transmission, array processing, voice mail, and numeric processing functions.

Because of the dynamic range of the 56001's 24-bit architecture, the device also is particularly suited to high-end audio applications. The DSP market is an emerging area for Motorola. Its design-win in the NeXT computer could prove significant to the company in establishing a place in a DSP market currently dominated by TI.

Microcontrollers

Microcontrollers claim a larger share of microcomponent revenue than microprocessors. (Microcontrollers accounted for approximately 36 percent of the $7 billion microcomponents market worldwide in 1988.) This market is extremely cost-sensitive, however, and nowhere more so than the automotive and consumer segments, where the company achieves its highest volumes. Motorola has successfully used the lessons it learned from manufacturing in Japan to achieve significant improvement in domestic manufacturing efficiency over the past three years. It is a testimony to Motorola's manufacturing capability and status as a low-cost manufacturer that it competes successfully with its Japanese competitors. Motorola is the leading worldwide supplier of 8-bit microcontrollers. In Japan, the company is expanding aggressively into the automotive and consumer segments. Motorola has announced the industry's first 32-bit microcontroller, the 68332, which is expected to be available in production quantities in the fourth quarter of this year.

A close working relationship with the customer is also called for in this area, and Motorola caters to customers' needs by providing product proliferation geared toward specific applications. In the future, Motorola expects to place more emphasis on ASIC-like microcontrollers, at least for products at the high end of the spectrum. By modularizing its designs, the company will be able to speed up its design turnaround time.

Continuing Investments in Process and Product Technology

Good products and successful marketing, although important to winning in the marketplace, cannot sustain long-lasting success without state-of-the-art technology. But state-of-the-art technology carries a heavy price tag. In spreading its technology investments over a broad product spectrum, Motorola faces significant capital investment costs. Participation in both leading-edge commodity products such as high-density DRAMs and higher-margin businesses such as microcomponents and ASICs will be more difficult to support. For the first time since 1980, Motorola's semiconductor capital spending exceeded the industry average in 1987 and is expected to grow to $490 million in 1989 (exclusive of expenditures on the joint venture with Toshiba). Table 5 provides capital and R&D expenditures as a percentage of semiconductor revenue.

Table 5

Motorola's Capital and R&D Spending (Millions of Dollars) (1984–1988)

	1984	1985	1986	1987	1988
Total Semiconductor Revenue	$2,319	$1,830	$2,025	$2,430	$3,035
Semiconductor Capital Spending	$ 412	$ 330	$ 250	$ 350	$ 430
Capital Spending as a Percent of Revenue	17.8%	18.0%	12.3%	14.4%	14.2%
Semiconductor R&D Spending	$ 176	$ 192	$ 199	$ 207	$ 225
R&D as a Percent of Revenue	7.6%	10.5%	9.8%	8.5%	7.4%

Source: Dataquest
July 1989

Process Technology

Motorola divides its process technology development into three major development groups:

- Semiconductor Research and Development Lab (SRDL) focuses on discrete power circuits, non-VLSI analog technology, basic process technology, and packaging.
- Bipolar Technology Center (BTC) focuses on high-performance bipolar, mixed-technology BiCMOS, and process module development.
  - As an evolving technology, BiCMOS can be approached either as uncompromised bipolar technology with CMOS integrated to serve high-performance requirements or as uncompromised CMOS technology integrating bipolar technology to serve high-density needs. In order to eventually merge the two approaches, certain commonality is being built in, such as common layout rules when possible, common lithography, and common metallurgy where possible.
- Advanced Products Research and Development Lab (APRDL) focuses on CMOS and process module development.

Product Technology

Although this newsletter focuses on certain product areas critical to the realization of Motorola's strategic aims, the company has been active in other product segments. Highlights in a number of these segments are summarized in the following paragraphs.

Memory. Increasing priority is being given to the company's fast SRAM family as can be seen from the following:

- In 1987, a family of high-performance CMOS SRAMs was added to Motorola's product line, including 4K, 8K, 16K, and 64K densities with speeds up to 25ns.
- Product announcements expected in the near future will introduce a 16Kx4, 32Kx8, 256Kx1, and 64Kx4 with access times of 20 to 25ns.
- By 1990, Motorola expects to introduce a 1Mb SRAM and bring a 256K SRAM in BiCMOS to market also.

Although current BiCMOS designs are at 1.5 microns over the next 18 months, in terms of production, Motorola hopes to bypass the 1.5-micron level and move directly to production at 1 micron. Motorola plans to use this process technology in product applications such as high-density, fast gate arrays; standard cells; next-generation microprocessors; and custom designs.

Motorola has been withdrawing gradually from the nonvolatile memory market but is expected to preserve EPROM capability to support manufacturing technology and microcomponent and ASIC product offerings.

Discrete. In a market dominated by Japanese companies, Motorola has long been the leading discrete supplier and was dislodged from the number one position only in 1987 by Toshiba. Within the discrete market, Motorola holds strong positions in all the major product areas. Leadership in discretes is driven by Motorola's major business sector, communications. Synergy between these products and microprocessors, for instance, allows the sale of a microprocessor to bring in as much revenue in discretes as it does in microprocessors. Motorola will continue to invest in the discrete product area and, despite the complex problems associated with managing a very broad product line with thousands of package types, will continue to maintain its diverse product portfolio.

Serving the broad range of discrete markets also requires a broad range of capabilities including advanced submicron technology for such products as radio frequency (RF) semiconductors and power MOS devices plus leading-edge manufacturing technologies for mature, high-volume semiconductors. These new technologies often combine discrete and integrated circuit technologies to provide new products containing substantial added value.

Logic. In the standard logic arena, Motorola is a major market participant, ranking among the top five suppliers in both bipolar and CMOS in 1988. In that year, the company introduced a new ECL flagship product based on a gate array with gate delays of less than 150ps using its new ECLinPS process (for ECL in picoseconds). Motorola offers products in the CMOS metal gate and high-speed families. The company entered the FACT CMOS market in late 1988 through a licensing agreement with National. Motorola will also second-source Toshiba's new 74BC BiCMOS family, entering the market in mid-1989. The company will continue to expand its product portfolio aggressively for its FACT and ECLinPS families. Motorola is committed to gaining significant market share as a supplier of FAST and expects to remain price competitive in this arena.

ASICs. In addition to working closely with key customers to offer high-performance system solutions in both CMOS and bipolar technologies, a key feature of Motorola's strategy in the ASIC market is to drive industry standards for CAD actively in order to accelerate the availability and utility of open-architecture alternatives.

Motorola is the leading supplier of ECL gate arrays to the merchant market. Motorola's current process, MCA III, has yielded 2,200-gate and 10,000-gate ECL arrays featuring typical delays in the range of 100 to 150ps. In 1989, the company will augment this product family with introductions of devices with 2,600 and 7,600 gates. The next generation of bipolar arrays, the MCA IV, will be fabricated in 1-micron technology with four layers of metal, offering gate densities of 15,000, 25,000, and 50,000. Other architectural features will include a BiCMOS process option, built-in testability, and 512-lead tape automated bonding (TAB) packaging as well as pin grid array (PGA) packaging.

In the arena of CMOS process technology, Motorola has introduced a family of high-density CMOS gate arrays manufactured in a 1.2-micron process. The HDC Series utilizes a sea-of-gates architecture and ranges in gate count from approximately 3,000 to 105,000 gates. The next generation of these CMOS arrays will be manufactured in a 0.8-micron process and will offer a configurable base array option. High I/O applications are driving the migration to CMOS TAB packaging.

Analog. Although a large number of companies are participating in the analog market, few are as broad-line a supplier as Motorola. Motorola's analog business comprises the following eight major segments:

- Op amps
- Interface
- Power
- Telecommunications
- High frequency
- Automotive
- Special products
- Magnetics

The product areas that Motorola will emphasize in the future are:

- Op amps, where a very high performance market has developed (The company's strong position in op amps results from the technology pull of mobile communications and cellular radio.)
- Power devices, where motor control technology is evolving and smart power and BiCMOS will become increasingly dominant
- Telecommunications, where Motorola benefits from synergy with its communications sector and boasts many proprietary products
- High frequency, where Motorola will target the consumer market and invest in the technology and design tools to deliver mixed-signal technology

- Automotive, where Motorola is already a leading supplier in a market that is expected to grow rapidly in the future

- Special products, where Motorola offers custom, high-performance products using advanced processes, tools, and mixed-signal testing

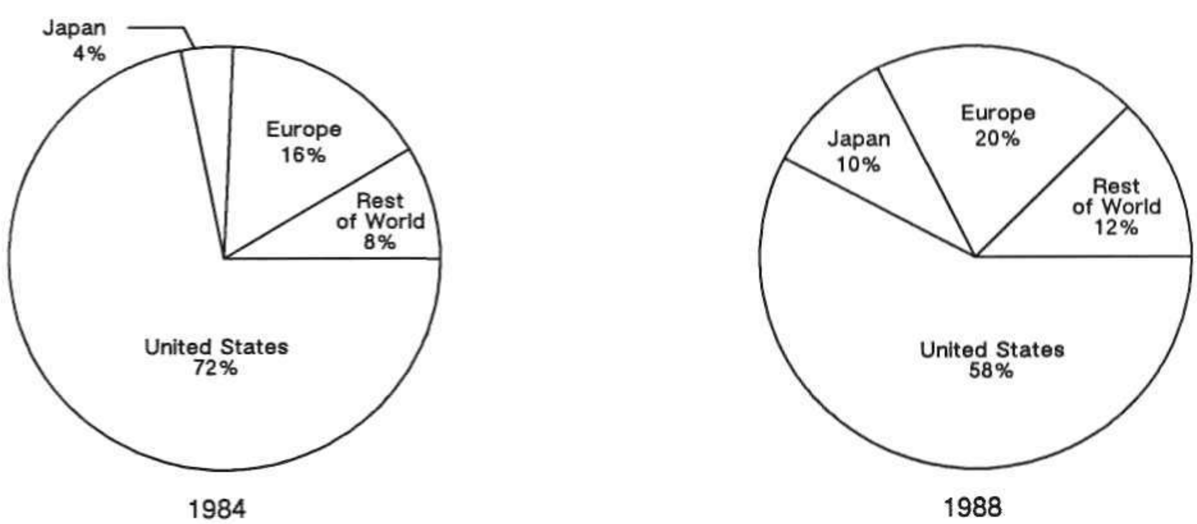
Globalization

Today's competitive environment is dictating that being a world-class manufacturer requires global manufacturing capability. In the future, it will become more difficult to enter a market without having established local manufacturing capabilities or access to them through an alliance.

Motorola is becoming an increasingly international company. Figure 3 shows that the percentage of the company's nondomestic revenue has increased significantly from 1984 to 1988. Motorola has extensive regional manufacturing capabilities. The company operates wafer fabrication facilities in six non-U.S. locations worldwide: Aizu and Sendai, Japan; East Kilbride, Scotland; Toulouse, France; Guadalajara, Mexico; and Seramban, Malaysia. In addition, it has several assembly facilities and five nondomestic design centers.

Figure 3

Motorola's Regional Market Share Based on Semiconductor Revenue (1984 and 1988)



0004375-3

Source: Dataquest
July 1989

However, it is also instructive to look at the profile in Table 6 of the regional composition of Motorola's revenue in comparison with the other leading semiconductor manufacturers. Considered from a home-base viewpoint, Motorola is most comparable to Toshiba. Whereas Toshiba may target Europe for increased penetration, the table shows that Motorola should concentrate its resources on further penetrating the Japanese market. Currently, Motorola is expending a great deal of effort and expense in building an infrastructure in Japan in order to expand market share there. Motorola has recently opened a large new administrative headquarters building in Tokyo at considerable expense and has instituted a graduate program to recruit new hires from colleges, just as its Japanese counterparts are so adept at doing. In 1988, Motorola recorded a 70 percent revenue increase in Japan. This is an indicator that the company's pursuit of success in Japan is starting to pay off. Growth in this market, the largest semiconductor market in the world, is essential in order for Motorola to remain a broad-based supplier.

Table 6

1988 Estimated Semiconductor Revenue of Top Five Semiconductor Companies by Geographic Region (Millions of Dollars)

	U.S. Revenue	Percent of Semiconductor Revenue	Rank	Japanese Revenue	Percent of Semiconductor Revenue	Rank
NEC	$ 525	11.6%	8	$3,287	72.3%	1
Toshiba	$ 968	22.0%	4	$2,496	56.8%	2
Hitachi	$ 457	13.0%	9	$2,470	70.5%	3
Motorola	$1,770	58.3%	1	$ 290	9.6%	13
TI	$1,186	43.3%	3	$ 599	21.8%	10

	European Revenue	Percent of Semiconductor Revenue	Rank	ROW Revenue	Percent of Semiconductor Revenue	Rank	Worldwide Total Semiconductor Revenue
NEC	$387	8.5%	8	$344	7.6%	4	$4,543
Toshiba	$390	8.9%	9	$541	12.3%	1	$4,395
Hitachi	$246	7.0%	11	$333	9.5%	5	$3,506
Motorola	$616	20.3%	4	$359	11.8%	3	$3,035
TI	$647	23.6%	3	$309	11.3%	7	$2,741

Source: Dataquest
July 1989

Silicon Harbor Project

Table 6 pointed to ROW as a region where Motorola has achieved considerable success. This is not by accident—it is, rather, the result of concerted ongoing investments in the Asia/Pacific region. In 1988, Motorola broke ground for its Silicon Harbor project, a multistory semiconductor design and manufacturing facility on a 7.2-acre site near Hong Kong's Tolo Harbor. This represents the first major project in Hong Kong by a foreign-owned semiconductor company. It will serve both as Motorola's Asia/Pacific headquarters and as its springboard for penetration into the Chinese market. The Silicon Harbor facility will produce bipolar and MOS application-specific standard products, custom design, ASICs, and microprocessors. The project is estimated to cost several hundred million Hong Kong dollars and will help Motorola consolidate its position as a serious competitor in Asia, where it already is making significant headway.

Asia/Pacific

Currently in the Asia/Pacific region, Motorola has established 10 regional sales offices in seven countries and eight test/manufacturing plants in six countries. The company's two design centers located in Hong Kong and Taipei focus on local market needs.

The personal communications field is expected to represent a major opportunity in the 1990s, and Motorola is already strong in mobile radio communications equipment and cordless telephone ICs. With its expertise in both semiconductors and systems, as well as local presence, Motorola would appear to be well positioned for making further inroads in this product area in the future.

China

In China, Motorola will spend "multi-tens of millions of dollars," according to Chairman Robert Galvin, on two factories in Tianjian, the closest port to the capital city of Beijing. The plants will supply semiconductors and mobile radio equipment for the Chinese market and for export.

CHALLENGES

A major challenge facing Motorola is whether or not the company can be successful in all business areas, and, if not, where it will focus its resources.

Motorola has many strengths; the company is confident that it has both the vision and the resources to continue to position itself as a broad-based supplier of semiconductors. The company competes worldwide directly against its Japanese competitors in semiconductors and communications. Motorola enjoys strong customer relationships, a strong sales organization, good technical skills, and a solid balance sheet. Nevertheless, the challenges Motorola faces are many.

To support its contention of being a broad-based supplier, it was necessary that Motorola deal with the gaping hole that memories represented in its product portfolio. Trading members of its popular microcomponent product line with Toshiba for memory technology is not without risk, but the payoff is substantial if Motorola executes well. Motorola's intentions with respect to the memory market must, however, be long-term and committed, despite the vagaries of the market.

The need for increased presence in Japan has also been identified. An aggressive stance with respect to other world regions is meeting with success, but success in the world's largest semiconductor market is critical in order for Motorola to continue to rank among the top-tier semiconductor suppliers worldwide.

Although a relatively small market at this time, the programmable logic device (PLD) market is expected to grow rapidly and will affect the gate array business, where Motorola is very prominent. So although Motorola at this time has no presence in the PLD business, it is conceivable that the company may await standardization in the market before making a move, which Dataquest believes could possibly involve entering the market through an acquisition.

DATAQUEST CONCLUSIONS

Motorola believes that it has both the vision and the resources to position itself as a broad-based supplier. The scope of the company's activities leads Dataquest to conclude that it is committed to being a broad-based supplier by adhering to its policies of ensuring the timely availability of the requisite technologies, delivering superior service to clients (an area within the company's control), and working closely with key customers to better understand their system needs in guiding the company's standard and custom product development efforts. In more established and mature product areas, Motorola concentrates on ongoing cost savings in order to achieve a competitive edge and greater market penetration. Motorola recognizes that it cannot single-handedly support all the activities that it wishes to pursue and so has an aggressive strategic alliance policy with other semiconductor companies and with customers as a means of complementing its own capabilities.

However, the true test of how the sector is measuring up will be evidenced by performance according to these two major sector imperatives, which place Motorola's semiconductor strategy within the context of the overall company:

- Consistent, superior financial performance

- Market share gains worldwide

How successful Motorola is in these quantifiable objectives will determine how well the company is accomplishing its goals and its financial ability to pursue its ambitious strategy. It will take all the skill of Motorola's stable management to handle the company's resources for the best return on investment.

Patricia Galligan

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Source Code: K4

	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
WORLD MKT	8953	11106	14098	14801	15231	19537	28825	24341	30834	38251	50859	57213
U.S. COS	4953	6431	8062	7601	7829	9565	13948	11051	12809	14930	18586	19978
%	55.3%	57.9%	57.2%	51.4%	51.4%	49.0%	48.4%	45.4%	41.5%	39.0%	36.5%	34.9%
JAPANESE COS	2540	2861	3856	5252	5375	7583	11456	10144	14160	18450	25942	29809
%	28.4%	25.8%	27.4%	35.5%	35.3%	38.8%	39.7%	41.7%	45.9%	48.2%	51.0%	52.1%
EUROPEAN COS	1442	1789	2145	1903	1929	2215	3183	2851	3443	4200	4917	5443
%	16.1%	16.1%	15.2%	12.9%	12.7%	11.3%	11.0%	11.7%	11.2%	11.0%	9.7%	9.5%
ASIAN COS	18	25	35	45	98	174	238	295	422	671	1414	1983
%	0.2%	0.2%	0.2%	0.3%	0.6%	0.9%	0.8%	1.2%	1.4%	1.8%	2.8%	3.5%

Source: Dataquest

	1990
WORLD MKT	58414
U.S. COS	21307
%	36.5%
JAPANESE COS	28905
%	49.5%
EUROPEAN COS	6155
%	10.5%
ASIAN COS	2047
%	3.5%

Source: Dataq

TOTSEMI

Table 1
FINAL 1984 MARKET SHARE ANALYSIS
Total Semiconductor
(Millions of Dollars)

15-Feb-91

Company Base	North America	Japan	Europe	Asia/ Pacific/ ROW	World
	Regional Market				
North America	$9,767	$926	$2,548	$707	$13,948
Percent of Regional Market	75%	11%	52%	32%	48%
Percent of Company Sales	70%	7%	18%	5%	100%
Japan	$2,065	$7,787	$597	$1,007	$11,456
Percent of Regional Market	16%	89%	12%	46%	40%
Percent of Company Sales	18%	68%	5%	9%	100%
Europe	$1,157	$56	$1,717	$253	$3,183
Percent of Regional Market	9%	1%	35%	12%	11%
Percent of Company Sales	36%	2%	54%	8%	100%
Asia/Pacific	$17	$5	$2	$214	$238
Percent of Regional Market	0%	0%	0%	10%	1%
Percent of Company Sales	7%	2%	1%	90%	100%
World	$13,006	$8,774	$4,864	$2,181	$28,825
Percent of Regional Market	100%	100%	100%	100%	100%
Percent of Company Sales	45%	30%	17%	8%	100%

Source: Dataquest
May 1990

TOTSEM1

Table 1
FINAL 1985 MARKET SHARE ANALYSIS
Total Semiconductor
(Millions of Dollars)

15-Feb-91

Company Base	North America	Japan	Europe	Asia/ Pacific/ ROW	World
	Regional Market				
North America	$7,380	$695	$2,428	$548	$11,051
Percent of Regional Market	78%	9%	51%	28%	45%
Percent of Company Sales	67%	6%	22%	5%	100%
Japan	$1,279	$7,387	$549	$929	$10,144
Percent of Regional Market	14%	91%	11%	47%	42%
Percent of Company Sales	13%	73%	5%	9%	100%
Europe	$731	$60	$1,806	$254	$2,851
Percent of Regional Market	8%	1%	38%	13%	12%
Percent of Company Sales	26%	2%	63%	9%	100%
Asia/Pacific	$28	$7	$12	$248	$295
Percent of Regional Market	0%	0%	0%	13%	1%
Percent of Company Sales	9%	2%	4%	84%	100%
World	$9,418	$8,149	$4,795	$1,979	$24,341
Percent of Regional Market	100%	100%	100%	100%	100%
Percent of Company Sales	39%	33%	20%	8%	100%

Source: Dataquest
May 1990

3

TOTSEMI

Table 1
FINAL 1986 MARKET SHARE ANALYSIS
Total Semiconductor
(Millions of Dollars)

15-Feb-91

Company Base	North America	Japan	Europe	Asia/ Pacific/ ROW	World
	Regional Market				
North America	$8,566	$933	$2,580	$730	$12,809
Percent of Regional Market	79%	8%	46%	29%	42%
Percent of Company Sales	67%	7%	20%	6%	100%
Japan	$1,434	$10,851	$715	$1,160	$14,160
Percent of Regional Market	13%	92%	13%	46%	46%
Percent of Company Sales	10%	77%	5%	8%	100%
Europe	$751	$63	$2,282	$347	$3,443
Percent of Regional Market	7%	1%	41%	14%	11%
Percent of Company Sales	22%	2%	66%	10%	100%
Asia/Pacific	$93	$8	$10	$311	$422
Percent of Regional Market	1%	0%	0%	12%	1%
Percent of Company Sales	22%	2%	2%	74%	100%
World	$10,844	$11,855	$5,587	$2,548	$30,834
Percent of Regional Market	100%	100%	100%	100%	100%
Percent of Company Sales	35%	38%	18%	8%	100%

Source: Dataquest
May 1990

Table 1
FINAL 1988 MARKET SHARE ANALYSIS
Total Semiconductor
(Millions of Dollars)

15-Feb-91

Company Base	North America	Japan	Europe	Asia/Pacific/ROW	World
	Regional Market				
North America	$11,146	$1,965	$3,664	$1,811	$18,586
Percent of Regional Market	70%	9%	43%	31%	37%
Percent of Company Sales	60%	11%	20%	10%	100%
Japan	$3,277	$18,630	$1,466	$2,569	$25,942
Percent of Regional Market	21%	90%	17%	45%	51%
Percent of Company Sales	13%	72%	6%	10%	100%
Europe	$1,006	$115	$3,196	$600	$4,917
Percent of Regional Market	6%	1%	38%	10%	10%
Percent of Company Sales	20%	2%	65%	12%	100%
Asia/Pacific	$415	$62	$165	$772	$1,414
Percent of Regional Market	3%	0%	2%	13%	3%
Percent of Company Sales	29%	4%	12%	55%	100%
World	$15,844	$20,772	$8,491	$5,752	$50,859
Percent of Regional Market	100%	100%	100%	100%	100%
Percent of Company Sales	31%	41%	17%	11%	100%

Source: Dataquest
May 1990

TOTSEMI

Table 1
FINAL 1987 MARKET SHARE ANALYSIS
Total Semiconductor
(Millions of Dollars)

15-Feb-91

Company Base	North America	Japan	Europe	Asia/Pacific/ROW	World
	Regional Market				
North America	$9,671	$1,249	$2,845	$1,165	$14,930
Percent of Regional Market	75%	8%	44%	29%	39%
Percent of Company Sales	65%	8%	19%	8%	100%
Japan	$2,110	$13,588	$900	$1,852	$18,450
Percent of Regional Market	16%	91%	14%	47%	48%
Percent of Company Sales	11%	74%	5%	10%	100%
Europe	$913	$70	$2,714	$503	$4,200
Percent of Regional Market	7%	0%	42%	13%	11%
Percent of Company Sales	22%	2%	65%	12%	100%
Asia/Pacific	$164	$20	$39	$448	$671
Percent of Regional Market	1%	0%	1%	11%	2%
Percent of Company Sales	24%	3%	6%	67%	100%
World	$12,858	$14,927	$6,498	$3,968	$38,251
Percent of Regional Market	100%	100%	100%	100%	100%
Percent of Company Sales	34%	39%	17%	10%	100%

Source: Dataquest
May 1990

Table 1
FINAL 1989 MARKET SHARE ANALYSIS
Total Semiconductor
(Millions of U.S. Dollars)

Company Base	Regional Market: North America	Japan	Europe	Asia/ Pacific/ ROW	Worldwide
North American Companies	$11,715	$2,162	$4,032	$2,069	$19,978
Percent of Regional Market	65%	9%	41%	32%	35%
Percent of Company Sales	59%	11%	20%	10%	100%
Japanese Companies	$4,574	$20,628	$1,924	$2,683	$29,809
Percent of Regional Market	26%	90%	20%	41%	52%
Percent of Company Sales	15%	69%	7%	9%	100%
European Companies	$1,025	$130	$3,562	$726	$5,443
Percent of Regional Market	6%	<1%	37%	11%	10%
Percent of Company Sales	19%	2%	66%	13%	100%
Asia/Pacific Companies	$623	$77	$237	$1,046	$1,983
Percent of Regional Market	3%	<1%	2%	16%	3%
Percent of Company Sales	31%	4%	12%	53%	100%
Worldwide	$17,937	$22,997	$9,755	$6,524	$57,213
Percent of Regional Market	100%	100%	100%	100%	100%
Percent of Company Sales	31%	40%	17%	12%	100%

Source: Dataquest
May 1990

Table 1
FINAL 1990 MARKET SHARE ANALYSIS
Total Semiconductor
(Millions of U.S. Dollars)

Company Base	North America	Japan	Europe	Asia/Pacific/ROW	Worldwide
	Regional Market				
North American Companies	$11,942	$2,402	$4,492	$2,701	$21,537
Percent of Regional Market	69%	11%	42%	35%	37%
Percent of Company Sales	55%	11%	21%	13%	100%
Japanese Companies	$3,777	$19,825	$1,814	$2,961	$28,377
Percent of Regional Market	22%	88%	17%	39%	49%
Percent of Company Sales	13%	70%	6%	11%	100%
European Companies	$1,074	$164	$4,117	$851	$6,206
Percent of Regional Market	6%	<1%	39%	11%	11%
Percent of Company Sales	17%	3%	66%	14%	100%
Asia/Pacific Companies	$593	$117	$238	$1,157	$2,105
Percent of Regional Market	3%	<1%	2%	15%	3%
Percent of Company Sales	28%	6%	11%	55%	100%
Worldwide	$17,386	$22,508	$10,661	$7,670	$58,225
Percent of Regional Market	100%	100%	100%	100%	100%
Percent of Company Sales	30%	39%	18%	13%	100%

Source: Dataquest
May 1990

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Research Bulletin

TI ALLIANCE TARGETS HDTV: THE CONSUMER MARKET BECKONS

INTRODUCTION

Anyone who has read a newspaper, not to mention a trade press periodical, in the last year must know by now that the advent of improved-definition TV (IDTV), enhanced-definition TV (EDTV), and high-definition TV (HDTV) has refocused U.S. interest on an estimated $170 billion 1988 consumer market largely lost to the Japanese. Texas Instruments (TI) has announced an important next step in its overall strategy to penetrate the advanced vision systems (AVS) segment of the semiconductor consumer market, which it believes will be the system's technology driver of the 1990s.

THE AGREEMENT

Texas Instruments Japan, Limited, has signed an agreement with Nippon Hoso Kyokai (NHK), the Japan Broadcast Corporation, for its MUSE or "Hi-vision" advanced TV receiver technology. Transferring NHK's technology to TI will involve an explanation of the decoder, transfer of the transistor-level logic circuit diagrams and enabling memory codes, and review of the circuits comprising the MUSE system. TI will use this acquired system knowledge to develop chip sets to participate in these three HDTV markets based on different standards: MUSE in Japan, HD-MAC in Europe, and the future U.S. HDTV standard. Financial details of the agreement were not revealed, although it was made known that TI will pay for the technology transfer.

TI'S STRATEGY

Why is TI pursuing this market? The significance of HDTV cuts across many of TI's strategic thrusts, particularly as it concerns the following:

- TI's identity as a Japanese supplier
- The importance of the consumer electronics market
- The technology benefits of HDTV to TI's semiconductor business

In 1988, TI's semiconductor sales to the Japanese market totaled approximately $600 million, an increase over the previous year of almost 50 percent. TI is now the 10th largest Japanese semiconductor supplier and the largest U.S. participant in the Japanese semiconductor market. Given TI's identity as a Japanese company, its thrust into the AVS market is headed by Masa Hayashida of TI Japan, who will be supported by TI's worldwide resources. From a trade perspective, TI's approach answers one of the product deficiencies often cited by Japanese companies as reasons for not purchasing more U.S. semiconductors—that U.S. semiconductor companies do not produce the consumer devices they need.

Although it may not be associated readily with the consumer electronics market, TI recognizes that this is a market it cannot afford to ignore—for many reasons. Aside from the sheer dollar volume represented by this market, the economies of scale associated with it are in keeping with TI's role as a commodity semiconductor manufacturer. As Pat Weber, president of TI's Semiconductor Group, noted during the company's recent Technology Trends Seminar, "The consumer market hones TI's quality and cost performance." From the standpoint of specific semiconductor product areas, TI believes that the consumer market will be increasingly important to success in analog ICs. Even in a product area like DRAMs, so closely identified with the data processing market,

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TI believes that noncomputer applications will account for approximately 40 percent of the memory market by the mid-1990s.

THE RIPPLE EFFECT

Aside from its importance to consumer electronics, HDTV, in TI's words, "will emerge as a large market with broad implications for the entire electronics industry." Dataquest believes, as does TI, that HDTV will permeate other industries such as training and simulation, films, medicine, telecommunications, and the military/aerospace industry. Through this agreement, TI will also pursue complementary AVS segments including high-performance audio systems, video camcorders, advanced cameras, and video tape recorders. With roughly one-third of its business coming from the defense industry, a market currently in decline, addressing these other markets takes on added significance for TI.

Also significant are the spin-off semiconductor technologies that will be driven by HDTV—technologies that address a spectrum of TI's product offerings in memories, microcomponents, DSP, and analog. Examples of such products include 200- to 300-MBps processors, video processor chips, A/D converters, video frame storage devices, fiber-optic transceivers, and advanced compression and processing algorithms for signal processing.

Perhaps most important to TI's position in data processing is its vision of HDTV as the vehicle by which computers will become pervasive in the home—integrating telecommunications, entertainment, and data processing. This convergence would represent a quantum leap over the personal/home computer as we understand it today. With the market opportunities that this would create, it is not surprising that TI seems to be positioning itself to be a major supplier of components to the PC market. Evidence of this can be gleaned from current activities at TI, which include:

- The development of software automation tools aimed at creation of object-oriented data bases
- The relationship between TI's concept of hypermedia as the new user-interface paradigm and its efforts in high-performance PC chip sets, graphics chip sets, DSP, and speech synthesis
- Its entry into 32-bit RISC microprocessors through an alliance with Sun Microsystems
- TI's contract from the Defense Advanced Research Procurement Agency (DARPA) to develop a semiconductor process technology for display generation

DATAQUEST CONCLUSIONS

Dataquest believes that HDTV and the intermediate markets of IDTV and EDTV represent a significant opportunity for U.S. companies. More is at stake than the considerable revenue associated with the consumer TV market. Although the ancillary market opportunities are strategically important, the long-term implications for the mainstay of the U.S. electronics market—data processing—makes U.S. participation in this market a strategic imperative. These issues are discussed in detail in a Dataquest report entitled *High-Definition Video Technology: The Collision between Television and Computers*.

Michael Boss
Patricia Galligan

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Research Newsletter

QUARTERLY SEMICONDUCTOR COMPANY FINANCIAL RESULTS

INTRODUCTION

Dataquest regularly reports on semiconductor company financial results through its weekly on-line news service, *The DQ Monday Report*. As a service to the Products, Markets, and Technology segment binderholders, a summary of this information is provided herein.

Table 1 summarizes the net sales and income disclosures from selected semiconductor companies based on data from quarterly report periods that ended during the May through July time frame. This information is compared with the 1988 May through July time frame and is provided in millions of dollars. Table 2 provides a similar summary for fiscal year revenue and income for applicable

TABLE 1
Quarterly Financial Summaries for Selected Semiconductor Companies (Millions of Dollars)

Company	End of Quarter	Quarter Revenue	Percent Change*	Quarter Income	Percent Change*
Adaptec	(6/30, Q1)	$ 23.2	65%	$ 2.0	581%
AMD	(6/25, Q2)	$ 274.9	(11%)	$ 12.1	(54%)
Altera	(6/30, Q2)	$ 14.5	57%	$ 2.6	42%
Burr-Brown	(7/1, Q2)	$ 44.1	(4%)	$ 2.1	(32%)
Chips & Technologies	(6/30, Q4)	$ 61.8	43%	$ 10.1	60%
Cirrus Logic	(6/30, Q1)	$ 14.8	142%	$ 2.5	3,748%
Cypress	(7/3, Q2)	$ 50.6	58%	$ 7.6	62%
Intel	(7/1, Q2)	$ 747.3	3%	$ 99.3	(24%)
Linear Tech.	(7/2, Q4)	$ 17.7	21%	$ 2.4	12%
IDT	(7/2, Q1)	$ 51.6	19%	$ 5.2	2%
Logic Devices	(6/30, Q2)	$ 4.0	140%	$ 0.8	241%
LSI Logic	(7/2, Q2)	$ 140.9	52%	$ 4.5	(38%)
Maxim Integrated Products	(6/30, Q4)	$ 11.7	39%	$ 1.5	23%
Motorola	(6/30, Q2)	$2,385.0	14%	$154.0	28%
National Semiconductor	(5/28, Q4)	$ 419.1	**	$ 77.1	244%
Texas Instruments	(6/30, Q2)	$1,563.5	**	$106.1	16%
Weitek Corporation	(7/1, Q2)	$ 11.5	37%	$ 1.6	90%
Western Digital	(6/30, Q4)	$ 243.5	12%	$ 4.3	(707%)
VLSI Technology	(7/2, Q2)	$ 70.7	32%	$ 0.7	(76%)
ZyMOS Corporation	(6/30, Q2)	$ 8.5	68%	($ 0.3)	N/M

*Compared with corresponding period a year ago
**Negligible change, less than 1 percent
N/M = Not Meaningful

Source: Company Literature

SIS Newsletters 1989 Executive Issues

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TABLE 2
Fiscal Year Financial Summaries for Selected Semiconductor Companies (Millions of Dollars)

Company	Fiscal Year Revenue	Percent Change*	Fiscal Year Income	Percent Change*
Chips & Technologies	$ 217.6	54%	$33.0	49%
Linear Technology	$ 64.7	26%	$ 8.9	**
Maxim Integrated Products	$ 42.1	49%	$ 5.5	55%
National Semiconductor	$1,647.9	15%	($23.2)	N/M
Western Digital	$ 992.1	29%	$58.7	3%

*Compared with corresponding period a year ago
**Negligible change, less than 1 percent N/M = Not Meaningful

Source: Company Literature

companies. Descriptive summaries of quarterly performance highlights for the companies listed follow these tables.

ADAPTEC, INC.

Adaptec announced its second quarter of record revenue. According to the company's CFO, Paul G. Hansen, Adaptec has been experiencing increasing shipments of its SCSI products, as well as improved manufacturing efficiencies at the recently established Singapore facility. The company anticipates a continuing trend of increasing revenue and profitability. Adaptec's cash balance and line of credit will provide the company with sufficient resources to fund ongoing expansion programs during the second quarter.

ADVANCED MICRO DEVICES, INC.

Although Advanced Micro Devices (AMD) reported financial results that showed an improvement over its first quarter results, sales and income were hit quite hard when compared with the same quarter a year ago. AMD's chairman and CEO, W.J. Sanders III, noted that the company shipped 80286 microprocessors in record volumes. Demand for programmable logic devices (PLDs) was recovering, but EPROM shipments, although up, were under considerable price pressure. Mr. Sanders said that AMD would continue to manage its business very closely, especially given the expectation that the company would see flat revenue for the rest of the year.

ALTERA CORPORATION

Results for Altera's second quarter included a nonrecurring charge of $300,000 associated with restructuring of the company's facilities leases. These results marked Altera's 10th consecutive quarter of record profits. Company chairman and CEO, Rodney Smith, stated that the overall order rate was strong throughout the quarter.

BURR-BROWN CORPORATION

The company attributed its decline in earnings to the rapid dollar appreciation during the quarter. With almost 70 percent of its business overseas, Burr-Brown tends to be very sensitive to currency shifts. If currency effects were eliminated, the company would have experienced sales growth of approximately 3 percent over the second quarter of 1988. Orders booked in the quarter were down approximately 9 percent from the first quarter and 7 percent from the corresponding quarter a year ago.

CHIPS & TECHNOLOGIES, INC.

In fiscal 1989, Chips & Technologies (C&T) invested more than 15 percent of sales in product design and development. According to the company, its CHIPset solutions are being well accepted by the PC AT market segment. Record bookings during the fourth quarter mean that the company is entering its new fiscal year with a very healthy backlog. C&T president Gordon A. Campbell said that based on a strong product portfolio, a substantial order backlog, and a high level of design-in activity, the company is optimistic about its growth prospects during the upcoming fiscal year.

CIRRUS LOGIC, INC.

Michael L. Hackworth, president and CEO of Cirrus Logic, said that this quarter's sales were higher than expected because of a more rapid phase-in of extra production capacity. Overall, incoming orders continued to be strong both in the company's display graphics and mass storage businesses, and progress in the Japanese marketplace was encouraging.

CYPRESS SEMICONDUCTOR CORPORATION

The company achieved its 22nd consecutive quarter of increasing revenue. Cypress Semiconductor believes that an ongoing ability to bring new products to market will be helpful in maintaining the company's revenue growth in the upcoming quarters. Fifteen new products were introduced in the second quarter. Cypress also set another bookings record for the quarter.

INTEL CORPORATION

Income for the second quarter, although up slightly from the first quarter of 1989, was down significantly from the same quarter a year ago. This quarter's results include a $17 million charge to cover costs associated with the planned closing in 1990 of an old wafer fabrication facility in Livermore, California. Intel will try to place the 400 employees affected by the closure in other company plants. According to Intel, second quarter orders were higher than those in the first quarter, with a book-to-bill ratio slightly above 1:0. New orders for advanced microprocessors and 1Mb EPROMs were strong. Intel employees will receive cash bonuses totaling $14 million for the first half of fiscal 1989.

LINEAR TECHNOLOGY CORPORATION

Although the company recorded a 26 percent increase in sales for fiscal 1989, net income was down slightly from the previous year. However, during 1988, the company benefited by a $2 million tax net operating loss carryforward, so on a comparative basis (exclusive of the tax benefits) income for fiscal 1989 increased 29 percent over the prior year. Linear Technology increased its international sales presence by adding personnel to existing offices in addition to opening two new offices in the Far East. At the same time, the company announced approval by its Board of Directors of a company stock repurchase plan that is intended to offset dilution in share ownership resulting from employee stock option and stock purchase plans.

INTEGRATED DEVICE TECHNOLOGY, INC.

Integrated Device Technology (IDT) announced record sales in its first quarter. The company described itself as cautiously optimistic, and demand for its products is such that it is continuing to ramp-up production at a moderate rate. IDT expects to continue to grow in the current quarter.

LOGIC DEVICES, INC.

The company reported record net sales and income for its second fiscal quarter. However, company president Bill Volz cautioned that should the current softness continue, third quarter results would not be able to sustain such growth rates. Second-quarter results mark the 15th consecutive quarter of profitability for the company, which supplies SRAMs, DSP devices, and math coprocessors.

LSI LOGIC CORPORATION

According to Wilfred J. Corrigan, chairman and CEO of LSI Logic, earnings did not meet expectations in the second quarter because total revenue grew more moderately than anticipated. Consequently, factory utilization was lower than expected. The company did, however, set a record in new orders. In response to a more cautious business outlook among its customers, Mr. Corrigan said that LSI Logic would be controlling costs closely.

MAXIM INTEGRATED PRODUCTS, INC.

Maxim reported record revenue for its fourth fiscal quarter, which ended in June. According to the company, its fourth-quarter bookings substantially exceeded both third-quarter bookings and fourth-quarter shipments. Jack Gifford, president and CEO, stated that increasing demand for the company's new products in all major world regions contributed to Maxim's continued growth.

MOTOROLA INC.

Motorola posted record results for its second quarter, although margins declined in the communications and semiconductor sectors. Sales for the semiconductor products sector grew 9 percent, new orders rose 11 percent, and backlog increased. However, George Fisher, president and CEO, said that because of competitive pricing in discrete and standard logic products and increased R&D expenditure, operating profits were flat. Orders increased in all major market regions, led by Asia/Pacific's continued growth in the consumer, communications, and personal computer industries. The computer, industrial, and military segments were slightly higher in orders, while automotive, consumer, and distribution orders declined.

NATIONAL SEMICONDUCTOR CORPORATION

National Semiconductor Corporation released fourth quarter and fiscal year 1989 results from continuing operations this week. Results from fiscal 1989 and 1988 have been restated to reflect the sales of National Advanced Systems (NAS) and Datachecker Systems. For the quarter that ended May 28, National's revenue decreased slightly, to $419.1 million, over fourth quarter a year ago. Income of $77.1 million showed a marked improvement over the previous year, recording an increase of 244 percent. These results include a post-tax gain of approximately $175 million from the sale of NAS, which offset operating losses of almost $98 million in the quarter. (This is inclusive of a one-time restructuring charge of approximately $45 million related to the consolidation of manufacturing capacity.) The company reported a net loss for fiscal year 1989 of $23.2 million on revenue of $1.6 billion as compared with income of $62.7 million from fiscal year 1988 revenue of $1.4 billion. National's president and CEO, Charles Sporck, commented that the company saw marked improvement in the fourth quarter, and this improvement in performance is expected to continue into first quarter 1990. The company should return to profitability in the second quarter of fiscal 1990.

TEXAS INSTRUMENTS, INC.

Company revenue for the quarter essentially was unchanged compared with the same quarter a year ago. Semiconductor sales by Texas Instruments (TI) were up slightly over last year, but increases in semiconductor memory sales were essentially offset by weakness in demand for bipolar products and the effect of currency changes. TI's orders of $1.3 billion for the second quarter were down 5 percent over the same period last year and down 9 percent in semiconductors. Results for the quarter also included royalty income of $63 million from patent license agreements. President and CEO Jerry Junkins stated that, in response to what TI views as a period of slower growth in its major markets, the company would continue tight control of operating expenses and reduction of product costs while maintaining a high level of R&D to strengthen the company's technology base and deliver new products.

VLSI TECHNOLOGY, INC.

Although VLSI Technology's reported net income of $705,000 represents a marked improvement over the loss of $6.2 million reported in the first quarter, these results still were affected by the company's efforts to recover from the last quarter's problems concerning the delay of the San Antonio, Texas, fab's production schedule and capacity constraints. However, VLSI achieved record levels of new bookings, which means the company is entering its third quarter with a strong backlog. According to the company, order strength was broadly based across virtually all product lines and geographical markets, and the company's overall business outlook remains quite good.

WEITEK CORPORATION

Weitek reported record sales and income in its second fiscal quarter, which ended July 1. Company president Arthur Collmeyer attributes Weitek's strong financial performance to its success in the ultrahigh-performance numeric processing business, in which the company specializes.

WESTERN DIGITAL CORPORATION

Roger W. Johnson, chairman, president, and CEO of Western Digital, characterized the company's fiscal year revenue as essentially flat, attributing this to slower growth rates in the PC industry and several major internal product and technology transitions. Mr. Johnson stated that overall results were adversely affected by the unprofitable performance of the integrated systems line and, to a lesser extent, the disk drive line. Mr. Johnson also noted, however, that a combination of cost improvement measures, along with increased orders for core logic chip sets, should result in improved performance of the integrated systems product line.

ZYMOS CORPORATION

A company spokesperson attributed the second quarter net loss to the cost of developing, producing, and introducing new products. The net loss of $324,000, although down significantly from a $476,000 loss for the second quarter of 1988, was up from first quarter 1989's loss of approximately $188,000. However, having achieved operating profitability over the past two quarters, the company is making progress and anticipates a strong second half of the year.

Patricia Galligan

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Research *Bulletin*

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FOR SILICON VALLEY FABS, THE QUAKE WAS A HICCUP

SUMMARY

Dataquest clients in Europe and Asia recently witnessed scenes of shocking devastation in the wake of the earthquake that struck Northern California on Tuesday, October 17. Many of our clients are wondering what effect the quake had on Silicon Valley chipmakers. Dataquest analysts have been in touch with a number of semiconductor suppliers in the San Francisco Bay Area and are pleased to report that for the most part, it is "business as usual" in the Silicon Valley.

ASSESSING THE DAMAGE

Tuesday's earthquake, which registered 7.1 on the Richter scale, certainly was the cause of a great deal of personal tragedy—the horror of which has been well documented by the international press. It must be remembered, however, that the worst of the quake damage was fairly localized. Silicon Valley chipmakers (and many of their major systems customers) have the good fortune of being located in areas less affected by the quake, such as San Jose, Santa Clara, and Sunnyvale. Based on conversations with our semiconductor manufacturing clients, Dataquest analysts report the following:

- Silicon Valley wafer fabs received little or no structural damage. Temporary losses of power caused the cancellation of production shifts immediately following the earthquake. As far as we know, all local manufacturers were back to full production schedules as of Thursday, October 19.

- Some semiconductor suppliers reported damage to pipes conveying gases and chemicals. National Semiconductor, for example, was forced to make immediate repairs to a waste treatment plant. No significant leaks were otherwise reported.

- As one might imagine, the earthquake created some yield problems for in-process wafers. In some cases, companies scrapped boats of wafers. The net effect on production, according to local chip manufacturers, should not result in lead time problems or order cancellations. Despite the disruption to production shifts, most sales and administration staff were back at their offices the day after the quake. The power outages and disruptions to communications that continue to plague other areas affected by the quake have spared Silicon Valley.

- One problem that is affecting almost all Silicon Valley companies is the ability of their employees to get to work. Portions of several major arteries into the area from outlying communities were damaged. The closing of some Bay Area schools, although temporary, also caused working parents to miss time from their jobs in order to arrange for child care. In addition, employees residing in some of the hardest-hit areas sustained damage to their homes. In communities such as Los Gatos and Santa Cruz, some residences were completely destroyed. It is estimated that up to 10,000 people are homeless in the Santa Cruz area, less than one hour's commute time from Silicon Valley. The effects of these dislocations on the personal lives of a number of Silicon Valley workers may linger for some time.

SOME EQUIPMENT COMPANIES ARE HARDER HIT

The damage assessments reported from electronic equipment manufacturers in the Bay Area are fairly consistent with those from their semiconductor vendors. There are some exceptions, however. According to a report in The Wall Street Journal (Thursday, October 19), Hewlett-Packard sustained damage estimated in millions of dollars and will experience a "minimal suspension" of manufacturing activity for an indefinite period. Flooding caused by broken water pipes closed IBM's storage device plant in San Jose. Apple Computer received damage to a building in Cupertino that was formerly owned by Four Phase. For the most part, however, a return to full production by local manufacturers typically was expressed in terms of days.

THE WAKE OF THE QUAKE

For clients unfamiliar with the San Francisco Bay region, of which the Silicon Valley is a part, the pattern of destruction caused by the second-strongest earthquake in the area's history may seem arbitrary. It is not, however, only a matter of randomness that Silicon Valley was less affected than San Francisco, which is farther away from the quake's epicenter. For one thing, buildings constructed in the Silicon Valley typically are newer than those in San Francisco and were built to conform to stringent codes regarding earthquake safety. As stated by a report from the Santa Clara County Manufacturing Group, released on October 19, "...our industry sustained relatively minor damage due to the newness of our facilities, the fact that many of our building and chemical areas have been reinforced for earthquakes, and because our companies do extensive training for their emergency response teams."

MORE THAN MEETS THE EYE

The extent to which the Silicon Valley was spared the fate of harder-hit areas of Northern California can be appreciated from damage estimates that just now are being reported. While these estimates vary from $5 billion to $10 billion, the estimated damage to Santa Clara County (the home of Silicon Valley) currently has been placed at about $220 million—with a good portion of this estimate reflecting the extensive damage in the town of Los Gatos.

Although reports from major Silicon Valley chipmakers have been positive thus far, one wonders if an uglier reality lurks below their surface. While the possible long-term effects of the quake are difficult for us to speculate on, the fact remains that the Silicon Valley's chipmaking foundation rests on seismically unstable soil. The thought of sensitive wafer fab equipment such as CVD furnaces, steppers, and ion implantation machines being shaken around during the earthquake and its numerous aftershocks conjures up the possibility that local fabs may not yet have achieved a complete return to prequake yields.

DATAQUEST CONCLUSIONS: AN ARGUMENT FOR DECENTRALIZATION

The October 17 earthquake occurred in the middle of Dataquest's annual Semiconductor Industry Conference, which was held in Monterey, California—a location closer to the quake's epicenter than San Francisco. For our clients, this conference was surely one to remember, and Dataquest is grateful that they suffered nothing beyond anxiety. Ironically, the quake underscored our conference theme of "globalization." Consider the example of National Semiconductor: with only 8 of its 23 worldwide manufacturing operations located in the Silicon Valley, a less fortunate outcome of the quake would not necessarily have been disastrous for its clients. With more semiconductor suppliers placing production closer to the regions they serve, damage to any given facility can be countered by shifting capacity to another. This flexibility should be a comforting thought to semiconductor users. After all, uncertainty is not just a fact of life for those of us living in the shadow of a killer quake.

Michael J. Boss

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PMT Executive Memo

BELOW THE ICEBERG'S TIP: THE LOSS OF DOMESTICALLY OWNED SILICON WAFER SUPPLY

SUMMARY

In the U.S. semiconductor market, much of the editorial energies of 1988 have been spent over the issues of DRAM availability and the dependence of U.S. systems manufacturers on a handful of key Japanese vendors. Sermons warning of the dangers of this dependency have been delivered from a number of pulpits: the press, the Defense Science Board, Sematech, the Semiconductor Industry Association, and the American Electronics Association, not to mention the less publicized misgivings of some U.S. electronics companies.

As an admonitory example of the dangers of market share erosion, however, the state of domestic DRAM supply may be just the tip of a larger, more ominous, technology iceberg. During the final months of 1988, two announcements were made that portend a major change in the regional ownership of the merchant silicon and epitaxial wafer market. The first announcement, made in November 1988, was that Monsanto Company had agreed to sell its silicon operations (the Monsanto Electronic Materials Company) to Huels AG of West Germany. The second announcement, made less than a month later, was that Osaka Titanium Company, Ltd. (OTC) of Japan had entered into negotiations to purchase the semiconductor materials division of Cincinnati Milacron, one of the largest suppliers of epitaxial wafers in the United States.

This newsletter, the first in an ongoing series of editorial pieces designed exclusively for subscribers to the Products, Markets and Technology (PMT) segment of Dataquest's Semiconductor Industry Service (SIS), offers some analysis on the current state of domestic silicon wafer supply in light of the Monsanto and Cincinnati Milacron announcements.

LOSING MARKET SHARE

The impact of both the Monsanto and Cincinnati Milacron acquisitions on the regional composition of silicon wafer supply ownership is illustrated in Table 1. Based on 1987 market analysis by Dataquest's Semiconductor Equipment and Materials Service (SEMS), the market share of U.S.-owned merchant silicon wafer companies will drop to 2 percent worldwide—with a mere 8 percent of the domestic market—if the two acquisitions are approved.

Table 1

Shifts in Market Shares of Regionally Owned Merchant Silicon and Epitaxial Wafer Companies

	1987 Actual Share	With Monsanto Acquisition	With Cincinnati Milacron Acquisition
World Market Share			
Japanese Companies	70%	70%	72%
European Companies	16%	26%	26%
U.S. Companies	14%	4%	2%
United States Market Share			
Japanese Companies	32%	32%	40%
European Companies	23%	52%	52%
U.S. Companies	45%	16%	8%

Source: Dataquest
February 1989

WHO'S LEFT?

With the acquisition of Monsanto' and Cincinnati Milacron's wafer divisions, silicon production by U.S.-owned merchant suppliers will drop below the level of captive silicon production in the United States. This will leave eight merchant suppliers under U.S. ownership: Crysteco, Epitaxy, Inc., General Instruments Power Semiconductor Division, M/A-COM Semiconductor Products, Pensilco, Recticon, Spire Corp., and Virginia Semiconductor. These companies, with 1987 world sales ranging from $1.0 million to $9.5 million, are small, niche-oriented market participants. In addition to these, four captive silicon producers—AT&T, IBM, Motorola, and Texas Instruments—have internal silicon operations to supply some portion of their own requirements.

DEEP-POCKET REQUIREMENTS

Looking at the market share ranking of merchant silicon wafer suppliers in the Table 2, it becomes apparent that all of the major merchant silicon companies in the world today have large corporate parents. This type of relationship provides a cash flow buffer against downturns in the business cycle as well as a source of funding for new facilities and capacity expansions. In today's business environment, it is not clear that a standalone entrepreneurial silicon operation could compete and survive against the major silicon suppliers with their deep-pocket parents.

Table 2

Top Five Merchant Silicon Suppliers after the Monsanto/Cincinnati Milacron Acquisitions Based on 1987 Worldwide Revenue (Millions of Dollars)

Ranking			1987 Sales
			Reflecting
Before	After	Company	Acquisition
1	1	Shin-Etsu Handotai	$484.7
3	2	Osaka Titanium Co.	$259.5
2	3	Mitsubishi Metal	$265.3
8	4	Huels AG	$248.0
4	5	Wacker	$214.8

Source: Dataquest
February 1989

Both Monsanto and Cincinnati Milacron's wafer divisions were part of larger, diversified businesses whose funding and strategic vision could extend beyond the current business cycle. The fact that they are being sold by their larger parent companies is a repetition of an increasingly familiar refrain in U.S. business. Rather than emulating the vertical integration and divisional synergies of their international competitors, U.S. companies seem more driven than ever to divest themselves of businesses that are peripheral to the markets they dominate, or that do not have the kind of immediate growth potential that will appeal to investors.

Positioned as a major manufacturer of robots and metrology and inspection systems for industrial automation applications, Cincinnati Milacron may have asked itself if owning an epitaxial wafer division made sense. Positioned as a supplier of key materials, OTC may have asked the same question. The difference in the two answers has some disturbing long-term consequences for the U.S. semiconductor industry, itself a supplier of strategic components. The absence of large, U.S. companies with a long-term strategic commitment to the critical materials requirements of the domestic chip industry creates a dependency on offshore supply that should give cause for concern.

STRATEGIC IMPLICATIONS

Recognition of the strategic importance of domestically owned merchant silicon wafer production, whatever its merits as a business venture, may have some impact on the successful conclusion of the Monsanto and Cincinnati Milacron deals. One of the concerns of the current DRAM situation has been that U.S. computer companies may not be able to rely on their Japanese suppliers, also computer manufacturers, to share their most advanced IC technology. The same argument can certainly be applied to the basic materials that enable production, regardless of the offshore origin of the supplier.

In light of this, the foreign acquisitions of the leading U.S. silicon wafer manufacturer (Monsanto Electronic Materials Company) and one of the largest epitaxial wafer producers (Cincinnati Milacron's epi wafer division) may encounter a brick wall in the form of the recently passed Omnibus Trade Bill. The trade bill amends Title VII of the Defense Production Act of 1950, allowing the president of the United States to block a foreign acquisition if it is determined, upon investigation, that U.S. national security is compromised.

DATAQUEST CONCLUSIONS

In early November, Dataquest analysts spent two days in research visits with corporate and product management at Motorola Inc. Part of one day was spent at Motorola's new MOS 6 fab, which will bring up the 1Mb DRAM process gained from the company's technology agreement with Toshiba. Although excited about the prospects of stepping back into the DRAM business, Motorola representatives expressed concern over yet another issue of dependency: In order to bring the Toshiba process up at MOS 6, Motorola has had to use materials and equipment from Japanese suppliers. Even with its own captive silicon operations, recent events in the merchant silicon wafer market have, no doubt, given Motorola something else to worry over.

There is, however, a big difference between the loss of domestic supply versus the loss of domestically owned suppliers in a key materials area. The difference apparently has not been lost on the Departments of Defense and Commerce of the U.S. government—as of this writing, a governmental task force has recommended to the president that Huels AG be allowed to go through with its acquisition of Monsanto's Electronic Materials Company. The rationale: Since no viable alternative exists in the form of a domestic interest in the company, a foreign owner would at least inject needed capital into the operation, thus preserving it as a domestically based source of production. U.S. semiconductor manufacturers, in light of their renewed commitment to regaining technological leadership through consortia efforts such as Sematech, must now give serious consideration to whether this is assurance enough for them.

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PMT Executive Memo

THE NEC/INTEL JUDGEMENT: WHAT DOES IT MEAN?

SUMMARY

At the end of a bout of courtroom pugilistics, such as we observed in the NEC/Intel trial, one looks for the court to raise the gloved hand of a contestant and declare, "The Winner." In reality, however, understanding just what was won and by whom may not be so straightforward—and in the case of the court's decision on the NEC/Intel copyright infringement case, both sides have declared victories! Let's take a closer look at the implications of Judge William Gray's recent decision for both the litigants and the industry.

At first glance, NEC's declaration of victory seems the more credible. Since the beginning of the trial, NEC had claimed that it merely needed to win one of the many issues before the court (copyrightability of microcode, infringement, Intel's forfeiture of copyright, and the status of the V20/30 as "improvements" over the μPD 8086/88), while Intel needed to win on all. As it turns out, NEC scored on both the forfeiture and infringement issues.

But what has NEC actually "won?" To be sure, a legal cloud has been lifted from its V20 and V30 microprocessors. Although the V30 has been designed into some laptop PC models, both the V20 and V30, along with their Intel counterparts, have now been eclipsed technologically. Well before Judge Gray's decision, NEC had introduced a "hardwired" version of the V30, the V33, which in addition to bypassing the need for microcode, significantly outperforms the older V30 device. It is unlikely, therefore, that the recent court decision will dramatically increase the number of V20/30 devices sold in the United States. NEC does, however, believe that its courtroom victory will make its V40 and V50 microprocessors more appealing design-in choices for embedded control applications. Here NEC can compete with Intel without being hobbled by the onus of litigation.

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NEC's victory on the issue of infringement creates another possibility: the pursuit of its countersuit against Intel on the charges of anticompetitive business practices. Here, NEC's assessment of the financial impact of Intel's suit on its V-Series devices may determine whether or not it wishes to press forward with this suit. Given the company's size relative to the damages it might collect, the need to focus its energies on expanding products and markets, and its relationship with Intel as a major customer, NEC may find the old axiom, "Quit while you're ahead," to be particularly appropriate to the situation. Foregoing further legal action would also yield better PR than going after the shining star of the Silicon Valley.

WHAT DID INTEL LOSE?

The most obvious question following Judge Gray's decision concerns just what Intel might have lost, since it was not only ruled that NEC was innocent of infringement on Intel's copyright on its 8086/88 microcode, but that Intel lost its copyright to begin with as a result of omissions in the affixing of the copyright notice. In view of this decision, it is possible that Intel's numerous second sources will be considering whether there is any further sense in mailing royalty checks to Intel for licenses to copyrights it can no longer claim.

Immediately following the NEC/Intel decision, there was wide speculation in the press that Intel might be besieged by a tidal wave of 80386 clones, previously held in check only by the fear of legal reprisal. In Dataquest's opinion, this possibility is no more likely than it was before Judge Gray's decision. There are a number of reasons for this:

- Cloning any high-end microprocessor still involves maneuvering around patented architectures. Would NEC have been able to launch its V-Series to begin with if it had not obtained patent licenses from Intel? Patent law has little tolerance for similarity, "substantial" or no, and therefore remains a very effective force in the protection of intellectual property.

- Intel's high-end microprocessor path represents a fast-moving target. Intel has continued to push the performance parameters of its 386 devices to a point where imitating a slower version in the face of softening demand makes no sense. In addition, Intel will raise the bar again with its upcoming RISC processor and its 80486 CISC microprocessor.

- Regardless of patent considerations and market timing, producing devices of the complexity of an 80386, and supporting the marketing and engineering efforts required to establish yourself as a viable source for companies who will be betting their systems on you, requires both technical expertise and substantial financial resources. Although many Japanese companies can obviously take on these market demands, the focus of much of Japan's microprocessor interest is aimed at TRON, not at cloning U.S. chips.

- Regardless of Judge Gray's decision on the issue of microcode infringement, copyright is still a part of the intellectual property arsenal available to Intel or any other microprocessor supplier. Add to this arsenal patent and trade secret law and the protection of mask works under the Semiconductor Chip Protection Act, and you hardly have an industry vulnerable to the whims of technology pirates. The cost of litigation alone, regardless of the outcome, will remain a daunting factor to any but the largest of semiconductor manufacturers.

DOES COPYRIGHT HAVE TEETH?

It is on this last point, the copyrightability of microcode, that Intel feels that it has won a victory not only for itself, but for the entire semiconductor industry. But in its application to microcode, as understood through Judge Gray's decision, what kind of teeth does copyright really have? The judge's decision makes it clear that the familiarity of NEC's microcode designer with the 8086/88 microcode, by virtue of having disassembled it, did not constitute copying when the knowledge was applied to the creation of the V-Series microcode. In one of the most telling statements on the applicability of copyright to microcode to be found in Judge Gray's 40-page decision, he cites two previous copyright cases in the opinion that "a defendant may legitimately avoid infringement by intentionally making sufficient changes in a work which would otherwise be regarded as substantially similar to that of the plaintiffs."

In the final analysis, the protection offered to microcode by copyright law appears extremely limited. Since in the case of creating software-compatible devices, some degree of functional constraint can always be argued to limit microcode design options, Judge Gray's ruling suggests that microroutines, particularly the shorter and simpler ones, "may be protected only against virtually identical copying." Given such an interpretation, no clear line can be drawn between legitimate reverse engineering and plagiarism.

WHAT NEXT FOR THE INDUSTRY?

In a sense then, Judge Gray's decision defines where microprocessor manufacturers add value from the court's point of view. Since microcode is the by-product of a microprocessor architecture (which can to some extent be protected by patent) and a macroinstruction set (which is in the public domain), the real value is in the architecture. The message to the industry from the NEC/Intel decision is that it had better look to strong patents as the first line of intellectual property defense.

Does this mean that Judge Gray's decision is a bad one? In seeking an answer to this question, one must understand that a judge's appointed role is to guard the intent of law in its application to litigated disputes, not to find in the favor of a U.S. industry—no matter what its importance. From this standpoint, Judge Gray has acted wisely upon the court's understanding of the nature and limitations of copyright law. From a practical perspective, the semiconductor industry must now ask itself not whether Judge Gray's decision was fair, but whether it is satisfied with the type of protection that copyright can offer an asset such as microcode. If the answer to this question is "no," than the next step should be to consider if microcode is deserving of a special type of protection that is neither clearly patent nor copyright in nature. It was this kind of consideration that eventually led to the passing of the Semiconductor Chip Protection Act for semiconductor mask works.

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DO ASIC MANUFACTURERS NEED THEIR OWN SEMATECH?

By now it appears that almost everyone who is even a casual observer of the semiconductor industry has come to the realization that ASICs are not just another hot product. At the heart of the ASIC phenomenon is a design methodology that points to the way successful components suppliers will continue to add value in this industry.

Recently, Dataquest published an ASIC market forecast predicting that worldwide ASIC consumption would grow at a compound annual rate of nearly 16 percent between 1989 and 1994. This growth will result in a worldwide market worth nearly $18 billion in five years! ASICs already account for more than 20 percent of worldwide integrated circuit consumption. Clearly, dominance in this market is a matter of strategic importance to regional as well as corporate interests.

GOOD NEWS/BAD NEWS

Looked at from the point of view of global competitiveness, the news for the United States is good, especially when compared with the U.S. position in DRAMs. Based on preliminary market share data, U.S.-based companies accounted for nearly 52 percent of worldwide ASIC shipments in 1988. By comparison, Japan-based companies claimed 39 percent of the worldwide ASIC market.

This does not, however, suggest that ASICs are the plum of the U.S. semiconductor industry. Since 1984, the U.S. share of the worldwide ASIC market has declined roughly 7 percent, while Japan's share has grown by about double that figure. As a result of this increased penetration of the ASIC market, three of today's top five ASIC vendors are Japanese. In 1983, only one of the top five worldwide ASIC suppliers was based in Japan.

Looking at Japan's growing ASIC strength, we must be careful not to draw the misleading conclusion that we are witnessing the demise of U.S. leadership in yet another segment of the semiconductor market. For the sake of balance, it should be stressed that much of the Japanese companies' ASIC revenue comes from internal sales, as opposed to the predominately merchant nature of U.S. ASIC revenue. U.S. companies

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also enjoy a leading position in cell-based design, ASIC CAD tools, and advanced PLD architectures, as well as the synergistic advantages of leadership in the high end of the computer market.

GROWING COMPETITIVE PRESSURES

Nevertheless, Japan is not far behind. Japanese semiconductor companies have gained licenses to U.S. RISC technology that will augment their own cell libraries (it was a Fujitsu gate-array implementation that brought Sun Microsystems' SPARC device to market), and have formed a number of alliances with U.S. CAD tool vendors to improve their design software capabilities. Although Japan has been conspicuous by its absence in the PLD market, Fujitsu recently announced a PLD product that it will begin shipping in 1989.

Ultimately, it may be that the vertically integrated nature of Japanese companies will prove to be the strongest card in their ASIC hands. The reason for this comes down to the fundamental issue behind the struggle for market share: the ability of a company or region to invest in its basic technological and manufacturing capabilities.

During the next two years, ASIC suppliers will find themselves increasingly caught in a cross fire between weaker demand, local content requirements, and technology lag. Although Japanese ASIC suppliers will be no more immune to these forces than their U.S. competitors, they very likely will be better able to weather them financially.

Between 1989 and 1990, Dataquest expects the worldwide ASIC market to grow only 6 percent, from $8.6 billion to $9.1 billion—a sharp contrast to the double-digit growth that ASICs have experienced for many years. At the same time the worldwide ASIC market is slowing, ASIC vendors are having to confront the necessity of becoming regional suppliers in order to compete in a global market. The reasons for this are several, and have to do with local content laws (Europe as it approaches 1992), end-user demands for more complex designs and faster design turnaround, rapid changes in products and applications, and the corresponding need for faster production response.

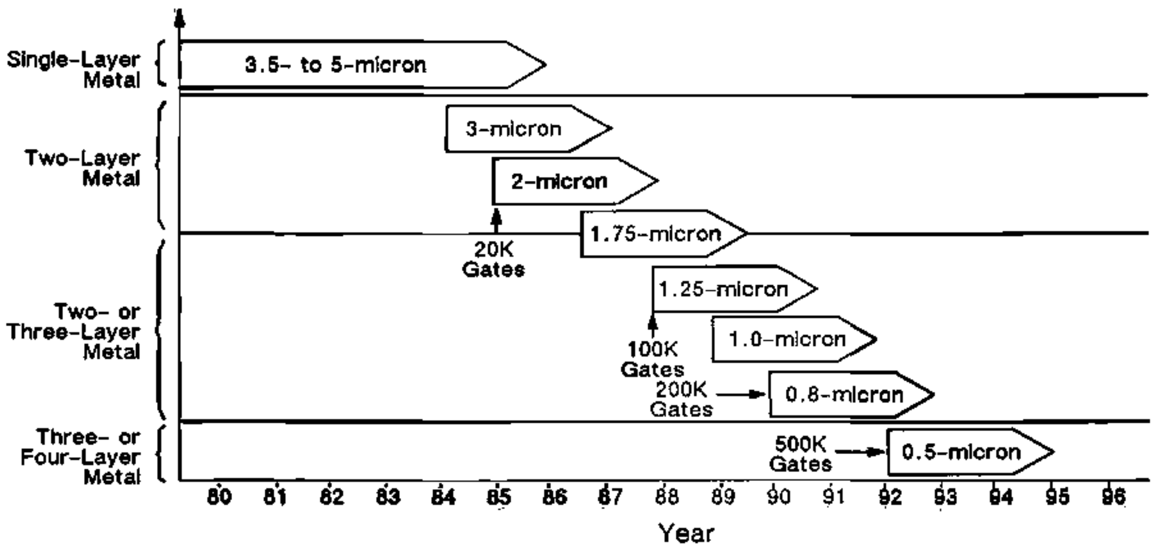
Combined, these factors will favor those ASIC suppliers with a manufacturing presence in markets they serve. This presence will not only require establishing sales and distribution channels in offshore markets, but will necessitate significant investments in design centers, field engineering support, and ultimately, in wafer fabrication facilities as well.

DIVERGING TECHNOLOGIES

For ASIC suppliers, the period between the late 1980s and the early 1990s will prove a technology watershed. As shown in Figure 1, CMOS ASIC technology has progressed from 3.5- to 5-micron range design rules requiring single-layer metal interconnects to gate densities in the 100,000 to 200,000 range that require 1.25- to submicron geometries and two or three layers of metallization. In terms of offering the architectural flexibility required to be a leading-edge ASIC supplier, today's technology is rapidly reaching its limits. To move into the next major generation of ASIC products, which will involve designs using up to 500,000 gates, ASIC manufacturers will need to manufacture devices at the 0.5-micron linewidth level, using three to four layers of interconnection.

Figure 1

The CMOS ASIC Technology Road Map



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Source: Dataquest May 1989

WHERE WILL TOMORROW'S PROCESS TECHNOLOGY COME FROM?

The cost of making the leap from today's generation of ASIC devices to tomorrow's will not only lengthen the journey of ASIC suppliers along the technology road map illustrated above, but will make the path a more costly one to follow. Given an increasingly crowded ASIC market, this barrier alone will undoubtedly weed out a number of companies whose profit margins during the upcoming industry slowdown make it financially impossible, or inadvisable, to stay in the race. Needless to say, the vertical integration of Japanese ASIC vendors will prove advantageous in the ASIC market of 1990.

Also advantageous to Japanese ASIC companies will be the strength of their memory-driven CMOS process technology, which continues to push the leading edge of device density and yield. From this standpoint, U.S. ASIC companies will find themselves to some degree dependent on process technology that has gone the way of the DRAM—to Japan. With diminishing revenue and margins forecast for the next two years, how will U.S. ASIC suppliers be able to advance their process technology to keep pace with that of their Japanese competitors, let alone surpass it?

ENTER SEMATECH

During its somewhat turbulent funding quest, critics of the U.S. semiconductor manufacturing consortium pointed out that basing future manufacturing technology on memories was an antiquated notion. The process driver of the future, they argued, would be ASICs. Sematech's proponents have argued that the consortium's "manufacturing device vehicles" (MDVs), DRAMs and SRAMs, would strengthen the U.S. foundation in equipment, materials, and process technology in a way that would ultimately benefit an LSI Logic as much as a Motorola.

To a degree, the Sematech argument is a valid one. As a process driver, DRAMs remain the ideal vehicle for pushing the absolute limits of line geometry. Memory production provides a "test pattern" that ensures the highest levels of productivity and reliability in equipment. Beyond this lowest common denominator, however, the requirements of ASIC suppliers and memory manufacturers begin to diverge, and this divergence is growing. Future memory products stress trench technology, optimum cell design, high-volume production, and cyclical yield and reliability improvements. By contrast, success in leading-edge ASICs demands processes that stress complex interconnects, planar surface technology, low-quantity/quick-turnaround production, rapid yield and reliability improvements, and high pin count packages.

However the Sematech mission may be expanded to address the priorities of ASIC manufacturing technology, the present reality of Sematech's MDVs falls short of meeting the process technology needs of tomorrow's ASIC products. Perhaps it is a mistake to think that Sematech should even try to be the panacea of all the challenges facing the U.S. semiconductor industry. The problem is, however, that given the environment in which U.S. ASIC manufacturers will be operating over the next two years, the industry's ability to fund its way over the technology hurdles that it faces may be seriously diminished.

Sematech arose to fill a process technology void left by the departure of U.S. semiconductor companies from a critical component market. It is entirely possible that ASIC manufacturers may themselves face a similar void in the not-so-distant future. Ultimately, the issue of whether ASIC companies require their own unique version of Sematech, and some sort of government support, must be judged on their market share success. If the United States has learned from history, government's participation in securing the future of U.S. ASIC technology will, if required, take place <u>before</u> the serious erosion of domestic ASIC supplier bases and before end users are forced to rely on the latest technology from their offshore systems competitors.

The issue, as with Sematech and DRAMs, is not about propping up noncompetitive companies, but about sustaining a technology that embodies the future of the semiconductor and electronics industries. While semiconductor memories drive improvements in the cost and performance of electronics systems, ASICs are becoming the embodiment of these systems in silicon. Their strategic value to the U.S. electronics industry is therefore too critical to risk being second best.

Michael J. Boss
Andy Prophet

Dataquest
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Research Bulletin

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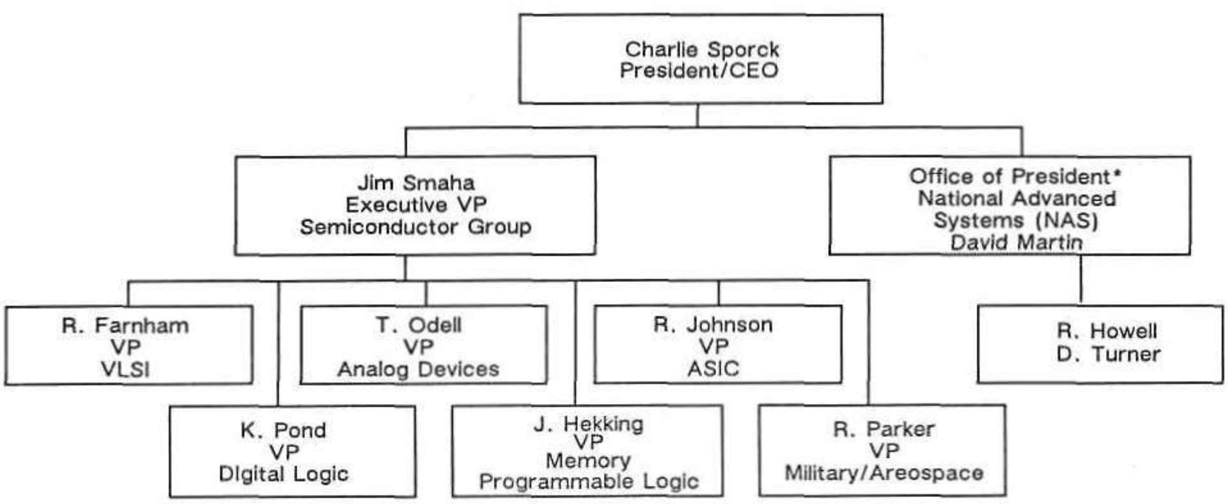
NATIONAL SEMICONDUCTOR RESTRUCTURES

National Semiconductor has undergone a tremendous amount of change in its struggle to identify a structure that will result in profitable operations. Organizationally, the most significant outcome of these efforts so far has been the shedding of its nonsemiconductor-related lines of business, allowing the company to focus entirely on the successful positioning of its components products. Figure 1 illustrates the revised organizational structure of National Semiconductor in the wake of announcements made during the past two months. Because of the number and nature of these announcements, Dataquest offers this Research Newsletter to our Products, Markets, and Technology clients in order to bring them up to date on National's restructuring efforts.

Figure 1

National Semiconductor Organizational Structure (As of March 1989)



*Subject to change upon the completion of the sale of 50 percent interest in NAS to Memorex Telex, when NAS will operate as a separate entity.

0003306-1

Source: National Semiconductor

In December 1988, National Semiconductor announced the sale of its retail systems unit, Datachecker Systems, to a United Kingdom-based company, ICL. This move was followed in mid-January 1989 by an agreement with Memorex Telex to form a joint venture in which each company would own a 50 percent interest in National Advanced Systems (NAS). Memorex Telex, a Dutch company, is a $2 billion supplier of plug-compatible computer equipment and accessories. The deal with Memorex Telex called for National to receive a cash payment of $250 million and 4 million shares of Memorex Telex common stock. In addition to its 50 percent share of NAS, the agreement gave Memorex Telex an option to purchase the remaining stock in the organization, which would be operated as a separate entity headquartered in Santa Clara, California. At the end of February 1989, National broke off its tentative agreement with Memorex Telex, which had apparently encountered difficulties in financing the buyout of NAS. Instead, National has accepted a $398 million cash offer from Hitachi Ltd. of Japan and Electronic Data Systems (EDS), a subsidiary of General Motors Corporation. Under the agreement, NAS will be sold to a joint venture created by Hitachi and EDS. NAS acts as a distributor of IBM-compatible, large and medium-size computers and peripherals made by Hitachi.

Shortly after the initial disclosure of its deal with Memorex Telex, National announced that it would lay off 2,000 employees. The work force reduction affects all levels of staff in Asia, Europe, and the United States, and it will take place through March 1989. The number represents about 5 percent of the corporation's reported head count as of the close of fiscal year 1988. National, which reported a loss of approximately $56 million for the first half of its fiscal year 1989, has said that the reductions are necessary to bring the company's staffing levels and cost structure into alignment with its current business environment.

As evidence of its renewed emphasis on its core semiconductor businesses, National recently announced the formation of a new VLSI division, which comprises the company's microprocessor, microcontroller, advanced peripherals, and interface groups. This new division will report to vice president Ray Farnham. The memory and programmable logic groups will be combined under John Hekking. The military and aerospace group will report to Randy Parker. National intends to strengthen its position in the military market, in which it became a more powerful contender through its acquisition of Fairchild. All of these groups will report to James Smaha, executive vice president of the semiconductor group. Clark Davis will be in charge of the newly formed function of worldwide strategic planning. The strategic market development group will be headed by Walt Curtis. These last two individuals will report to Joe Van Poppelen, vice president of semiconductor marketing.

National's information systems group, of which NAS is the major part, accounted for approximately 43 percent of National's fiscal 1988 revenue of $2.5 billion. Its 1988 fiscal year ended May 29. The divestiture of NAS signals a major change in National's strategy, and a significant impact will be felt on the company's revenue. Nevertheless, National should see an improvement in profitability as a result of the sale of NAS. Partly due to the yen appreciation during the past few years, which has affected the cost of its equipment purchases from Hitachi, NAS has experienced increased pressure on its profit margins. By increasing its reliance on its semiconductor products, however, National becomes more vulnerable to the boom/bust cycles that have up to now typified the semiconductor industry. Just how National goes about positioning its broad line of components products will bear watching as the company stakes its future on being a pure-play semiconductor company.

Michael J. Boss

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QUARTERLY SEMICONDUCTOR COMPANY FINANCIAL RESULTS

INTRODUCTION

Dataquest regularly reports on semiconductor company financial results through its weekly on-line news service, The DQ Monday Report. As a service to Products, Markets, and Technology clients, a summary of this information is provided below.

Table 1 summarizes the net sales and income disclosures from selected semiconductor companies based on data from quarterly report periods ending December 1988/January 1989. The data are compared with year-earlier periods. Table 2 provides a similar summary for fiscal-year revenue and income for applicable companies. Descriptive summaries of quarterly performance highlights for the selected companies follow the tables.

Table 1

Quarterly Financial Summaries for Selected Semiconductor Companies

Company	Latest Qtr. Revenue	Percent Change	Latest Qtr. Income	Percent Change
Altera	$ 10.7M	63%	$ 2.1M	174%
AMD	$248.0M	5.5%	($ 34.0M)	N/M
California Micro Devices	$ 6.4M	(13%)	$ 2.4M	(95%)
Chips and Technologies	$ 54.4M	68%	$ 7.9M	41%
Cypress Semiconductor	$ 41.2M	70%	$ 6.3M	58%
IDT	$ 43.5M	36%	$ 2.9M	(11%)
Intel Corp.	$727.0M	27%	$ 86.0M	(10%)
KLA Instruments	$ 41.5M	63%	$ 2.8M	46%
Lam Research	$ 31.8M	80%	$ 2.4M	168%
Linear Technology	$ 15.7M	28%	$ 2.1M	(11%)
LSI Logic	$119.4M	53%	$ 5.3M	(8%)
Motorola, Inc.	$ 21.9M	18%	$124.0M	22%
SEEQ Technology	$ 14.5M	(4%)	$ 1.1M	(42%)
Silicon General	$ 9.6M	55%	$0.453M	N/M
Texas Instruments	$ 16.9M	10%	$ 95.0M	4%
VLSI Technology	$ 64.9M	38%	$ 2.9M	56%
Weitek	$ 10.1M	47%	$ 1.4M	196%

N/M = Not Meaningful

Source: Company Information

Table 2

Fiscal Year Financial Summaries for Selected Semiconductor Companies

Company	Fiscal Year Revenue	Percent Change	Fiscal Year Income	Percent Change
Altera	$ 37.9M	83%	$ 7.1M	248%
AMD	$ 11.3M	13%	$ 19.3M	N/M
Cypress Semiconductor	$139.4M	80%	$ 20.8M	55%
Intel Corp.	$ 27.8M	51%	$453.0M	83%
LSI Logic	$379.0M	45%	$ 24.7M	118%
Motorola, Inc.	$ 82.5M	23%	$445.0M	45%
Texas Instruments	$ 63.0M	13%	$366.0M	14%
VLSI Technology	$221.2M	29%	$ 6.7M	(6%)
Weitek	$ 35.2M	65%	$ 4.0M	279%

N/M = Not Meaningful

Source: Company Information

Altera

The leading supplier of CMOS PLDs in 1988, Altera attributed this record performance to ongoing strong demand for its mature products, and to initial shipments of its new Multiple Array matrix parts and development systems.

AMD

AMD's fourth-quarter fiscal 1988 loss included an unusual charge associated with a work force reduction, a plant closure, and other restructuring activities. Softness in the PC industry negatively affected sales in the microprocessor and PLD areas. EPROMs, however, achieved record sales, and more than half of the company's EPROM revenue was generated from CMOS EPROMs.

California Micro Devices (CMD)

CMD's revenue was negatively affected by a drastic drop in product demand from GTE. Higher development costs associated with 1.5-micron MOS processing technology also had a detrimental effect on profitability. Company chairman Chan Desaigoudar said that the affected division is restructuring in order to handle the reduced demand from GTE and the increased demand from foundry customers. Thus, more favorable results are expected in the latter half of the company's current fiscal year.

Chips and Technologies

According to president and CEO Gordon Campbell, increased sales for the company's most recent quarter reflected increased demand for AT-compatible chip set products, particularly the company's higher-speed line for 286- and 386-based systems. Shipments to OEMs and deliveries from distributors to customers increased.

Cypress

The company attributed much of its outstanding results to the successful expansion of capacity and improvement of yields attained by its new Round Rock, Texas, wafer fabrication facility. In the fourth quarter, one half of the company's product shipments came from this facility. A rash of new product introductions in the third quarter resulted in Cypress experiencing strong new-product performance in the fourth quarter.

IDT

In January, IDT indicated that it was lowering estimates for its third-quarter results. Demand was weaker than expected, although the company believes that the disparity between product availability and demand was of a temporary nature. New orders booked during the quarter and backlog at the quarter's end both were at record levels, and the company is "cautiously optimistic" about the fourth quarter.

Intel

The company experienced another outstanding year. However, inventory corrections at the end of the year—when supply and demand for the 80386 reached parity—resulted in a weak quarter. Intel views this event as a correction phenomenon, not the signal of a downturn. In separate announcements, Intel reported that it had adopted a shareholder rights plan to protect the company in the event of a takeover bid, and that it had appointed 10 new operating group vice presidents.

KLA

The company stated that, while orders for its systems increased strongly during its most recent quarter, continued investment in the start-up of two new business areas and an increase in engineering and R&D investments negatively affected financial results in the first half of fiscal 1989.

Lam Research

Lam reported a record level of backlog in its second quarter. The company's new Rainbow etch systems, which reached their 100th order milestone in the quarter, accounted for 65 percent of orders booked. Much of this increased sales activity came from the Pacific Rim market, while the domestic market continues to show strength as well.

LSI Logic

The company said that its Canadian affiliate would take a one-time restructuring charge in the fourth quarter. This charge was associated with the termination of sales of PC products, which amounted to a $5 million negative impact on net income. LSI's book-to-bill ratio was running in excess of 1.10 in the fourth quarter, and the dollar volume of new orders grew about 20 percent from the prior quarter. The company expects that orders in the first quarter of 1989 will be be stronger.

Motorola

Sales in communications, cellular telephone, and semiconductor products remained strong during Motorola's most recent quarter. With respect to the semiconductor products sector, sales increased 25 percent and orders rose 21 percent from the year-earlier period. Demand is especially strong in Japan and the Pacific Rim market.

Silicon General

The company reported results for its semiconductor business only, because it is in the process of turning its telecommunications activities into a separate business entity. Record revenue for the quarter reflected good demand from the company's military sector, as well as good demand from its other semiconductor markets. The company is optimistic about its business prospects for the next few quarters.

SEEQ

The company's poor results in its first quarter of 1989 were due to poor wafer fabrication productivity and lower-than-expected yields. As a result, the company did not meet its shipping commitments. SEEQ believes that it has addressed its production problems. Bookings for the quarter were at a 23-year high, with most of the strength coming from new CMOS product lines. This backlog, combined with a return to normal manufacturing, should result in improved future performance.

Texas Instruments (TI)

TI's semiconductor business achieved record net sales and significantly improved operating performance primarily because of demand for its memory products. Demand for DRAMs and EPROMs was especially strong. However, a mature part of the company's business, bipolar logic, is being displaced by other logic technologies and, as a result, pricing pressures were severe. Component revenue experienced an approximate 27 percent increase in 1988, reaching $3.1 billion in sales. TI's income includes royalty of $124 million from DRAM patent litigation settlements. This amount compares with $191 million gained by TI in similar royalty payments last year. TI is expecting slower growth in 1989; shortages will ease in memory products, and pricing pressure will continue in mature, general-purpose logic and linear products. In a letter to stockholders, TI chairman, president, and CEO Jerry Junkins indicated that the company will continue cost-reduction actions to keep operations aligned with market demand. These actions will include a program in the first quarter to reduce employment levels in selected areas of the company's operations.

VLSI Technology

Fourth-quarter bookings remained relatively strong, equaling approximately the levels of a strong third quarter. Chip set business for the Asian market was very weak, but the company's European operations reported a strong quarter. Margins in the fourth quarter were adversely affected by the continued start-up expenses related to the company's new Texas wafer fab, but the additional capacity and advanced process technology from the new facility is expected to contribute to improved financial results during the course of 1989.

Weitek

The company saw strong performance from its processor and coprocessor product lines, where revenue more than doubled in 1988 over 1987. Weitek's outlook for 1989 sales is optimistic.

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QUARTERLY SEMICONDUCTOR COMPANY FINANCIAL RESULTS

INTRODUCTION

Dataquest regularly reports on semiconductor company financial results through its weekly on-line news service, The DQ Monday Report. As a service to binder holders of the Products, Markets, and Technology segment, a summary of this information is provided herein.

Table 1 summarizes the net sales and income disclosures from selected semiconductor companies based on data from quarterly report periods that ended during the February through April time frame. This information is compared with the 1988 February through April time frame and is provided in millions of dollars unless otherwise indicated. Table 2 provides a similar summary for fiscal year revenue and income for applicable companies. Descriptive summaries of quarterly performance highlights for the companies listed follow these tables.

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Table 1

Quarterly Financial Summaries for Selected Semiconductor Companies (Millions of Dollars)

Company	Latest Quarter Revenue	Percent Change	Latest Quarter Income	Percent Change
Altera Corp.	$ 12.5	59.0%	$ 2.3	103.0%
California Micro Devices	$ 7.6	(4.0%)	$ 76.0*	(87.0%)
Chips and Technologies	$ 57.4	59.0%	$ 9.4	71.0%
Cypress Semiconductor	$ 46.2	58.0%	$ 7.1	61.0%
Dallas Semiconductor	$ 17.1	46.0%	$ 2.1	6.0%
Exar Corporation	$ 18.3	12.0%	$959.0*	N/M
IDT	$ 47.6	28.0%	$ 4.2	(2.0%)
IMP	$ 12.2	13.0%	($ 3.3)	N/M
Intel Corporation	$ 713.0	12.0%	$ 97.0	3.0%
Linear Technology	$ 16.5	23.0%	$ 2.2	4.0%
Logic Devices	$ 3.8	134.0%	$791.0*	434.0%
LSI Logic	$ 133.9	83.0%	$ 8.0	71.0%
Micron Technology	$ 113.8	95.0%	$ 29.2	72.8%
National Semiconductor	$ 589.0	3.0%	($ 44.6)	N/M
Silicon General	$ 8.2	11.0%	$275.0*	16.0%
Siliconix	$ 26.4	(9.0%)	($ 6.7)	N/M
Texas Instruments	$1,561.0	6.0%	$ 85.0	0
VLSI Technology	$ 60.0	37.0%	($ 6.2)	N/M
Western Digital	$ 243.2	28.0%	$ 4.4	(46.0%)
Xicor Inc.	$ 22.0	13.0%	$ 2.9	0.8%
ZyMOS Corporation	$ 7.7	(10.0%)	($188.0)*	N/M

Table 2

Fiscal Year Financial Summaries for Selected Semiconductor Companies (Millions of Dollars)

Company	FY Revenue	Percent Change	FY Income	Percent Change
Exar Corp.	$ 75.3	25%	$ 4.9	N/M
IDT	$180.7	49%	$ 17.9	55%
IMP	$ 52.5	7%	$169.0*	(97%)

*Thousands of dollars
N/M = Not Meaningful

Source: Company Literature

Altera

Altera's sales during the first quarter of 1989 were 17 percent over those of its fourth quarter of 1988. Operating income grew to $2.7 million, up from $1.2 million in the first quarter of 1988 and $1.9 million for the fourth quarter of 1988. These results mark Altera's nineteenth consecutive quarter of increased sales and the company's ninth consecutive quarter of record profits. Altera's balance sheet currently shows a healthy $22.0 million in cash and short-term investments, $38.0 million of equity, a 5 to 1 ratio, and no long-term debt. Altera chairman and CEO Rodney Smith notes that the company's order rate during the quarter has remained strong and that, in general, business has increased in all channels worldwide.

California Micro Devices

For the first nine months of fiscal 1989, California Micro Devices has reported a loss of $675,000, compared with income of $1.4 million earned during the same period last year. Revenue for the first three quarters was $19.7 million compared with $20.8 million during the same period in fiscal 1988. The company attributes its loss in large part to a $1.5 million provision for acquisition expenses made during the first quarter. Although California Micro Devices has lost some revenue as a result of reduced product demand from GTE, the company's chairman and CEO, Chan Desaigoudar, has estimated new orders for the third quarter at $13 million. He also reports that the Microcircuits Semiconductor Division has corrected its previous manufacturing problems and has increased its yields on 1.5-micron CMOS wafer fabrication.

Chips and Technologies

For the nine-month period that ended on March 31, 1989, Chips and Technologies posted net sales of $155.8 million, an increase of 59 percent over net sales for the comparable period last year. Net income for the first nine months of fiscal 1989 increased 45 percent over 1988 to $23.0 million. President and CEO Gordon Campbell attributes his company's performance to the sales growth of Chips and Technologies' high-performance PC AT-compatible chip set products. During the third quarter, the company announced the formation of its Mass Storage Operation group and its first major product: a hard disk drive controller chip set for IBM PS/2 Micro Channel-compatible computers.

Cypress Semiconductor

The first quarter of fiscal 1989 marks 21 consecutive quarters of increasing revenue for Cypress Semiconductor, with revenue and net income up 12 percent and 13 percent, respectively, over the fourth quarter of 1988. President and CEO T.J. Rodgers notes that his company has continued to maintain 20 percent operating profit levels and an investment in R&D amounting to 26 percent of sales. As a result of this investment, Cypress and its subsidiary, Aspen Semiconductor Corporation, introduced 11 new products between them, bringing the total number of products in the Cypress catalog to 114.

Dallas Semiconductor

Net income for the first quarter of 1989 increased 7 percent over the fourth quarter of 1988, while net sales for the first quarter of 1989 grew 3 percent over the fourth quarter of 1988. First quarter of 1989 net income reflected an extraordinary credit of $157,000.

Exar Corporation

Exar Corporation has reported its financial results for the fourth quarter and fiscal year that ended on March 31. For the fourth quarter, Exar achieved net income of $959,000 on net sales of $18.3 million. This compares with a net loss of $3.8 million on sales of $16.4 million for the same period last year. Exar's sales for the year totaled $75.3 million—a 25 percent improvement over the $60.2 million reported for fiscal 1988. Exar's net income for fiscal 1989 reached $4.9 million compared with a net loss of $12.8 million for last year. Exar's fiscal 1989 results include 19 percent of the net loss of its subsidiary Exel. This proportion is due to a transaction completed in March 1988, in which Rohm Co., Ltd., the majority shareholder in Exar, acquired an 81 percent interest in Exel. Exar also notes that part of its fiscal 1989 revenue increase was attributable to a 36 percent increase in the sale of wafer services to Rohm.

IDT

Integrated Device Technology (IDT) ended its fiscal year on April 2. Revenue for fiscal 1989 was $180.7 million, a 49 percent increase over fiscal 1988. Net income was $17.9 million, an increase of 55 percent over the previous year. Dr. John Carey, chairman and CEO of IDT, noted a rebound in fourth quarter sales and earnings after a weak third quarter. In March the company broke ground on a 135,000-square-foot complex on nine acres of recently purchased land in North San Jose, California. The new facility will house a 6-inch, Class 1, half-micron wafer fab, which IDT hopes will see first silicon by the end of fiscal 1990.

Intel

In January, Intel had said that it expected its first quarter 1989 net income to decline in comparison with the fourth quarter of 1988's figure of $86 million. The company credited its higher-than-anticipated results on cost controls and good factory performance, combined with strong sales in March. President and CEO Andrew Grove notes, however, that a great percentage of first quarter orders were for delivery within 30 days, which, combined with a low backlog, "means that our visibility into the future remains limited."

International Microelectronic Products (IMP)

IMP's net revenue was $52.5 million with a net income of $168,500 for the fiscal year ending on March 25. Compared with fiscal 1988, net revenue increased by 7 percent in fiscal 1989, while net income decreased from $5.7 million during the previous year. In addition to inventory corrections in PCs, IMP president and CEO Barry Carrington explained his company's poorer profit performance as attributable to start-up difficulties on a new product. This constrained fourth-quarter sales at a time when the company was increasing its spending for capacity expansion. IMP believes that it has overcome these start-up problems, and it has nearly completed its conversion to larger diameter wafers in order to increase capacity.

Linear Technology

The company's third fiscal quarter for 1989 included a benefit from a net operating loss carryforward. On a comparative basis, income before extraordinary tax credit showed a 23 percent increase compared with the same period last year. The company achieved another quarter of steady sales growth and maintained pretax profits of 22 percent as a percentage of sales.

Logic Devices

The company's recent quarter results mark its 14th consecutive profitable quarter. Logic Devices' president Bill Volz credits initial revenue shipments of his company's new fast SRAM families with Logic Devices' strong first quarter performance.

LSI Logic

President and COO George Wells notes that although first quarter revenue is up 12 percent over fourth quarter 1988, LSI Logic has achieved a book-to-bill ratio of approximately 1.0 to 1.1, with bookings increasing each month of the quarter. The company now is operating at a revenue run rate of half a billion dollars a year. In addition, operating income for the first quarter of 1989 set a company record at $12.1 million, while operating expenses as a percent of revenue were at the lowest level in three years at 27.1 percent. During the first quarter, LSI introduced its Tape Quad Flat Pack plastic package, a surface-mount device with up to 500 pins.

Micron

For the first half of fiscal 1989, Micron has reported net income of $61.4 million on revenue of $224.2 million. This compares with revenue of $101.5 million and net income of $25.4 million for the comparable period in fiscal 1988. Micron chairman and CEO Joe Parkinson has noted increased market acceptance of his company's DRAM, fast SRAM, and video RAM (VRAM) products during Micron's second quarter. During the month of February, Micron began initial production testing and qualification of its FAB III plant, which offers 53,000 square feet of Class 1 clean room within a 120,000-square-foot facility.

National Semiconductor

For the first nine months of fiscal year 1989, National has reported a net loss of $100.3 million on sales of $1,849.0 million. This compares with net earnings of $40.3 million on sales of $1,615.7 million for the same period last year. During its third and most recent quarter, National reported a gain of $45.1 million from the sale of Datachecker Systems Inc. to ICL. The company also reported a one-time pretax restructuring charge of $8.5 million related to its worldwide work force reduction announced in January. National president and CEO, Charles Sporck, has noted a decline in bookings in late 1988, a reduced revenue base, pricing pressure on certain product lines, and consolidation costs associated with the acquisition of Fairchild, contributing to a "disappointing performance" by National's Semiconductor Group during the third quarter. National has signed a letter of intent with Electronic Data Systems (EDS) and Hitachi Limited for the sale of National Advanced Systems (which contributed positively to the company's operating performance during the quarter). This sale is expected to close during the fourth quarter, and it will mean almost $400 million in cash for National.

Silicon General

Financial results for the third quarter of 1989 are for the company's semiconductor business only, because Silicon General is in the process of making its telecommunications business a separate company. President and CEO Dan Rasdal observes that his company's shipments to disk drive producers have been lower than in earlier quarters. In the second and third quarters, however, demand has been strong in defense electronics, industrial power conversion, and automotive electronics.

Siliconix

Despite actions taken to improve gross margin and reduce spending, Siliconix, with shipments below the $29 million level was unable to avoid a loss. In February, the company decided to obsolete certain products and cease development work on A/D converters and gate arrays. This decision resulted in an inventory write-off related to these products totaling $1.1 million.

Texas Instruments

Net sales billed for semiconductors in the first quarter of 1989 were down slightly from the fourth quarter of 1988. Nevertheless, semiconductor sales during the first quarter have experienced double-digit growth over first quarter 1988. Profit from operations has increased 27 percent to $68.0 million from last year's first quarter, primarily because of higher semiconductor margins. This increase more than offset the effect of the company's lower margins in defense electronics and a continued loss in digital products. Royalty income for TI's DRAM litigation earned the company $32.0 million, down from $52.0 million during last year's first quarter. According to the company, its patent portfolio has been strengthened, and it will begin a new round of negotiations with its licensees late this year. During the company's annual shareholders' meeting, chairman, president, and CEO Jerry Junkins commented that a significant portion of TI's $760.0 million capital spending budget will be for submicron CMOS wafer fabs for memory and logic products.

VLSI Technology

Although up from the same period a year ago, VLSI's revenue was down 7 percent from the previous quarter. The company had warned earlier that the slowdown of its new San Antonio, Texas, wafer fab would have a negative impact on its first quarter 1989 results. In addition to the delay of the San Antonio fab's production schedule, revenue also was affected by continued capacity constraints, rescheduling of deliveries by selective customers, and continuing general softness and product demand changes in the personal computer market. VLSI has instituted additional expense and head count controls, and will introduce its next-generation design software during the second quarter.

Western Digital

Revenue for the first nine months of fiscal 1989 increased to a record $748.6 million, a 52 percent increase over the same period in 1988. Net income for the first nine months totaled $30 million, a 4 percent increase over the similar period last year. Western Digital's third-quarter earnings were affected by declining revenue levels and by costs associated with a reduction in force. Roger Johnson, Western Digital's chairman, president, and CEO, noted that although the company's video and communications businesses experienced record demand and operating results, overall performance was affected by soft demand for integrated systems products and the effects of the company's transition from standalone controllers to integrated disk drives. With its April increase in orders, Western Digital has an optimistic near-term outlook.

Xicor

Xicor president Raphael Klein has noted a strong demand for Xicor's products since the first of the year. In order to meet this demand, the company incurred significant overtime and quick-turn assembly charges during the first quarter. Mr. Klein also noted increased cost competitiveness as a factor keeping Xicor's profits from rising higher. In 1988, Xicor set in motion a three-year, $50 million program to modernize its production and R&D capabilities, including the building of a new 6-inch wafer fab line.

ZyMOS Corporation

ZyMOS has announced its financial results for the first quarter of fiscal 1989. The company recorded net income of $188,000 on revenue of $7.7 million, compared with a loss of $2.9 million on revenue of $8.6 million for the same period in 1988. President and CEO Dave Handorf stated that $1 million of ZyMOS' first-quarter revenue came through the sale of technology. Product sales, which make up the remaining $6.7 million, represented a $1.5 million increase over the fourth quarter of 1988. A spokeperson at ZyMOS claims that the higher revenue figure for the first quarter of 1988 was attributable to significant shipments of "end-of-life purchases resulting from ZyMOS' decision to discontinue older technology processes and low-margin products and focus on higher-margin PC chip sets, VGA products, and SuperCell ASIC capability."

Patrica Galligan

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Research Newsletter

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PMT Executive Memo

VERTICAL INTEGRATION U.S.–STYLE: THE FORMATION OF U.S. MEMORIES

SUMMARY

On Wednesday, June 23, 1989, a new company announced its intention to become the fifth U.S.–owned, noncaptive supplier of dynamic random access memory (DRAM) chips. The company is U.S. Memories. More significant than the fact that another manufacturer will join the ranks of a domestic supplier base that has been on the "endangered species list" since the 1985 industry downturn is the fact U.S. Memories will be a jointly owned venture funded initially by seven major U.S. electronics and semiconductor companies. The companies contributing seed money to the start–up are Advanced Micro Devices, Digital Equipment Corporation, Hewlett–Packard, Intel, IBM, LSI Logic, and National Semiconductor.

The new memory manufacturing entity will be headed by Sanford (Sandy) Kane, who will resign from his present position as vice president of technology at IBM to become the president and CEO of U.S. Memories. U.S. Memories' current objectives are to meet its approximately $1 billion funding requirement and to select a site by the end of this year. As ambitious as it may seem, the company also has stated its goal of building a wafer fabrication facility that will be in full–volume production of 4Mb DRAMs by the first half of 1991.

Whether or not U.S. Memories succeeds in its ambitious aim to be in volume production of cost–competitive, leading–edge memory products by mid–1991, the very act of its formation is evidence of profound changes in the U.S. electronics industry and its relationship with government. In the three years since the signing of the controversial semiconductor trade agreement with Japan, the U.S. semiconductor industry has implemented a major change in its culture and, quite possibly, in the infrastructure in which it operates. This newsletter looks at the major obstacles facing the formation of U.S. Memories and its larger significance to the U.S. semiconductor industry.

OBSTACLES

Between U.S. Memories and its vision of high-volume, leading-edge DRAM manufacturing in the early 1990s lie a number of hurdles. These include successfully addressing potential antitrust barriers, convincing other systems and components companies that they have a vested interest in participating in the new venture, and overcoming a late start in the 4Mb DRAM market--particularly in relation to Japanese competitors. We will now look more closely at these issues.

Antitrust Concerns

Sematech and other electronics research cooperatives, such as the SRC and the MCC, paved the way for dealing with antitrust issues involving joint R&D efforts by major U.S. electronics companies. U.S. Memories is unique, however, in that for the first time in electronics industry history, several U.S. semiconductor manufacturers and their customers have proposed sharing resources, risk, and output. Antitrust considerations now will have to be applied to the manufacturing issue. It is highly likely, however, that Sematech already has been sounding this issue with the federal government, and U.S. Memories expects no major obstacles in this regard.

Participation by Chipmakers

Made conspicuous by their absence from the roster of domestic semiconductor companies contributing to U.S. Memories are Micron Technology, Motorola, and Texas Instruments (TI). For these companies, U.S. Memories represents a potential competitor. The fact that they are represented in the Semiconductor Industry Association (SIA), the board of which unanimously approved U.S. Memories' formation, indicates no outright hostility to the new venture. Nevertheless, with impressive commitments already made to the DRAM market, it is unlikely that today's domestic DRAM leaders will find it a matter of vested interest to participate directly in U.S. Memories.

Other U.S. chip manufacturers may, however, want to give the matter some serious thought. To begin with, the DRAM market is simply too big to ignore. Dataquest currently forecasts that worldwide MOS memory consumption as a whole will have a compound annual growth rate (CAGR) of nearly 26 percent between 1988 and 1993—representing about 40 percent of the estimated $94 billion market for integrated circuit products that we have forecast for the next four years. In turn, DRAM products will make up the majority of this market. Although personal computer products will account for an ever-larger proportion of DRAMs (56.5 percent by 1990), PCs are becoming a less volatile, if slower-growing, end market. With increasing pervasiveness in other systems' applications, DRAMs constitute an important part of the product mix for any company wishing to satisfy the broad demands of the worldwide electronics market. Participation in U.S. Memories offers a way for domestic suppliers to address their customers' memory needs without the massive investment and risk that have come to characterize participation in the DRAM market.

Participation by Systems Companies

The announcement of U.S. Memories does not mark the first time that the semiconductor user community has been approached for investment in a U.S. DRAM manufacturing start-up company. Just seven months ago, Pierre Lamond of Sequoia Capital unsuccessfully pursued a joint venture, dubbed "Megaram," that would have created a 1Mb DRAM factory from the joint investment of a number of major memory users. Curiously, one of the companies approached is now an investor in U.S. Memories--Digital Equipment Corporation. One advantage that the new start-up offers chip users, in terms of investment risk, is that, unlike the Megaram proposal, U.S. Memories has the participation of a number of leading chipmakers. In addition, the process formula to be used by U.S. Memories is coming from the very company believed to be the largest producer of leading-edge DRAMs--IBM.

However appealing the theme "Buy American" is these days, it will not be reason enough for U.S. chip users to risk committing to the proposed purchase of 50 percent of U.S. Memories' chip production. To be sure, U.S. systems companies seem more sensitive to the long-term implications of depending on present or future competitors for their advanced component technology since the acrimonious finger pointing that took place between the semiconductor supplier and user communities following the U.S.-Japan Semiconductor Trade Arrangement.

Nevertheless, when all is said and done, U.S. Memories is another start-up company that will have to compete on the same quality, price, and delivery terms as every other chip supplier. Assuming that all of these conditions are met competitively by U.S. Memories, an example of the advantages it might offer customers/investors can be found in the equity investment deal cut last October between Amstrad of the United Kingdom and Micron Technology. Unlike the 20-plus Micron customers, who at the time of the Amstrad agreement had signed two-year noncancellable DRAM supply contracts, the British PC manufacturer did not have to commit to a fixed delivery schedule. In addition to negotiating prices on a quarterly basis, Amstrad was able to start with a ceiling price based on the weighted average of all other noncancellable contracts for the previous 90 days. Amstrad's investment position in Micron also gave its chairman a seat on Micron's board and, presumably, some say, in future product and marketing decisions. Because membership has its privileges, U.S. semiconductor users will have to weigh not only the risks of investing in U.S. Memories, but the possible risks of <u>not</u> getting involved.

Playing Catch-Up

The goals of U.S. Memories to select a site, build a new fab, and engage in volume production of 4Mb DRAMs by the first half of 1991 are not only extremely ambitious, they fly in the face of history. Based on data compiled by Dataquest's Semiconductor Equipment and Materials Service (SEMS), the average time involved for U.S. semiconductor companies to get from permit to full production is three to three and a half years. By contrast, the average for Japanese companies is about one year less than that. Of late, the United States has seen some notable exceptions to this three-year average, such as Cypress Semiconductor's Round Rock, Texas, facility and Sematech's fab facility in Austin, Texas. In fact, the first formal technology transfer made by Sematech to its member companies, many of which now are involved in U.S. Memories, was in the form of information pertaining to the design and construction of its fab.

Given this information, U.S. Memories' targeted first half of 1991 entry date into the 4Mb DRAM market is, at the very least, aggressive from a start-up company standpoint. Although the company's introduction date is ahead of the forecast peak year for 4Mb DRAMs, most Japanese DRAM manufacturers will be ramping up 4Mb DRAM production during 1990, and customer samples of 16Mb DRAMs will be available in 1991. Those companies that have reached peak volume production levels of 4Mb DRAMs by the time that U.S. Memories enters the market in 1991 could price their products too low for a late entrant to compete, particularly when the FMV price regulations are due to elapse in 1991 along with the rest of the U.S.-Japan Semiconductor Trade Arrangement.

RETURNING TO THE DRAM MARKET

In 1986, the U.S. semiconductor industry, represented by the Semiconductor Industry Association (SIA), and the U.S. government, represented by the Department of Commerce (DOC), took a controversial first step toward bringing the United States back into the commercial mainstream of commodity memory chip production. That first step was the creation of the U.S.-Japan Semiconductor Trade Arrangement--an agreement that was roundly criticized for bringing chaos to the world market for semiconductor memories, causing a two-tiered pricing system that forced U.S. systems companies to pay higher prices for key components than their Japanese competitors, causing shortages of 1Mb DRAMs, and ultimately benefiting the Japanese electronics industries through higher profit margins for memory chips.

Implicit in the arrangement was the belief that in "leveling the playing field" of semiconductor trade, the DOC would create an incentive for a resurgence of U.S. suppliers in the MOS memory market, particularly in the all-important segment of high-density DRAMs. From the federal government's standpoint, the rampant erosion of U.S. market share in this product segment would ultimately create an unhealthy dependence of U.S. electronics companies on Japanese semiconductor suppliers--a threat to national security. From the standpoint of U.S. semiconductor companies, the loss of the DRAM market meant not only exclusion from the largest revenue segment of the business, but the beginning of an insidious death spiral. Because advanced memory products serve to drive manufacturing process technology and equipment, lack of participation in this market would ultimately impair U.S. competitiveness in other segments of the chip market.

The return of U.S. semiconductor companies to high-volume, cost-competitive DRAM manufacturing was seen as a panacea for all of these concerns. Despite hand wringing in Washington and the invectives of their domestic customer base, however, U.S. chipmakers did not flock back to the DRAM business--the expanded DRAM commitments of Alliance Semiconductor, Micron Technology, and Motorola, notwithstanding. The reasons for this widespread reluctance, while not entirely comprehensible to those outside the industry, basically can be reduced to very pragmatic risk/reward considerations. To reenter the DRAM market at the leading edge, companies would have to play an incredible game of technology catch-up, invest in excess of $300 million dollars for a plant to run a highly complex process, and most likely hit full production during softening market conditions and the expiration of the trade agreement.

A QUESTION OF BALANCE

Positing a wholesale return to the DRAM business by U.S. semiconductor companies on the basis of the U.S.-Japan Semiconductor Trade Arrangement alone is like balancing on a one-legged stool. With its focus on pricing and market access, the arrangement addresses the environment that U.S. companies will compete in, not the basic infrastructure of the industry. The creation of Sematech, however, has since added another leg to the stool. Having as its charter the advancement of the domestic materials and equipment industries, Sematech links government labs, university research, semiconductor manufacturers, and equipment and material vendors in a way that promises to compress the cycle time between the identification of a next-generation integrated circuit and the availability of the equipment that will cost-effectively produce it.

U.S. Memories adds an important third leg to the stool on which major U.S. participation in the high-density memory market rests: the collective assumption of high costs and associated risks of large-scale memory manufacturing. Both Motorola and TI have addressed these issues through their alliance strategies, as well as through their participation in Sematech. Although the SIA and the American Electronics Association had spoken earnestly and often about the necessity of a user/vendor consortium effort, no one seemed very eager to put their money where their mouths were.

TOWARD VERTICAL INTEGRATION

U.S. Memories has dramatically changed all that by involving both semiconductor suppliers and users in the shared investment in leading-edge memory production. If successful, it will serve as a natural complement to Sematech by providing the high-volume manufacturing environment in which equipment and production techniques transferred by the consortium can be competitively proven. More importantly, U.S. Memories is a bellwether indicator that memory manufacture has begun to take on the aspects of vertical integration that characterize Japanese companies. Combined, Sematech and U.S. Memories link the research efforts of academia and industry, the process technologies and manufacturing experience of major semiconductor suppliers, the financial and end-user input of semiconductor customers, and the equipment and material foundation upon which the whole structure rests.

Although the realization of U.S. Memories' goals faces many significant hurdles, its very announcement indicates an important change in the culture of the U.S. semiconductor industry—no more business as usual. From now on, the industry will be less vulnerable to the charges that although it is willing to complain about trade practices, it is not willing to cooperate—that it is long on talk and short on action.

DATAQUEST CONCLUSIONS

Finally, U.S. Memories' creation points to an evolution in the relationship between government and industry in the United States. In just the past three years, the federal government has gone from trade intervention on behalf of industry, to investment in cooperative R&D unrelated to specific defense projects, to offering to play a seed-funding role in the development of a high-definition television (HDTV) consortium. Regarding U.S. Memories, the U.S. government can once again play a constructive role in the electronics industry by clearing away antitrust obstacles to the participation of leading industry competitors in a jointly owned manufacturing concern. In these endeavors, the federal government is involved in an evolution no less profound than the industry's—the evolution from referee to coach. The distinction is crucial to the future competitiveness of the U.S. electronics industry, for whereas the referee is concerned only that the rules of the game be followed by all its players, the coach has a vested interest in the outcome of the match.

Michael J. Boss

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Research Newsletter

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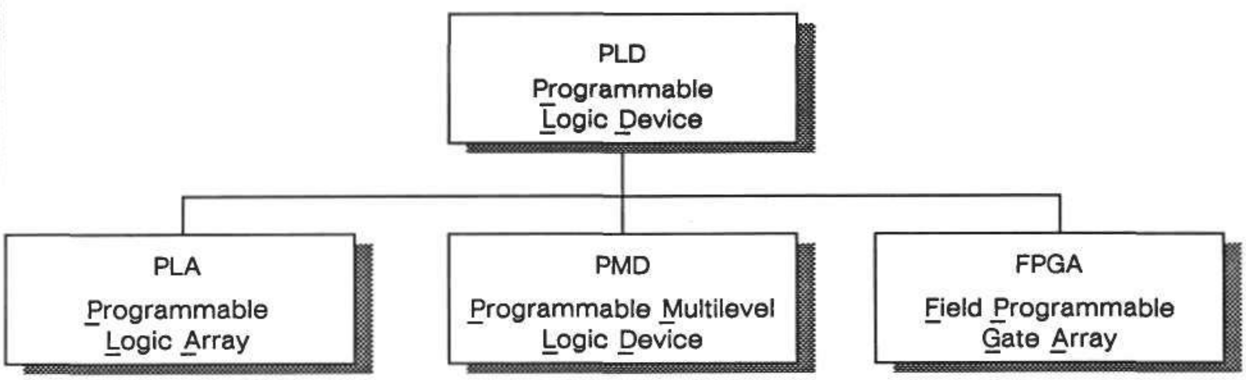
THE PLD EVOLUTION

SUMMARY

PLDs are going through a rapid evolutionary cycle. Fueled by high-density, high-performance process technologies, PLDs have evolved from low-density, low-functionality devices to products capable of implementing up to 9,000 equivalent gates. PLDs have grown from one to three basic architectures. The first is the traditional programmable logic array (PLA), which incorporates up to two levels of logic; the second is the programmable multilevel logic device (PMD), which evolved from the PLA but is capable of implementing multiple levels of logic; and the third, field programmable gate array (FPGA), traces its roots back to conventional gate arrays (see Figure 1). The latter two are capable of implementing very complex logic functions while still maintaining the inherent benefits of a PLD—low risk, low development cost, and quick time to market.

Figure 1

PLD Family Tree



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Source: Dataquest July 1989

Although the traditional PLA still provides more than 95 percent of the 1988 PLD sales revenue, Dataquest believes that it is time to define the other PLD categories and to track and forecast them separately from the PLA. Starting this process now will provide more meaningful analysis and forecasts to our clients, while resulting in only a modest modification to historical data.

SIMPLE QUESTIONS

Simple questions deserve simple answers. The answer to the question, "What is a PLD?" is, of course, "A PLD is a programmable logic device. Next question?" However, much confusion surrounds that "simple" question today. Dataquest's definition of a PLD is quite generic. Put simply, a PLD is any device containing logic elements, which, in its packaged form, can be programmed to implement an application-specific function.

This definition covers logic devices of all complexities. A device may contain dedicated I/O with fixed internal interconnects, or it may be able to configure any pin as an input, output, or I/O with complete flexibility in interconnecting the various elements within the device. It may contain a single logic array, or it may provide a nearly infinite number of internal logical levels.

The term PLD is meant to be as generic a descriptor as possible while still referring only to logic devices. Any use of broader terminology invariably would include other programmable devices such as PROMs, EPROMs, and EEPROMs. Inclusion of the word "logic" in the general descriptor specifically excludes these nonlogic products.

Another question is: "What are the various subgroups within the PLD category?" Dataquest has observed three, which are as follows:

- PLAs—These devices have fixed or preconnected architectures capable of providing up to two levels of logic without using additional input, output, or I/O cells or pins (e.g., PAL, GAL, PEEL, and 22V10-type devices). (PAL is a registered trademark of Advanced Micro Devices; GAL is a registered trademark of Lattice Semiconductor; PEEL is a registered trademark of Integrated CMOS Technology.)

- PMDs—These are devices with primarily fixed or preconnected architectures that can implement multiple levels of logic (more than two) without using additional input, output, or I/O cells or pins (e.g., PML, PEEL-Array, and MAX-type devices). (MAX is a registered trademark of Altera Corporation; PML is a trademark of Signetics.)

- FPGAs—These devices are based on programmable interconnect technology. Typically, they are capable of implementing multiple levels of logic, as is a PMD; however, they contain no preconnected routing channels (e.g., LCA- and ACT-type devices).

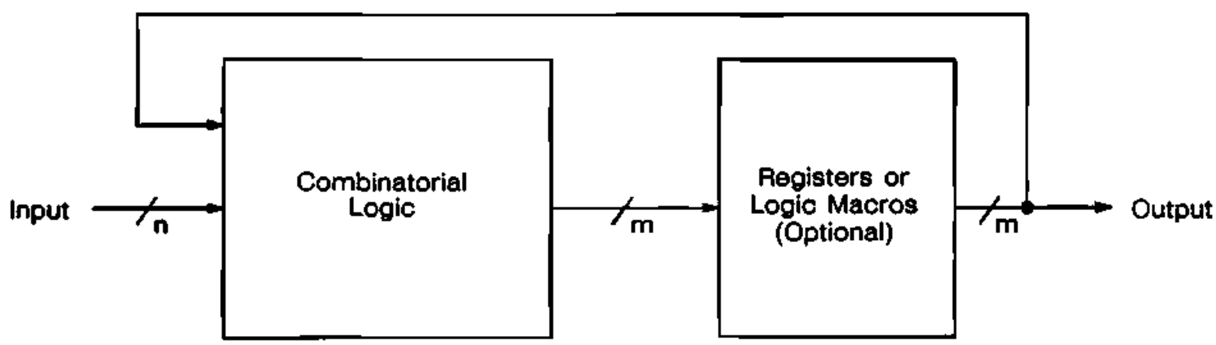
PLDs DEFINED

Programmable Logic Array (PLA)

PLA devices incorporate a one– or two–level programmable logic array with fixed interconnect paths (see Figure 2). This is the basic architecture of the original PLD product offerings, and it still is the primary contributor to the 1989 PLD sales revenue forecast of $898 million.

Figure 2

Typical PLA Block Diagram



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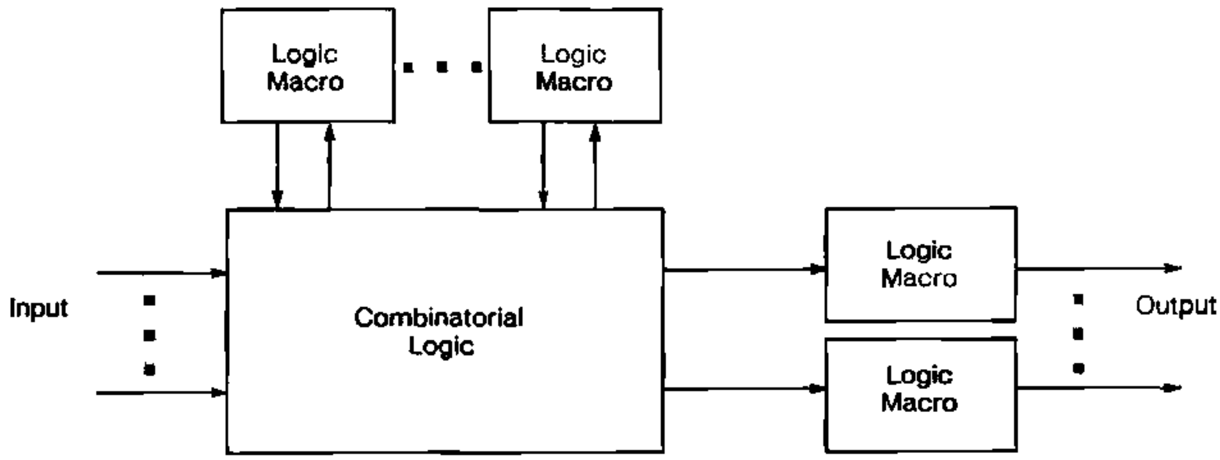
Programmable Multilevel Logic Device (PMD)

PMDs evolved from the basic PLA (see Figure 3). However, PMDs incorporate architectures to efficiently implement complex logic functions that cannot be addressed by the basic PLA. Typically, they are preconnected, as in a PLA; however, their architecture is not limited to an and–or array feeding a register bank. PMDs can implement multiple levels of logic (more than two) without sacrificing input, output, or I/O cells or pins. Simultaneously, these devices enjoy the benefits of a basic PLA in that they are easy to understand, development tools are available, and timing is predictable.

Figure 3

Typical PMD Block Diagram



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Source: Dataquest
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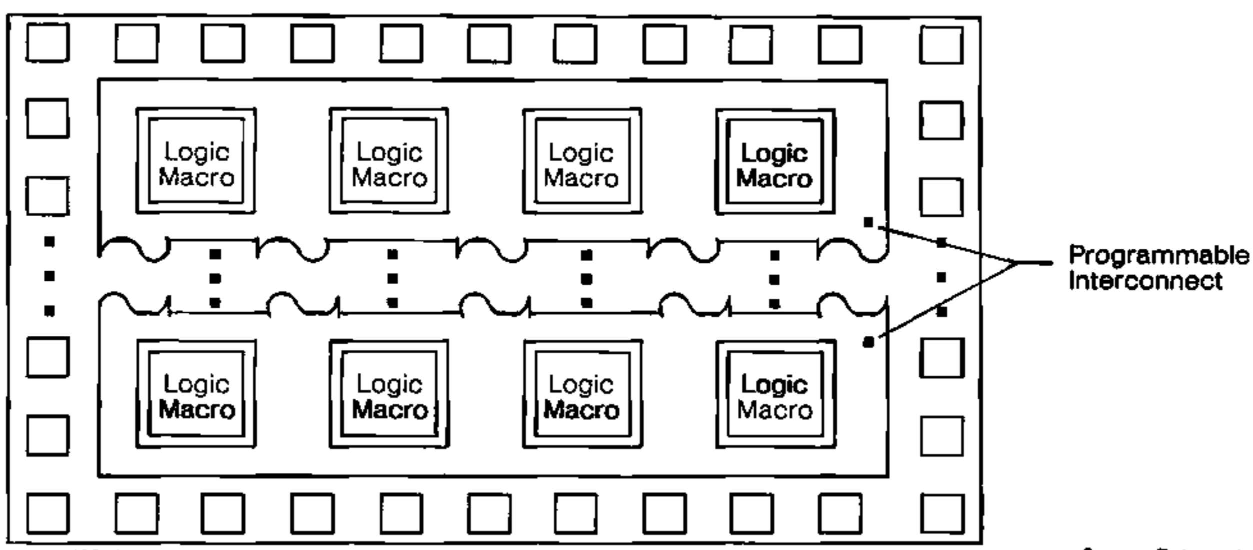
Field Programmable Gate Array (FPGA)

FPGAs incorporate an array of programmable logic elements that are not preconnected. Interconnections between the various elements are user programmable (see Figure 4).

Figure 4

Typical FPGA Block Diagram



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The programmable interconnect consists of predetermined levels of interconnect that can be connected to, or disconnected from, other interconnect lines as defined by the user. The device is analogous to a gate array in that it requires the use of the programmable interconnect in order to operate. The gate array analogy continues in that the performance of the device is a function of the fixed delays of the logic elements, as well as the variable delays of the interconnect paths. The interconnect delays in an FPGA can be quite substantial, as they consist of not only the resistance of the metal or polysilicon trace but also the resistance, capacitance, and propagation delay of the programmable switch used to connect one trace to another.

The development tools for FPGAs are somewhat more complex than those required for PMDs in that they must perform some form of AC timing analysis and require auto place and route software.

DATAQUEST CONCLUSIONS

The rapid transition of PLDs from low-density two-level logic replacements to devices that can implement multilevel logic functions of up to 9,000 equivalent gates demands that the PLD category be broken into finer resolution. The term "programmable logic device" (PLD) remains the generic descriptor, as any broader term does not exclude nonlogic devices. To reiterate, the PLD category easily breaks down into three distinct subcategories, as follows:

- Programmable logic array (PLA)
- Programmable multilevel logic device (PMD)
- Field programmable gate array (FPGA)

All future forecasting and product analysis will be based on these PLD definitions. Dataquest believes that this is the most comprehensive and meaningful way to analyze and forecast the PLD market.

Michael Boss
Jerry Banks

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Research Newsletter

SIS Code: Newsletter 1989
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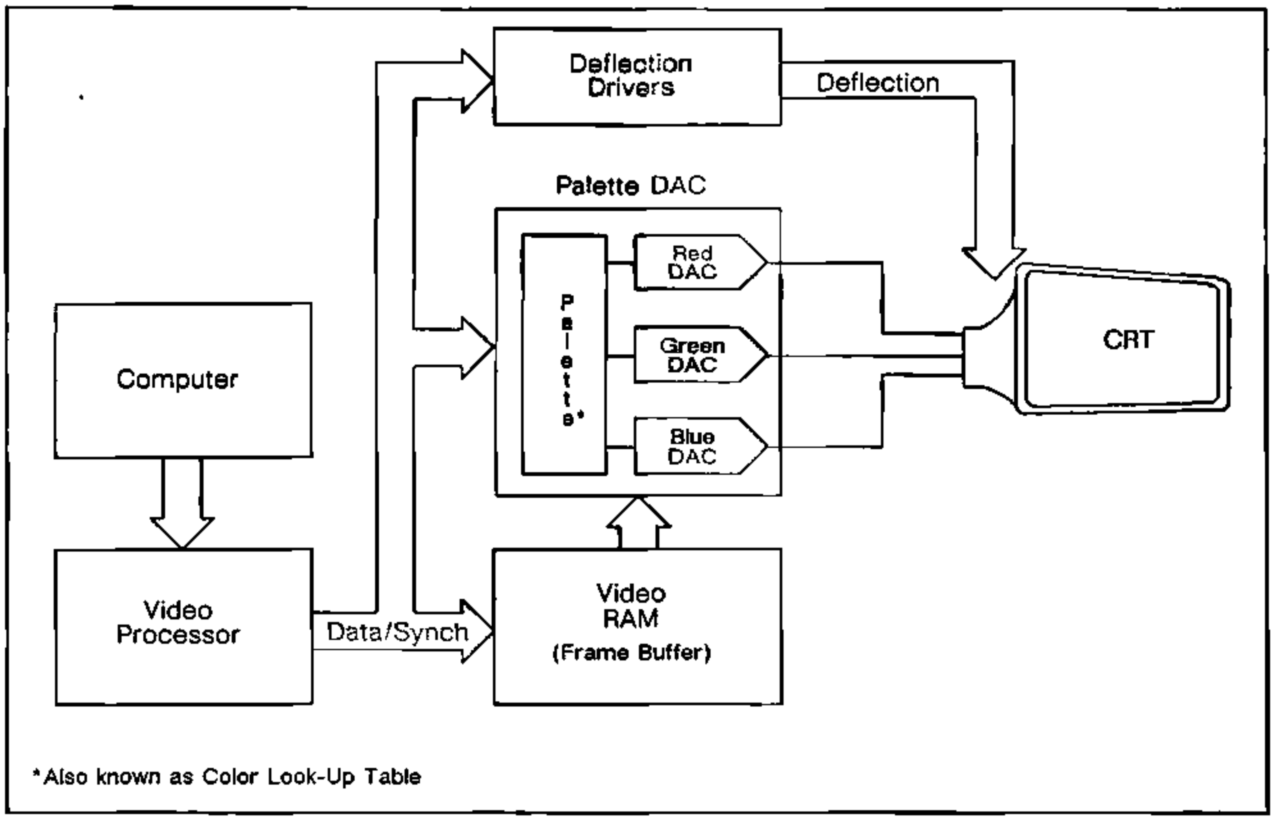
THE COLOR OF MONEY: ONE OF MANY HUES PROVIDED BY PALETTE DACs

OVERVIEW

A specialized digital–to–analog converter (DAC) that has become prominent in the graphics product market is known as the video DAC. Video DACs encompass a variety of products variously called RAM–DACs, palette DACs, and RGB DACs in addition to the more general term, video DAC. These products originated as high–speed, low–resolution DACs designed for creating images from computer–generated graphics data. As high–resolution computer graphics became more commonplace, the original hybrid triple DACs gave way to monolithic video DACs. More recently, these have been combined with RAM to create on–chip color lookup tables (CLUTs). This is the so–called color palette DAC, or RAMDAC. The introduction by IBM of the VGA graphics standard for PS/2 PCs, as well as the growth in graphics workstations, has greatly expanded interest in analog color graphics generation. As any color is created by combining the red, green and blue primary colors, analog signals are needed to modulate the intensity of the primary colors to create the wide range of hues needed for realistic graphics. Figure 1 shows a typical application of a triple DAC in a graphics application.

Figure 1

Palette DAC Application



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THE MARKET

The video DAC product market has exploded in the past year with rapid growth of workstation graphics products and the VGA standard in the PC arena. Video DACs have grown to a substantial portion of the monolithic DAC market, as shown in Figure 2. Presently, video DACs represent one-third of the market, and they are expected to grow to more than 41 percent of the monolithic DAC market by 1993.

Figure 3 shows unit sales breakdown by conversion speed. In 1988, the bulk of the video DACs consisted of lower-resolution applications such as VGA (640 x 480). This mix will change dramatically during the next five years, as the faster products needed for improved resolution become more available and at a lower cost. Super VGA (800 x 600) and other higher-resolution PC standards, such as IBM's 8514/A adapter and Compaq's noninterleaved graphics (both at 1,024 x 768 resolution), as well as the high-performance graphics used in workstations, will drive this resolution race. Figure 4 relates the conversion rate to the screen resolution in pixels (number of pixels per line times number of lines).

Figure 2

DAC Market by Segment

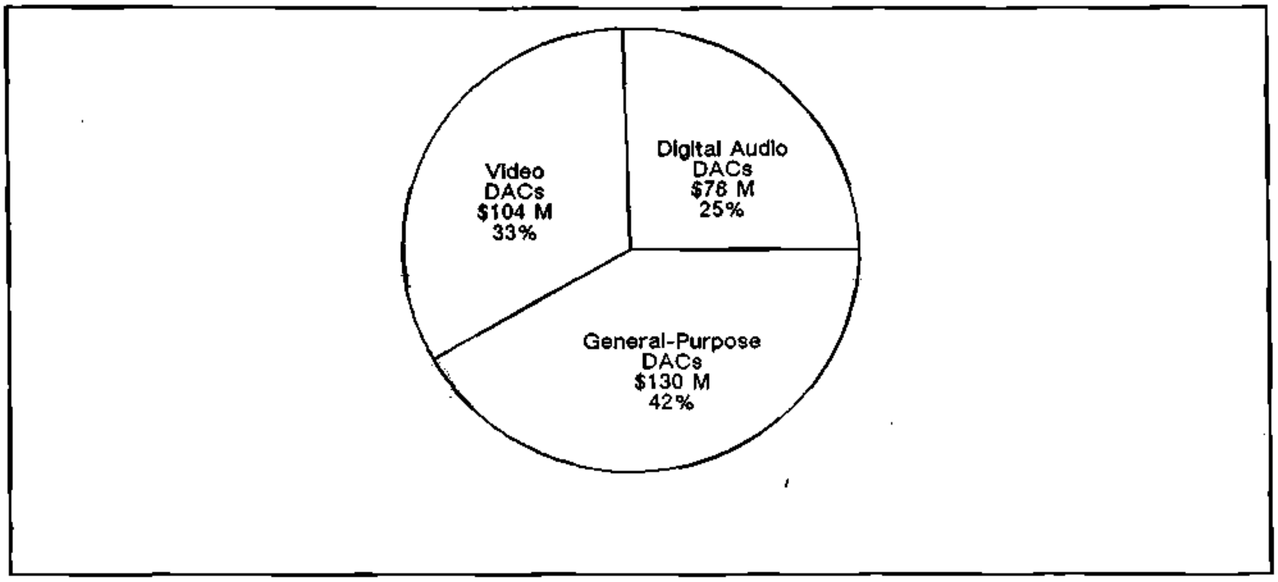

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Figure 3

1988 Video DAC Unit Sales by Conversion Rate

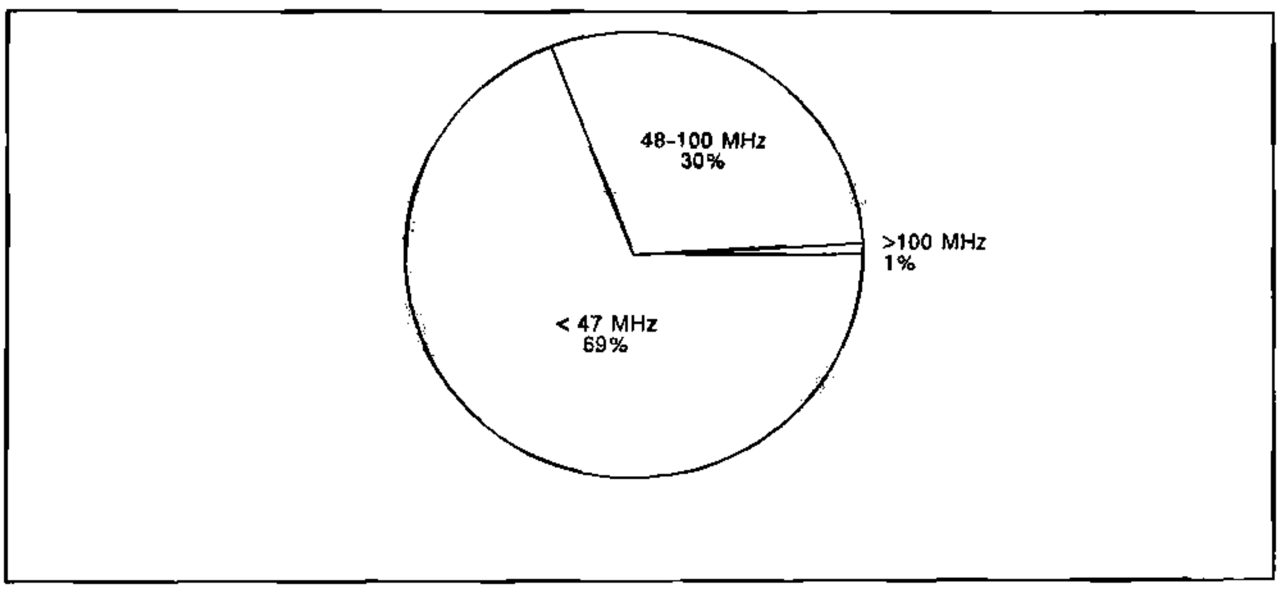

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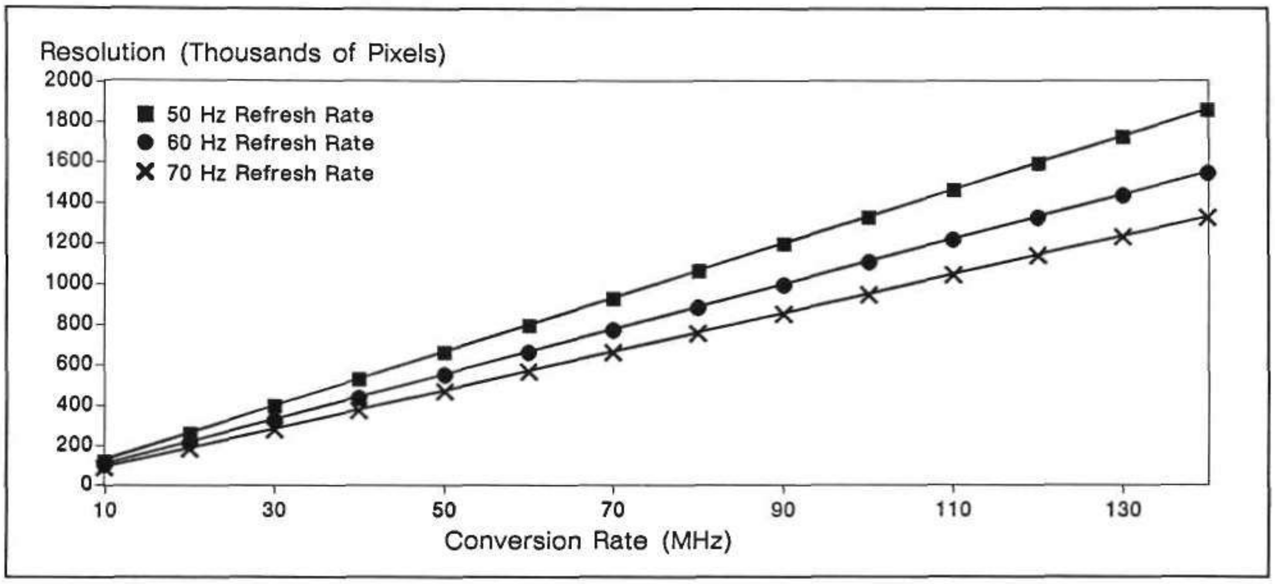
Figure 4

Video DAC Resolution versus Conversion Rate



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FORECAST

Growth in graphics workstations and greater graphics emphasis both in PCs and PC applications is widening the application of these products while pressing conversion speed higher. Figure 5 shows the anticipated growth in video DAC revenue from 1988 through 1993.

Although we forecast revenue to increase by a compound annual growth rate (CAGR) of 25 percent during this five-year period, we expect the number of units to grow even faster, by more than 41 percent CAGR (see Figure 6). Such growth may be a signal that significant price erosion can be expected.

Figure 5

Video DAC Revenue Forecast 1988–1993

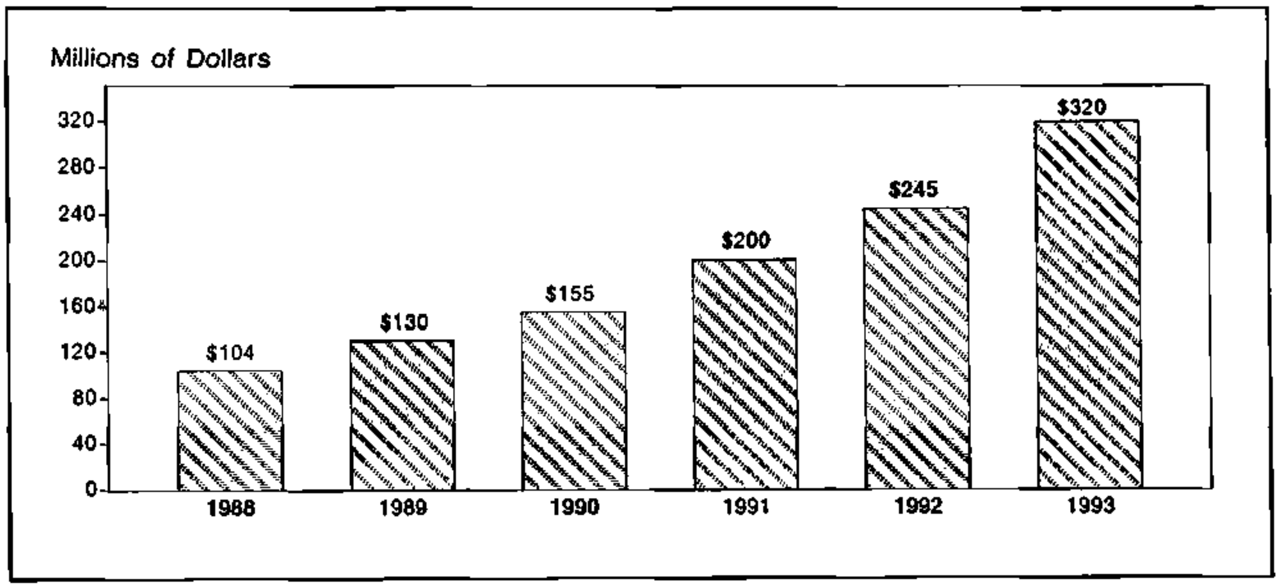

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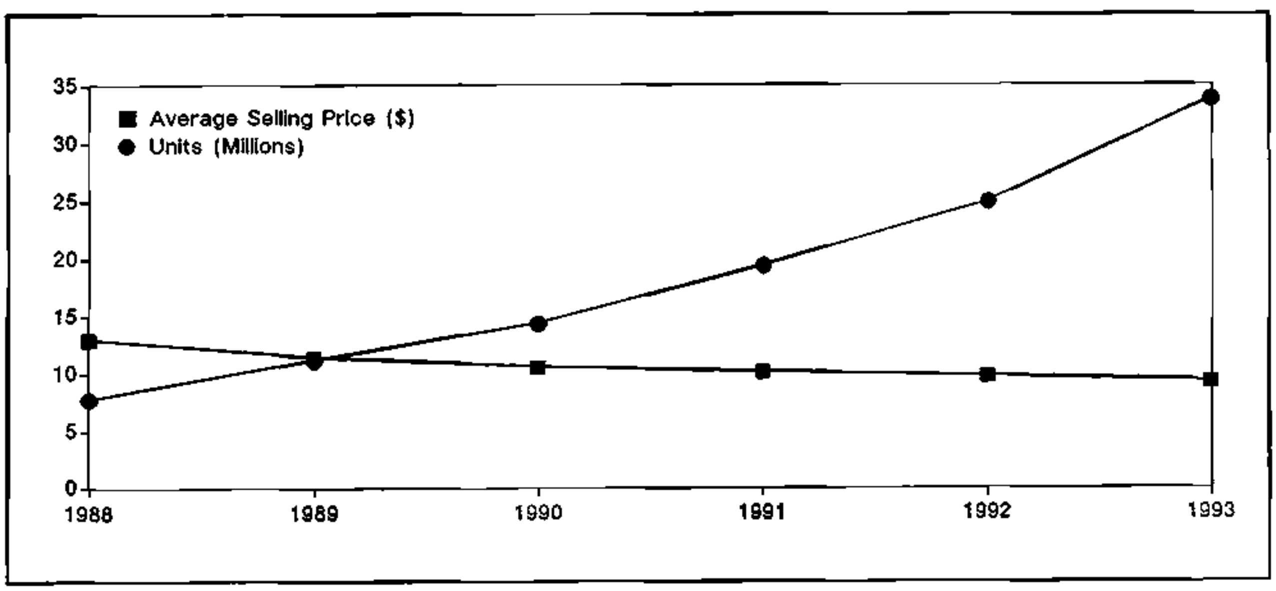
Figure 6

Palette DAC Unit and ASP Forecast



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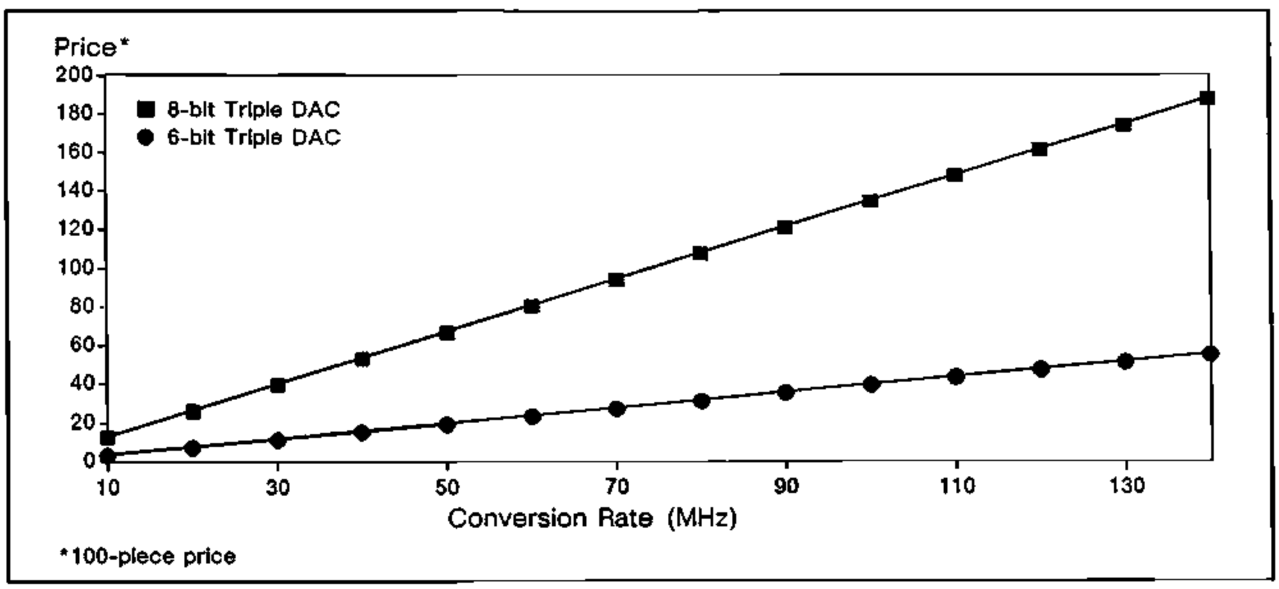
PRICING

Video DAC pricing varies widely. Although pricing is related to the conversion rate, the product features, and the size of the lookup RAM (the palette), the conversion rate appears to be the dominant pricing factor. Figure 7 shows an approximate pricing curve for 8-bit and 6-bit triple palette DACs by conversion rate (1988 prices, 100 pieces). The 8-bit pricing curve can be described as approximating a price line of $1.35 per megahertz—at 100 pieces, large-quantity pricing is approximately one-half of this. The 6-bit palette DACs follow a similar trend line, but at approximately 40 cents per megahertz, also at 100 pieces.

Figure 7

Palette DAC Pricing versus Conversion Rate
(8-Bit Triple-Palette DAC, 100-Piece Price)
Approximate Trend Lines



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Palette DACs have seen considerable price erosion in the first half of 1989 as new suppliers have entered the market. Price erosion will occur for all of these products, but the 8-bit triples are expected to show the most dramatic changes as 8 bits becomes the graphics standard. Dataquest believes that the 8-bit products will show more than a 50 percent price decline during the next five years. This price erosion could be accelerated if high-definition video appears in the consumer market. These changes in product resolution will effectively mask the ASP erosion that would otherwise be expected if resolutions and product mixes (PC graphics to workstation graphics) remained constant.

SUPPLIERS

Suppliers presently in the video DAC market include the following: AMD, Analog Devices, Brooktree, Cirrus Logic, Harris, IDT, Inmos, Intech, Motorola, National Semiconductor, Philips, Signal Processing Technologies, Inc., Silicon Systems, Triad Semiconductor, and VLSI Design.

SUMMARY

This product is in one of the fastest lanes of IC growth. Being involved in computer graphics, CAD/CAM, high-definition TV, medical imaging, and other leading-edge product areas makes the future for these products bright indeed. With a large number of traditional DAC suppliers and many mixed-mode ASIC suppliers entering the market, however, the outlook is for fierce competition, eroding prices, and the palette DAC product's rapid evolution. Higher conversion rates and lower glitch energies will give improved definition, while larger palettes, overlay palettes, and other interface and control enhancements will add features to the product. Vendors not willing to invest in developing high-performance, highly integrated video products will find tough going in the market.

Fred Jones
Gary Grandbois

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Research Newsletter

THE U.S. SEMICONDUCTOR MARKET: A BUMP AT THE END OF THE SOFT LANDING?

SUMMARY

Dataquest has predicted that over the next year, the U.S. semiconductor industry will achieve the industry equivalent of what has been referred to in macroeconomic terms as a "soft landing." Although industry growth will moderate substantially from that of 1987 and 1988, the factors that will bring about this moderation will be very different from the dynamics of the last industry recession, as contrasted in Table 1.

Given the basic differences in the industry dynamics of 1985 versus 1989, we believe that the nadir of the industry's latest cyclical downturn will be far less extreme than that of the last. Nevertheless, there are now some indicators in the U.S. semiconductor market that presage a rougher than expected landing during fourth quarter 1989. This newsletter provides a look at the current U.S. market environment, based on the most recent forecast efforts of Dataquest semiconductor analysts. In particular, this newsletter focuses on the following industry dynamics:

- Trends in the U.S. economy
- The outlook for the computer market
- End-user inventories and procurement plans
- Semiconductor price and market trends

ECONOMIC OUTLOOK

A growing consensus among U.S. economists is that the longest economic peacetime expansion on record is slowing down. This slowdown will be reflected in real gross national product (GNP) growth of 3.0 percent in 1989 versus the nearly 4.0 percent growth witnessed in 1988. The U.S. economy will further slow in 1990, with GNP growth falling to 1.8 percent, according to economists at The Dun & Bradstreet Corporation. The forecast for 1991 calls for renewed vigor in the economy, with GNP growing 3.5 percent over 1990.

Dataquest believes that most of the economic growth that will take place this year occurred during the first quarter. Despite the strengthening recently seen in the dollar, Dun & Bradstreet

TABLE 1
Comparison of Recession Characteristics 1985-1986 versus 1989-1990

1985-1986	1989-1990
Drastic declines in electronic equipment production	Slower growth in electronic equipment production
Excessive end-user inventories	Tighter inventory control by end users
Rapid expansion of manufacturing capability/excess capacity	Upgrading of capability and improvement in ratio of revenue-to-investment in property, plant, and equipment
Decline of average selling prices (ASPs) below anticipated learning curve	Slower ASP decline

Source: Dataquest
October 1989

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economists believe that the large U.S. trade deficit (forecast to be $110 billion in 1989 versus $120 billion last year) should continue to keep downward pressure on the dollar. Should the dollar fall, however, interest rates will likely increase—directly because of the Federal Reserve's attempts to stabilize and support the dollar, and indirectly because of acceleration in inflation resulting from higher prices for imported goods.

Despite this guarded outlook, there are signs that the U.S. economic slowdown will result in a soft landing rather than a crash. Among the most encouraging of these signs are the following:

- Reduced job creation rates and consumer spending growth in the first half of 1989 should take some of the steam out of inflationary pressure.
- Although inflation rates jumped upward earlier in the year, some of that acceleration was due to more transitory factors such as oil and food prices.
- Export and investment sectors of the U.S. economy should remain relatively strong. As a result, equipment investment spending will be one of the strongest areas of the economy. Until the dollar and interest rates stabilize, however, investment in additional plant capacity will probably lag behind increases in equipment sales to both domestic and foreign manufacturers.

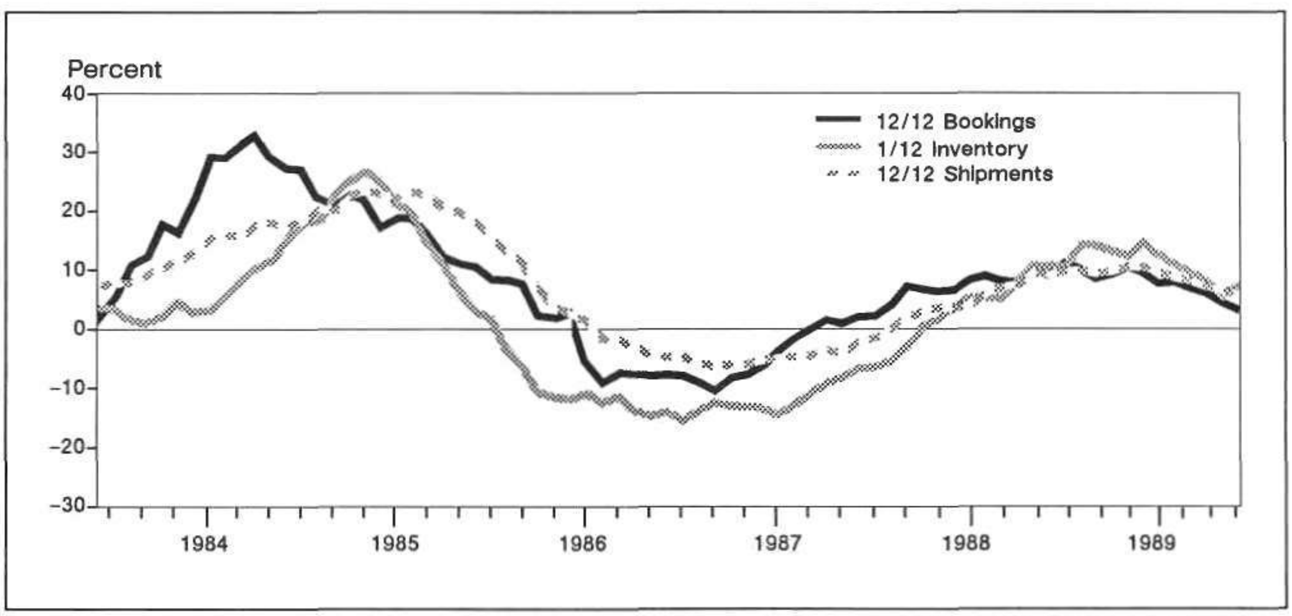
A recently published Dun & Bradstreet Business Expectations Survey seems to confirm these economic assumptions. Expectations for higher third quarter sales are down slightly from second quarter survey results. Expectations for selling price increases, profit gains, and inventory additions were similarly reduced. The latest optimism index for sales fell from 74 in the second quarter to 67 in the third—its lowest level since mid-1987.

Consistent also with the soft landing scenario, the Dun & Bradstreet survey reveals that inflation expectations are the lowest since the end of 1987. In addition, the survey notes that firms are not as adamant about adding to their inventories as they were in the second quarter, and hiring plans are slightly off from their 1988 peaks. If factors such as these can keep the lid on inflation, the U.S. economy may yet avoid interest rate hikes of a degree that would put an end to the 80-plus-month-old expansion.

ELECTRONIC EQUIPMENT SLOWDOWN

Monthly data from the U.S. Department of Commerce (DOC) shows that with the exception of radio and TV, bookings and shipments rates of change for major electronic equipment segments have either moderated or declined when measured on a 12/12 basis (see Figure 1). The DOC data for

FIGURE 1
Computers and Office Equipment Rate of Change



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Source: U.S. Department of Commerce

July shows a continuing slowdown in annualized shipments of computers and office equipment—from a 12/12 growth rate of 7.0 percent in June to 6.3 percent for July. More disturbing, however, is the fact that computer and office equipment orders, on an annualized basis, have fallen from a growth rate of about 10 percent in January of this year to less than 4 percent in July.

Looking at quarterly DOC data for computer shipments and orders, the situation looks even more grim. Quarterly growth rates in computer and office equipment shipments have been declining steadily since the beginning of this year, with the three-month period ending in July running only 3.9 percent above the same period in 1988. Relative to the same three-month period last year, quarterly bookings for computers and office equipment have declined nearly 3.0 percent from last year. At the same time, computer inventories have been increasing since the end of last year, with the average number of weeks of inventory running at just over nine weeks of sales—its highest level in two years.

THE PC OUTLOOK

Personal computer production currently accounts for 11.5 percent of North American chip consumption. Dataquest forecasts that the value of North American PC production in 1989 will be nearly $21 billion—a slightly more than 10.0 percent increase over last year.

During the next five years, we forecast North American PC production growth to peak in 1992 at 13.9 percent, as the next generation of systems is brought to market. We expect workstation growth to peak in 1989 at 38.4 percent, as unrelenting competition puts pressure on prices and the installed base widens.

Price pressure at the systems level will be mirrored in the semiconductor industry, even for chip suppliers at the leading edge of the micro, logic, and memory markets. Among the harbingers of harder times recently reported by Dataquest analysts are the following:

- LSI Logic announced that it expects to report a loss for the quarter ending in September of approximately $2 million to $3 million. This loss is attributed primarily to underutilization of capacity, pricing pressures, and disappointing revenue from its Headland Technology affiliate—a supplier of chip sets to the PC market.
- Chips & Technologies, a leading chip set supplier, has also lowered its earnings expectations, citing general softness in the PC market.
- Intel has warned that its third quarter financial results would be negatively affected by slower than expected sales of the 80386 microprocessor and that earnings could fall below those reported for the second quarter.

INVENTORY MANAGEMENT: THE SEESAW EFFECT

The infamous chip shortages of 1988 constrained the production capabilities of many computer manufacturers, and with growing availability of semiconductor products since fourth quarter 1988, computer inventories rose dramatically. At the same time, computer companies have worked down their order backlogs to very low levels. As a result, inventory management has become crucial.

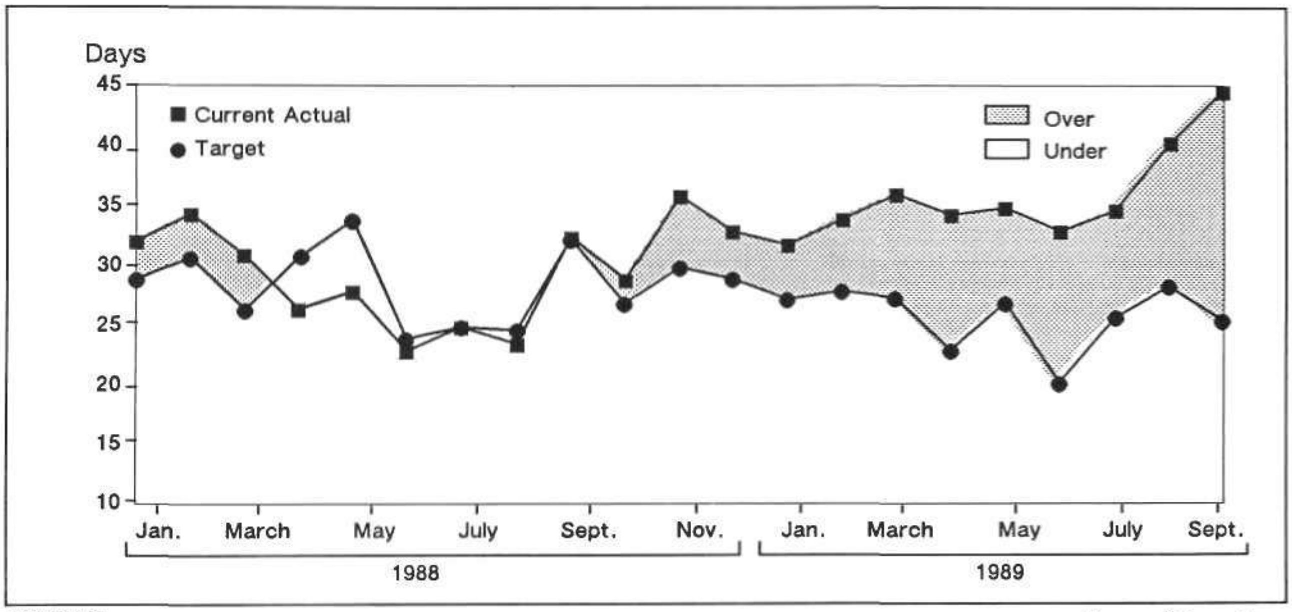
Given this climate of more carefully managed inventories, greater availability of key components, and declining ASPs, semiconductor users will rely more heavily on spot market buys and will order products closer to the date of scheduled production to minimize their inventory costs. Inventory control has now become as important an issue as price.

Dataquest's monthly survey of electronics original equipment manufacturer (OEM) procurement plans reveals that in spite of fairly static targets between the months of June through September, actual levels of semiconductor inventories have continued to rise for electronics OEMs. As shown in Figure 2, actual inventory levels rose in September to 44.8 days from 40.3 days in August. The good news is that both electronics OEMs as a whole and computer OEMs in particular have been able to reduce their non-DRAM inventory levels, which means that DRAM inventories are now the primary cause of the current disparity between target and actual semiconductor inventory levels.

ORDERS AND PRICE TURN DOWN

Not surprisingly, respondents to Dataquest's September procurement survey indicated that they would lower their September orders by 29 percent compared with the previous August. When indexed to December 1988, September's procurement survey marks the third straight month of order reductions. The fact that semiconductor buyers are

FIGURE 2
Actual versus Target Inventory Levels
Electronics OEMs



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Source: Dataquest
October 1989

seeing a deceleration in their systems sales and are attempting to keep their semiconductor inventories in line with their target levels is reflected in the recent relationship between semiconductor orders booked to shipments billed (Figure 3). In September, the U.S. book-to-bill fell below unity for the third consecutive month, reaching its lowest point since October 1988.

Despite the continuing decline in the level of semiconductor orders since April of this year, actual shipments to the U.S. market in August were $1,239.4 million—a 15.3 percent increase over the previous month and a new record for a four-week month. Shipments billed in the U.S. semiconductor market reflect an increased level of "turns" business, which is consistent with the behavior pattern of inventory-conscious semiconductor buyers. On a three-month average, shipments to the U.S. market have declined for the last three months in a row.

Given the buyers' market mentality of the current U.S. semiconductor business, semiconductor suppliers should expect to see more spot orders, an increase in turns business, and therefore more intense competition and pricing pressure. As shown in Figure 4, the downward trend in semiconductor ASPs overall has accelerated during the late second-early third quarter.

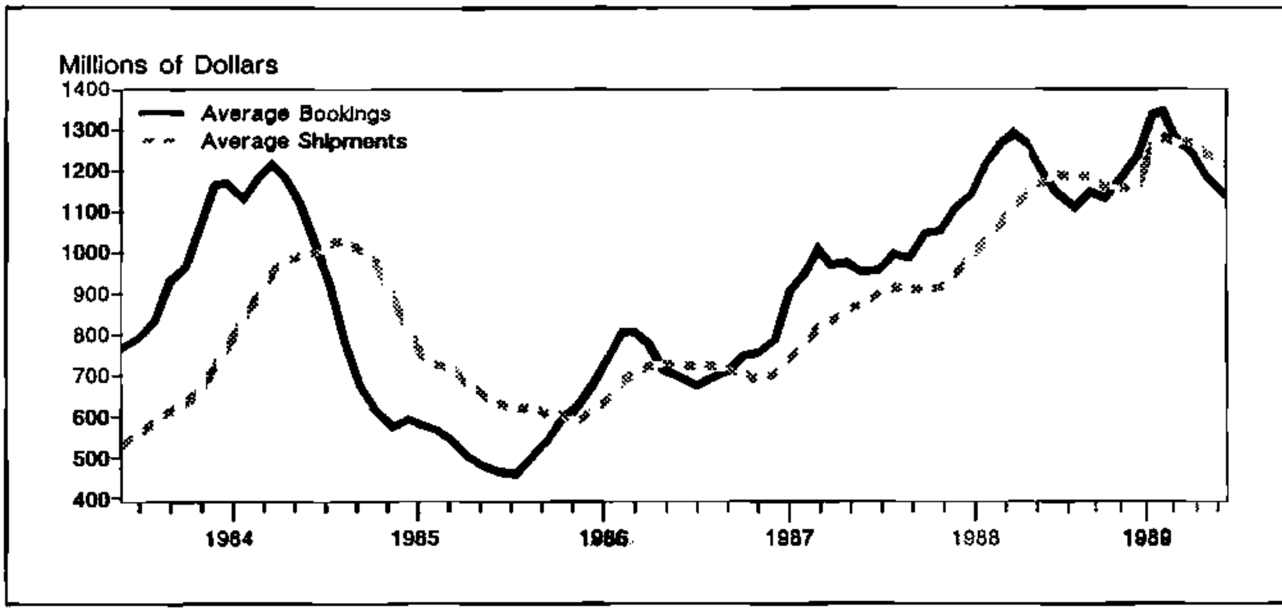
PRODUCT SUMMARIES

The booming semiconductor market of 1988 was founded primarily on very strong growth in the memory market and to a lesser degree, on microprocessor market growth. Trends for the first half of 1989 mark this year as a period of declining semiconductor prices and shorter lead times. Figure 5 illustrates quarterly changes in North American semiconductor consumption by major product segment, based on Dataquest's most recent semiconductor forecast. A summary of pricing and shipment trends for MOS memories, microcomponents, ASICs, and standard logic follows the figure.

Memory

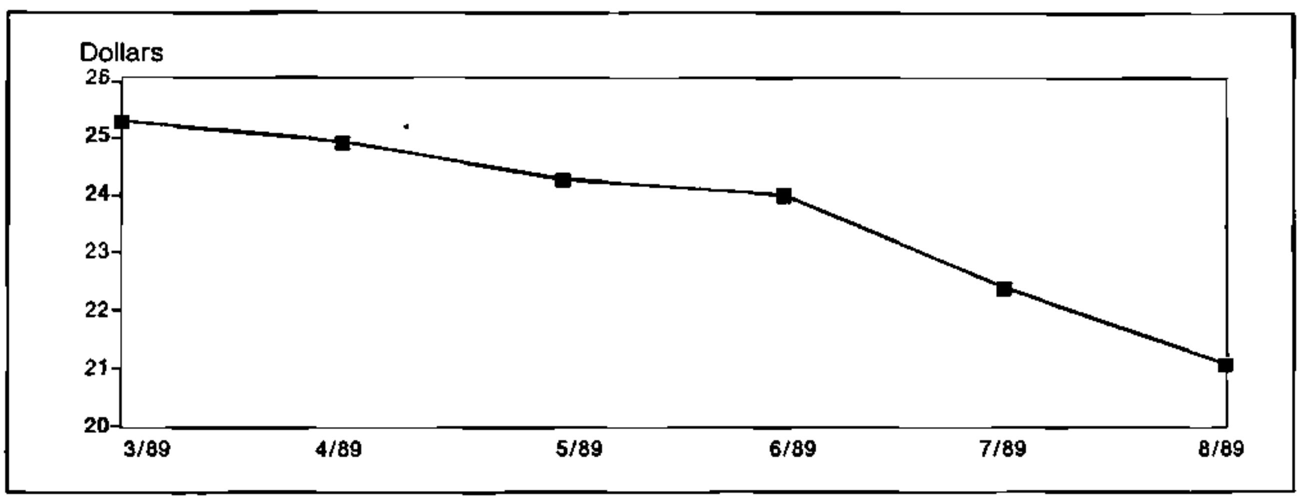
Events in the DRAM segment of the memory market continue to set the stage for memory price and lead-time declines. For the more than two years since the commencement of volume production of 1Mb DRAMs in first quarter 1987, the price remained relatively high (about ¥2,000 based on a yen/dollar exchange rate of 144). In April of this year, a gradual downward trend was observed, which accelerated in the July time frame, reaching a range of ¥1,800 to ¥1,700 (based on a yen/dollar exchange rate of 130).

FIGURE 3
Three-Month Average of U.S. Semiconductor Market Orders Booked versus Shipments Billed (Millions of Dollars)



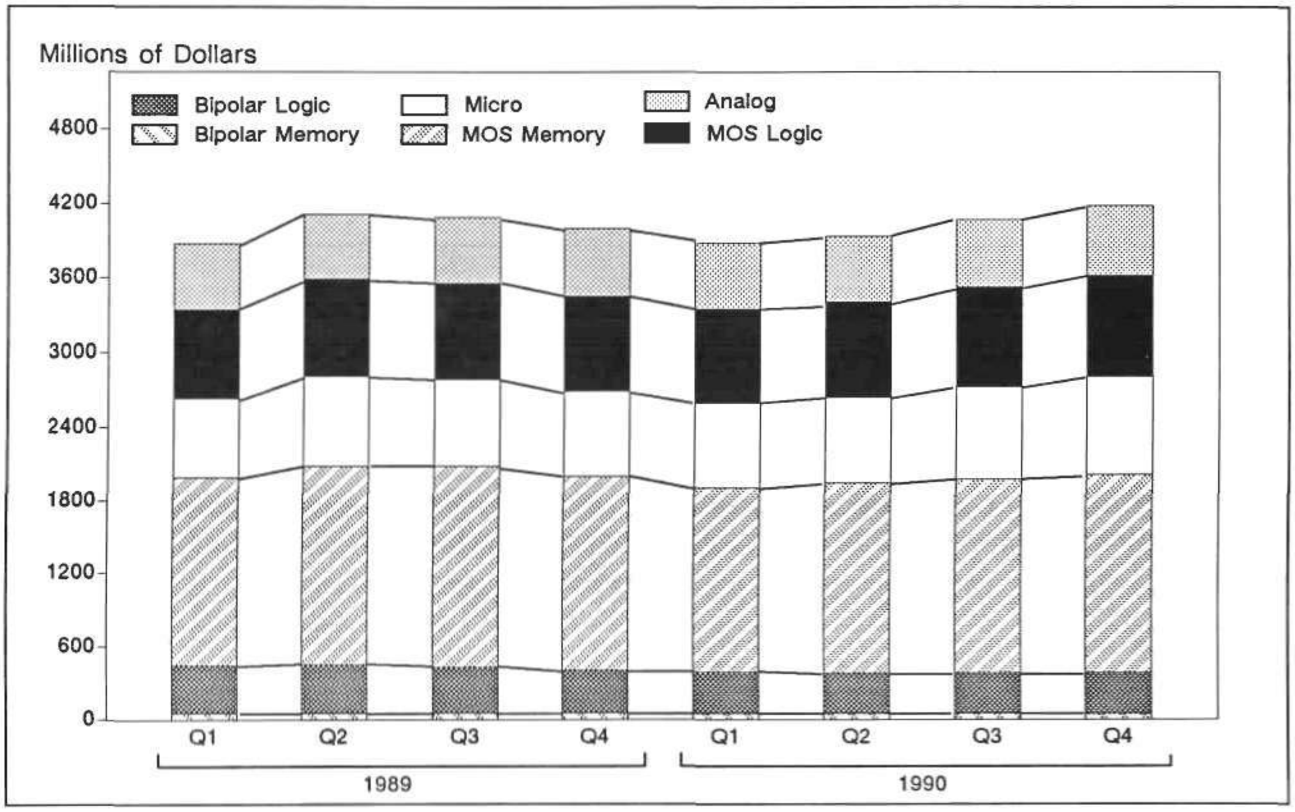
0005231-3 Source: WSTS

FIGURE 4
Semiconductor ASPs



0005231-4 Source: U.S. Department of Commerce World Semiconductor Trade Statistics Dataquest October 1989

FIGURE 5
North American Semiconductor Consumption by Major Product Segment (Millions of Dollars)



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Source: Dataquest October 1989

In an effort to avoid a precipitous decline in DRAM pricing and excessive supplies of such devices, the response by Japanese suppliers has been to try to manage their memory business—in this case by shifting some of the previously planned capacity expansion from 1Mb DRAMs to 4Mb DRAMs or SRAMs. The efforts by first-tier Japanese DRAM suppliers to preserve the relatively high prices of 1Mb DRAMs will also be tempered by increasing market participation from some of the smaller Japanese 1Mb DRAM manufacturers, as well as by the Korean suppliers, who are aggressively investing in 1Mb DRAM production capability. Samsung, for instance, has succeeded in gaining market share through an aggressive pricing strategy.

However, another trend that has emerged of late is a building of inventory by suppliers of the 1Mb DRAM. The inventory increases have been most conspicuous in North America, South Korea, and Hong Kong, although no world region has escaped this development as of midyear 1989. These market conditions mean that there is ongoing pressure on suppliers to reduce 1Mb DRAM inventories. Consequently, a continued decline in prices is expected to put the volume contract price of the 1Mb DRAM in the United States at about $10 in the fourth quarter. Most Japanese DRAM suppliers have responded to the excess supply of 1Mb DRAMs by cutting production 10 percent or more in an effort to control the supply/demand situation and hence salvage their margins.

Microcomponents

The slowdown in U.S. computer shipments has translated into downward pricing pressure in commodity 8- and 16-bit microprocessors, as well as the high-speed 16- and 32-bit devices. Lead times now range from 4 to 12 weeks, with the most dramatic lead-time improvement occurring in the 80286 segment. Some further shortening of lead times is anticipated. Shortened lead times combined with a more cautious business outlook on the part of some semiconductor suppliers will lead to further price declines as these companies attempt to lure contract business back from distribution channels. With respect to logic chip sets, the increased number of competitors combined with slower growth in PC unit shipments is leading to severe ASP declines in this area.

ASICs

Nearly all ASIC devices are declining in price this year with the exception of the 3-micron gate array, an older product now being displaced from systems. CMOS gate arrays are declining in terms of both price per gate and nonrecurring engineering costs, with the trend now quite apparent in the 2.0-micron and 1.5-micron segments. Some gate array suppliers are competing aggressively on pricing against manufacturers of cell-based ICs as part of the current battle for system design-ins. Pricing on the gate array front has led to more aggressive pricing in MOS PLDs in an attempt to narrow the gap in prices of PLDs versus gate arrays. Low-end bipolar PLDs are currently experiencing severe pricing pressure.

Cell-based IC prices are decreasing at a more moderate pace, but Dataquest believes that mounting competition from embedded array products (in which a memory cell is embedded in the base wafer) will result in serious pricing pressure during 1990.

Standard Logic

During the first half of 1989, the supply of standard logic products has exceeded demand, with corresponding downward pressure on pricing. The downward trend in pricing for the mature bipolar and HCMOS products has quickened, while pricing for newer families such as the 74AS and 74ALS should continue to decline at an aggressive rate as volume grows. Demand for bipolar standard logic in small-outline packages has bolstered its pricing, and the product is currently subject to extended lead times.

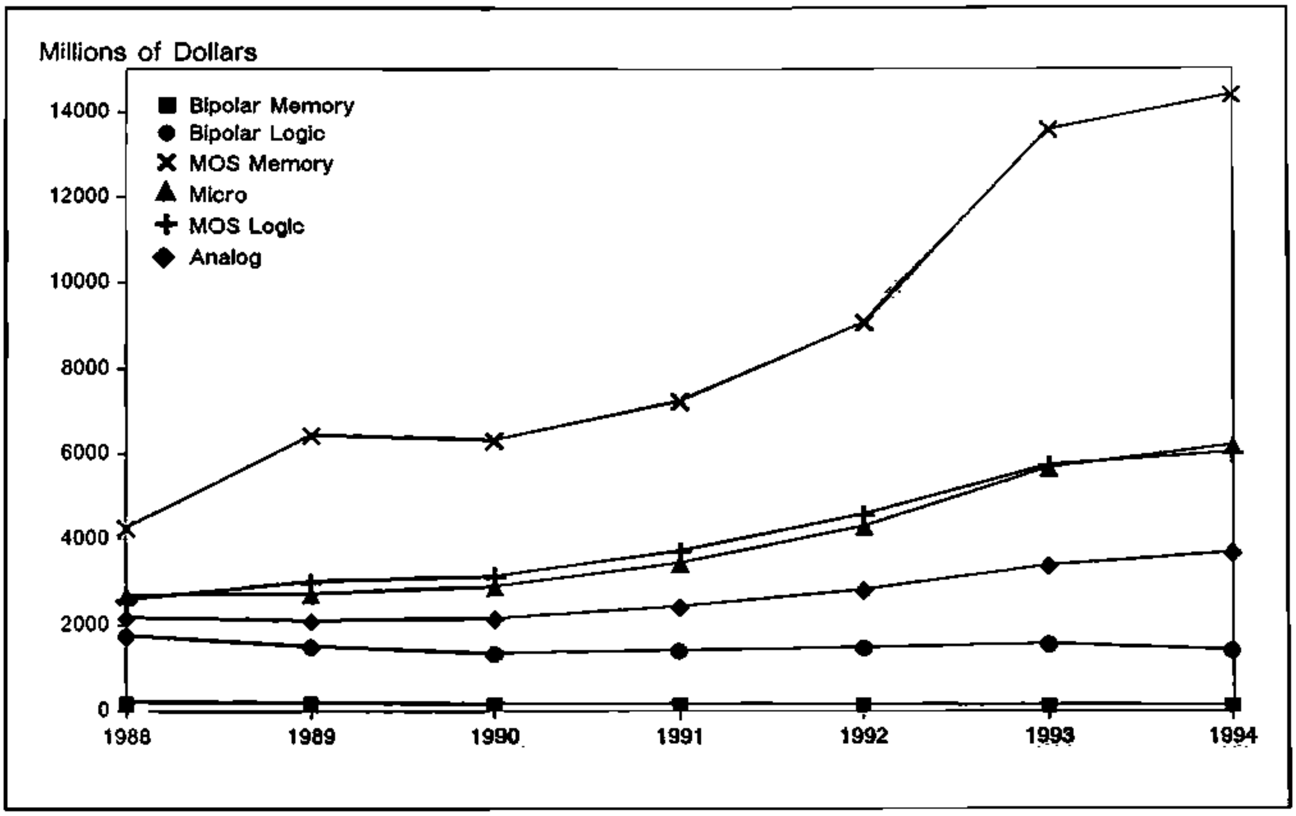
DATAQUEST CONCLUSIONS

Based on our most recent forecast data, Dataquest believes that the U.S. semiconductor market has entered into a slowdown as of third quarter 1989. The current recession in the U.S. semiconductor industry will be marked by negative quarterly growth from third quarter 1989 through first quarter 1990, with an upturn beginning in the second quarter of that year. As illustrated in Figure 6, this upturn will herald four successive years of industry growth that will positively affect all major product segments, with the exception of bipolar memory ICs.

Figure 6 reveals the good news-bad news message behind Dataquest's current forecast. The good news is that overall, the current industry downturn will be mild and brief. The bad news is that the modest growth that does take place between now and 1991 will be largely attributable to leading-edge MOS memory devices and segments of the MOS logic business, the market dynamics for which appear more volatile as 1989 progresses. This means that for many semiconductor companies, there will be little comfort to be derived from Dataquest's relatively sanguine outlook. Compared with the last industry downturn in 1985 and 1986, however, the effects of the current slowdown will more likely lead to belt-tightening than massive financial loss. Product line and regional market presence will be important factors in how well a semiconductor supplier weathers the next four quarters.

Michael Boss
Trish Galligan

Figure 6
North American Semiconductor Consumption by Product Segment 1988-1994 (Millions of Dollars)



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Source: Dataquest
October 1989

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Research Newsletter

PMT Executive Memo

MOTOROLA ANSWERS IBM'S CLARION CALL

SUMMARY

On October 25, 1989, IBM dedicated its Advanced Semiconductor Technology Center (ASTC) in East Fishkill, New York—a facility that in 1991 will house the first privately owned synchrotron storage ring for X-ray lithography. During the dedication ceremonies, which were attended by U.S. Commerce Secretary Robert A. Mosbacher as well as other industry, government, and academic leaders, IBM issued a call for government and industry cooperation in X-ray lithography "because of the enormous capital costs associated with the new technology" and offered to share its "X-ray capability with selected firms."

IBM's call for a national X-ray lithography program was heeded by the largest U.S. semiconductor supplier. Motorola became the first, and so far only, company to announce its collaboration with IBM on the development of practical X-ray tools for the manufacture of devices based on geometries of 0.25 micron and below. This announcement is important from a number of perspectives, including the following:

- The IBM/Motorola agreement increases the U.S. resources now being applied to X-ray lithography advancement.
- The agreement underscores IBM's increasing role in strengthening the U.S. semiconductor industry infrastructure.
- The agreement highlights the importance of nonoptical lithography techniques to the future of ultralarge-scale-integration (ULSI) IC development in the United States.

With respect to these points, this newsletter provides Dataquest clients with details of the IBM/Motorola agreement, reviews the potential impact of synchrotron orbital radiation (SOR) in the manufacture of future-generation semiconductor devices, compares the X-ray lithography efforts now under way in the United States with efforts in other regions, and takes a closer look at IBM's role in SOR through its new ASTC facility.

THE IBM/MOTOROLA AGREEMENT

Under the terms of the 21-month agreement, Motorola will pay IBM a "nominal" sum of money and will assign six to eight engineers to work at the National Synchrotron Light Source at Brookhaven National Laboratory in Upton, New York, which currently houses a synchrotron X-ray source that is shared by IBM. A compact synchrotron from Oxford Instruments of England is scheduled to be installed at IBM's ASTC in late 1991, after which time the joint IBM/Motorola program will transfer from Brookhaven to East Fishkill. The Advanced Lithography Facility, where the synchrotron actually will be housed, still is under construction and is expected to be completed next year.

The goal of the current phase of the relationship requires Motorola to assist IBM in perfecting the application of IBM's X-ray capability to a semiconductor "test vehicle" at 0.35-micron geometry. At Motorola's discretion, the current technical cooperation program could be extended to a second contract, enabling Motorola to build its own X-ray production facility based on IBM technology and similar to IBM's ASTC.

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WHAT IS SOR?

What is SOR and why is it of concern to companies such as IBM and Motorola? A synchrotron ring is basically a storage chamber into which electrons are injected and then circulated at an accelerating pace. Magnets bend the path of the speeding electrons, throwing off X-rays that travel down beam lines to exposure stations, or "ports." At these ports, mask-wafer alignment tools position the silicon wafers as the X-rays pass through the photo mask, leaving the circuit pattern imaged in the resist-coated wafer.

X-ray technology has numerous advantages over today's light-based optical lithography systems. These advantages include the following:

- X-rays have a shorter wavelength than light and can therefore be used to draw finer circuit lines.
- Unlike lasers, which can produce light only at discrete energies, SOR can be tuned to a broader spectrum of frequencies.
- X-rays pass through minute dirt particles that can block image-producing light in conventional lithography systems, making X-ray technology less sensitive to surface contaminants.
- Although electron-beam (e-beam) lithography offers significant improvements in resolution over conventional optical systems, the write time for each wafer is too slow for a volume production environment. At present, e-beam lithography is favored more for small batches of custom ICs and for the creation of masks.

Dataquest believes that the shift to X-ray lithography for R&D purposes by 1990 is inevitable because of the physical limitations of photolithography. Current optical steppers are capable of submicron geometries, but Dataquest believes that such optical steppers will reach a manufacturing limit between 0.25 and 0.50 micron, despite expected advances in mask and photoresist technologies. Below that level, researchers are exploring various approaches, as listed in Table 1.

SUBSTANTIAL INVESTMENT STARTING YESTERDAY

At the recent Dataquest Semiconductor Industry Conference (held October 16 through 18), Dr. Graydon Larrabee, Director of Texas Instruments' Microelectronics Manufacturing Science and Technology Program, presented a paper on the topic of wafer fab equipment technologies for succeeding device generations. TI believes that there is a 10+ year cycle, timed from the start of development to vendor qualification, for each succeeding generation of DRAM devices. Figure 1 illustrates this cycle with a timetable. Table 2 outlines TI's vision of the critical elements of the emerging technologies.

From TI's data, one could conclude that the development of new technologies in order to achieve vendor qualification of 256Mb DRAMs in 1997 should have been in process during the past three years—including work on X-ray lithography sources!

CURRENT EFFORTS

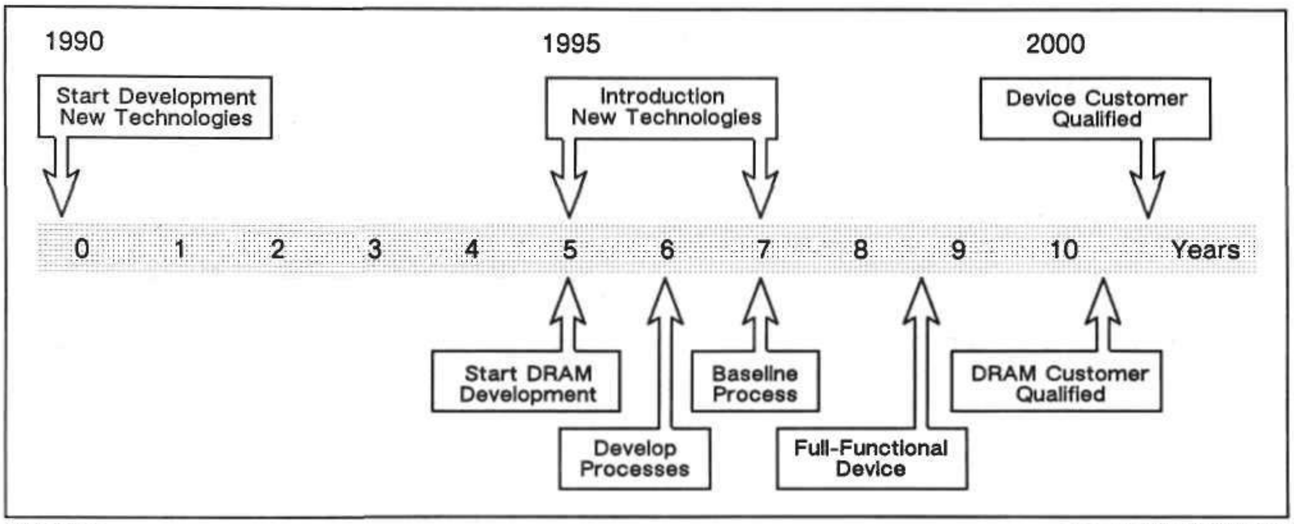
Japanese researchers currently are focusing on SOR technology because they believe that it offers the highest wafer throughput of all X-ray techniques and theoretically can achieve the geometries

TABLE 1
Submicron Lithography Approaches

Technology	Dimensional Limits (Micron)
Optical stepper	To 0.5
Excimer laser/deep-UV (i.e., step-and-scan)	0.6 to 0.35
Plasma X-ray	0.5 to 0.25
Direct-write e-beam	0.5 to 0.2
SOR	0.25 to 0.1
Focused ion beam	sub-0.2

Source: Dataquest
December 1989

Figure 1
Next-Generation Device Development
(0.15-Micron Minimum Geometries)



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Source: Texas Instruments

TABLE 2
Tools and Technologies for Succeeding Device Generations

	0.8μ	0.6μ	0.35μ	0.25μ	0.15μ
Year of Vendor Qualification	1989	1991	1994	1997	2000
Stepper Technology	G-line	G-, I-line	DUV	DUV, X-ray	X-ray
DRAM Size	4Mb	16Mb	64Mb	256Mb	1,024Mb

DUV = Deep ultraviolet

Source: Texas Instruments

required for 64Mb and 256Mb memories. Moreover, if compact SOR rings are developed, they could be used with steppers on existing fab lines.

The National Synchrotron Light Source, along with other U.S. laboratories, has pioneered large oval-shaped synchrotron rings for basic research. The federal government also is assisting in the development of X-ray sources at Louisiana State University and the University of Wisconsin. In the private sector, IBM received a $17.4 million contract from the U.S. Defense Advanced Research Projects Agency (DARPA) to conduct research in X-ray mask technology for the Naval Research Lab. IBM currently rents two SOR beam lines from the Brookhaven Lab, where it has designed and built an X-ray lithography exposure station that has been used to make actual devices.

While some debate continues in the United States over the relative merits of SOR because of the installed base of optical steppers and competition from excimer lasers and electron beam equipment, Japan is rapidly building momentum in the area of compact SOR rings for megabit SRAM and DRAM production. Dataquest believes that future ULSI labs will use ultrasmall SOR equipment, such as the 0.5m-diameter SOR machine currently being developed by NEC and Sumitomo Heavy Industries.

WHAT IS SEMATECH DOING?

Given the urgent need for the development of nonoptical lithography systems, one might ask why X-ray lithography has not been at the top of the

Sematech agenda. Sematech has, in fact, encouraged the establishment of an X-ray lithography initiative and has urged its member companies to participate in such an effort. Furthermore, one of the Sematech Centers of Excellence, the University of Wisconsin at Madison, is dedicated to X-ray lithography research. The problem facing Sematech's more direct involvement at this time is one of funds.

Estimates are that the individual components of the X-ray lithography implementation puzzle (i.e., masks, resist technology) each may carry a $100 million to $200 million development price tag—the equivalent of one-half to all of the current Sematech annual budget. Because manufacturers at the leading edge of device densities typically are DRAM producers, the majority of Sematech's participating companies would not find immediate investment in X-ray lithography to be to their greatest short-term advantage.

IBM: A COMPANY FOR ALL SEASONS

IBM has been involved in research on SOR for at least 10 years and currently plays a critical role in the implementation of basic research. IBM claims to be the first company to successfully form 0.5-micron patterns on silicon wafers using X-ray photolithography techniques. According to IBM president Jack Kuehler, IBM will have spent $435 million on the development of X-ray lithography by early summer 1990; and by the time production based on X-ray technology begins, IBM investment will have exceeded $1 billion.

As with Sematech and U.S. Memories, IBM once again stepped forward to offer its resources to the U.S. semiconductor merchant market and the equipment and material base that supports it. IBM executives also have urged the U.S. government to play a useful role in maintaining U.S. competitiveness in world markets along with industry participation in high-technology cooperative initiatives such as IBM's.

DATAQUEST CONCLUSIONS

Investment on the massive scale of X-ray lithography is too much for a single company, even IBM, to bear. The issue of advanced lithography is of particular concern to companies that require advanced memory technology—hence IBM's and Sematech's call for a national X-ray lithography program. Mr. Kuehler noted that some companies turned IBM down when it proposed a research technology cooperative to develop X-ray tools for 0.25-micron geometries. Motorola was the first major U.S. merchant semiconductor supplier to answer IBM's clarion call—perhaps not a moment too soon.

Referring back to Dr. Larrabee's Dataquest presentation, new technology development must start next year for gigabit-density memory devices that will be customer qualified in the year 2000. According to Dr. Larrabee's timetable, shown in Figure 1, the baseline process for such a device must be established by the seventh year after the start of development. Logically, this timetable would imply the characterization of the lithography system that would mass produce devices based on that process. Therefore, it seems as if Texas Instruments is a likely candidate for participation in an X-ray lithography effort, although TI's intention in this respect is as yet unknown. What is clear, however, is that the time for industry commitment is at hand.

Patricia Galligan
Michael J. Boss

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Research *Newsletter*

QUARTERLY SEMICONDUCTOR COMPANY FINANCIAL RESULTS

INTRODUCTION

Dataquest regularly reports on semiconductor company financial results through its weekly on-line news service, *The DQ Monday Report*. As a service to the Products, Markets, and Technology segment binderholders, a summary of this information is provided herein.

Table 1 summarizes the net sales and income disclosures from selected semiconductor companies based on data from quarterly report periods that ended during the August-through-October 1989 time frame. This information is compared with that of the 1988 August-through-October time frame and is provided in millions of dollars unless otherwise indicated. Table 2 provides a similar summary for fiscal year revenue and income for applicable companies. Descriptive summaries of quarterly performance highlights for the companies listed follow these tables.

TABLE 1
Quarterly Financial Summaries for Selected Semiconductor Companies
(Millions of Dollars except Where Otherwise Noted)

Company	Quarter End	Latest Quarter Revenue	Percent Change	Latest Quarter Income	Percent Change
Adaptec, Inc.	Sept. 29, Q2	$ 26.5	70%	$ 3.0	1,409%
Advanced Micro Devices	Sept. 24, Q3	$274.8	4%	$ 12.1	68%
Altera Corporation	Sept. 30, Q3	$ 15.7	55%	$ 2.9	43%
California Micro Devices	Sept. 30, Q1	$ 8.4	49%	$425K	N/M
Chips and Technologies	Sept. 30, Q1	$ 70.9	61%	$ 9.1	60%
Cirrus Logic	Sept. 30, Q2	$ 18.0	211%	$ 3.4	312%
Cypress Semiconductor	Oct. 2, Q3	$ 51.8	40%	$ 7.9	45%
Dallas Semiconductor	Oct. 1, Q3	$ 23.2	49%	$ 3.3	9%
IDT	Oct. 1, Q2	$ 54.1	17%	$ 5.8	1%
Intel Corporation	Sept. 30, Q3	$771.4	(2%)	$ 72.0	(50%)
IMP	Sept. 24, Q2	$ 17.1	15%	$236K	(87%)
Lattice Semiconductor	Sept. 30, Q2	$ 8.3	60%	$ 1.3	150%
Linear Technology	Oct. 1, Q1	$ 17.8	20%	$ 2.5	12%
Logic Devices	Sept. 30, Q3	$ 3.9	43%	$829K	59%
LSI Logic	Oct. 1, Q3	$133.7	42%	($35.7)	N/M

(Continued)

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TABLE 1 (Continued)
Quarterly Financial Summaries for Selected Semiconductor Companies
(Millions of Dollars except Where Otherwise Noted)

Company	Quarter End	Latest Quarter Revenue	Percent Change	Latest Quarter Income	Percent Change
Maxim Integrated Products	Sept. 30, Q1	$ 12.3	29%	$ 1.7	43%
Micron Technology	Aug. 31, Q4	$103.0	(9%)	$ 16.0	(63%)
Motorola, Inc.	Sept. 30, Q3	$2,408	20%	$ 89.0	2%
National Semiconductor	Aug. 27, Q1	$397.6	11%	($21.9)	N/M
SEEQ Technology	Sept. 24, Q4	$ 10.1	(35%)	($ 2.4)	N/M
Silicon General	Oct. 1, Q1	$ 9.1	5%	$425K	88%
Texas Instruments	Sept. 30, Q3	$1,538	(2.5%)	$ 65	(31%)
Unitrode Corporation	Oct. 28, Q3	$ 37.2	(9%)	$244K	(33%)
Weitek Corporation	Sept. 30, Q3	$ 12.8	38%	$ 1.8	64%
Western Digital	Sept. 30, Q1	$224.9	(9%)	($ 2.7)	N/M
Xicor, Inc.	Sept. 10, Q3	$ 21.2	4%	$863K	(77%)
VLSI Technology	Oct. 1, Q3	$ 77.1	31%	$ 3.3	44%
ZyMOS Corporation	Sept. 30, Q3	$ 10.1	57%	($500K)	N/M

K = Thousands
N/M = Not Meaningful

Source: Company Literature

TABLE 2
Fiscal Year Financial Summaries for Selected Semiconductor Companies
(Millions of Dollars)

Company	Quarter End	Fiscal Year Revenue	Percent Change	Fiscal Year Income	Percent Change
Micron Technology	Aug. 31, Q4	$446.4	49%	$106.1	8%
SEEQ Technology	Sept. 24, Q4	$ 55.1	(10%)	$ 1.1	(87%)

Source: Company Literature

FINANCIAL RESULTS BY COMPANY

Adaptec, Inc.

Results for Adaptec's second fiscal quarter reflected the company's achievement of its second consecutive quarter of record profits and third consecutive quarter of record revenue. Adaptec attributed its strong financial performance to a combination of increasing shipments of SCSI products and expanding international presence.

Advanced Micro Devices (AMD)

Results for AMD's third quarter were essentially flat over the immediately preceding quarter in terms of both revenue and net income. What is noteworthy, however, is the sharp improvement in income over the same period a year ago. The company attributed the increased profits on lower revenue to effective cost-containment measures. In his comments on the company's financial performance, W.J. Sanders, chairman and CEO, said that demand for AMD's iAPX86 microprocessors and programmable logic devices remained strong, permitting the company to "achieve ... flat results in a period of generally weak demand for semiconductors." The Asian market continued to show strength during the quarter. Mr. Sanders noted that the outlook for AMD in a period of moderate industry slowdown that was largely caused by declining DRAM prices bodes better for AMD than for the industry in general because the company does not participate in the DRAM market segment. For the nine-month period ended in September, AMD recorded income of $34 million on sales of $819 million, compared with income of $53 million on revenue of approximately $878 million last year.

Altera Corporation

Altera's third quarter fiscal results marked the company's 21st consecutive quarter of increasing sales and its 11th consecutive quarter of record profits. Rodney Smith, chairman and CEO, said that the company experienced steadily increasing demand for all its product lines of user-configurable components.

California Micro Devices

California Micro Devices' first fiscal quarter revenue reflected a 49 percent increase over the corresponding quarter a year ago, while remaining essentially flat over the immediately preceding quarter. However, income of $425,000 was a significant improvement over losses of $1.2 million and $1.1 million for fiscal first quarter 1989 and fourth quarter 1989, respectively. Chan Desaigoudar, company chairman and CEO, attributed the improved position in the semiconductor side of the business to increased demand for telecommunication products as well as more customer-furnished tooling business. The thin-film division, on the other hand, continued to report sluggish shipments. However, profitability has been restored, and the company looks forward to a promising future and the prospect of new product introductions.

Chips and Technologies (C&T)

Chips and Technologies' first fiscal quarter 1990 revenue reflects an increase of 61 percent over the same quarter a year ago and 15 percent over fourth quarter 1989. Although C&T's reported $9.1 million of income represented a 60 percent improvement over the same quarter last year, it was down 10 percent from the immediately preceding quarter. Gordon Campbell, president and CEO, said that sales growth was due to higher shipments of the company's CHIPSet products, particularly the NEAT and 386/AT product lines. Gross margin for the quarter fell to 47 percent of net sales, caused by "price protection on certain low-end products."

Cirrus Logic

Cirrus Logic reported an increase of 211 percent in revenue and 312 percent in net income over the corresponding period last year. Company president and CEO Michael L. Hackworth attributed the company's strong financial performance to increased demand from PC-compatible OEM systems customers for its VGA products as well as higher levels of acceptance of its hard disk drive controller products, particularly of the company's SCSI products. Moreover, the company's data communications controller is achieving increased rates of design wins.

Cypress Semiconductor

Cypress experienced strong growth in revenue and net income of 40 percent and 45 percent, respectively, over the same quarter a year ago. Growth over the preceding quarter was much slower, in the range of 2 percent in revenue and 4 percent in income. T.J. Rodgers, president and CEO of Cypress, characterized the company's quarterly results as successful and said that they were largely attributable to "the company's entrepreneurial start-up subsidiaries that are contributing positively both to the company's revenue and bottom line." Mr. Rodgers said also that given the uncertain short-term outlook for the industry, Cypress is maintaining a cautious position on new employee hiring and expense control.

Dallas Semiconductor

C. Vincent Prothro, chairman and CEO of Dallas Semiconductor, also has taken over as president of the company, replacing John W. Smith. Mr. Smith, who resigned to pursue other interests, will remain as a consultant. Mr. Prothro said that prospects for the company reflect continued growth.

Integrated Device Technology (IDT)

IDT reported record levels of sales and earnings for its second fiscal quarter. Revenue of $54.1 million represented an increase of 17 percent over the same quarter last year and an increase of 5 percent over the prior quarter. Income, however, while growing 11 percent over the immediately preceding quarter, was only 1 percent over the same quarter a year ago. IDT's chairman and CEO described the company's performance as "solid" and said, "We are cautiously optimistic that we will continue to grow in the third quarter."

Intel Corporation

Intel's third quarter financial results showed a 2 percent decline in revenue and a 50 percent decline in net income, compared with the same quarter a year ago. Compared with the immediately preceding quarter, the company's results registered a 28 percent decrease in income on a 3 percent increase in revenue. However, third quarter results include a $35 million charge associated with the potential sale of BiiN, the computer systems joint venture with Siemens AG. Dr. Andrew S. Grove, president and CEO, commented that "bookings improved as the quarter progressed...bookings were higher than the previous quarter, and our book-to-bill ratio exceeded 1.0." The company's 386SX continued its strong ramp-up while shipments of the 386DX were firm. Intel started first production shipments of the i486, and volume will ramp up in the fourth quarter. Intel's Systems Group is working to increase output of its 386-based OEM PC platforms.

International Microelectronics Products (IMP)

Revenue for the company's second fiscal quarter was $17.1 million, an increase of 15 percent over both the corresponding quarter last year and the immediately preceding quarter. IMP reported net income of $236,000; although a decrease of 87 percent from the like period a year ago, this income represents a return to profitability from losses of $941,000 in the prior quarter. The company views near-term prospects with confidence because bookings were at record levels for the quarter. Barry Carrington, president and CEO, said that IMP is ramping up production to meet strong demand for its products.

Lattice Semiconductor

Results for Lattice's second quarter of fiscal 1990 represent record quarterly revenue and earnings for the company and mark the company's 11th consecutive profitable quarter. Revenue grew 60 percent over the like period last year and 19 percent over the preceding quarter, while income increased 150 percent and 45 percent, respectively. Net proceeds of almost $14 million from a recent IPO of 2.9 million common shares will be deployed for general working capital requirements. Lattice is a supplier of proprietary PLDs called GALs (Generic Array Logic devices).

Linear Technology

Linear Technology reported record sales and income of $17.8 million and $2.5 million, respectively, for its first fiscal quarter. Company revenue grew almost 20 percent over last year but remained flat compared with the prior quarter. Net income increased approximately 12 percent over the corresponding quarter a year ago and 3 percent over the previous quarter. Robert H. Swanson, president and CEO, noted that Linear Technology modestly increased sales and income "despite a business climate that was generally trending downward."

Logic Devices

Logic Devices reported third quarter results showing income increases of 60 percent over the corresponding quarter a year ago and 2 percent over the prior quarter. Although revenue grew 43 percent over last year's like quarter, it declined slightly by 4 percent over second quarter 1989. Company president Bill Volz stated his gratification with these results, particularly in light of the fact that the company is now subject to taxation after using up the tax carry-forwards incurred during its start-up phase. Third quarter results mark the 16th consecutive quarter of profitability for the company, which supplies SRAMs, DSP devices, and math coprocessors.

LSI Logic

LSI reported a net loss of $3.1 million for the third quarter ended October 1, 1989. This loss was realized before taking a one-time, pretax charge of $43 million associated with a restructuring. The restructuring charge includes the write-off of LSI Logic's 5-inch wafer fab in Santa Clara, California—the company's first wafer foundry. LSI plans to put the outdated fab to future use as an R&D facility and pilot line. The company's $3.1 million loss compares with a $7.5 million profit earned during the third quarter of 1988. In addition to the write-off of its 5-inch wafer fab, LSI chairman and CEO Wilfred Corrigan attributes his company's losses to a combination of factors, including excess capacity exacerbated by a slowdown in the company's rate of growth, a slowing in the rate of new orders from the computer sector, a write-off of inventories related to its out-of-date manufacturing line, and discontinued product assets. For the first nine months of fiscal 1989, LSI Logic reported a net loss of $23.2 million on revenue of $408.5 million. This compares with a net profit of $19.4 million on revenue of $259.5 million for the same period last year.

Maxim Integrated Products

Maxim's record first quarter 1990 net income marks the company's 14th consecutive quarter of increasing profitability. During the quarter, Maxim announced 20 new products, including 12 proprietary parts, bringing the company's total analog product offering to 330 devices.

Micron Technology

Micron's fourth quarter earnings reflect a significant decrease from the corresponding quarter a year ago and a slowdown from the prior quarter's results. In the prior quarter, the company had income of approximately $29 million on sales of $119.2 million.

Motorola, Inc.

Motorola's third quarter results include a pretax provision of approximately $43 million to cover the anticipated costs of a voluntary severance program and a decrease in the company's estimated 1989 full-year tax rate. Motorola's third quarter earnings before taxes were $104 million—a 21 percent decrease from third quarter 1988. For the first nine months of fiscal 1989, Motorola reported earnings of $366 million on net sales of $6.97 billion. This compares with earnings of $321 million on net sales of $6.06 billion for the similar period last year. Comparing third quarter 1989 results for the company's Semiconductor Products Sector with those of the previous year, president and CEO George Fisher noted that both sales and orders increased 10 percent, while backlog rose 11 percent. Orders during the period ran slightly lower than sales. Lower average selling prices and higher engineering costs for R&D and product development combined to lower operating profits. Orders in all major regions were higher, with Japan, Asia/Pacific, and Europe providing the greatest boost to growth in orders. Memories, microprocessors, and analog devices were the product areas that saw the greatest order growth. Semiconductor order growth was highest in personal computer and communications end markets, although automotive, consumer, and industrial segments grew as well. Orders from the computer and military end markets declined.

National Semiconductor

National Semiconductors' first quarter results of $397.6 million from continuing operations reflected a decrease of almost 11 percent from the same quarter last year. The company reported a net loss of $21.9 million this year, compared with a loss of $30.5 million last year. However, considered from the point of view of continuing operations, this quarter's loss of $21.9 million compared unfavorably with earnings of $13.6 million for the corresponding period a year ago. Results were an improvement over the company's fourth fiscal quarter, however, when National reported a loss of $97.8 million on sales of $419.1 million from continuing operations, although down from net earnings of $77.1 million (which was generated from the sale of NAS). Charles E. Sporck, president and CEO, claimed to be encouraged by the company's "continued improved performance during a quarter which saw flat semiconductor business conditions, along with pricing pressure in certain areas." He also said that he expects the next fiscal quarter to mark National's return to profitability.

SEEQ Technology

SEEQ reported results for its fourth fiscal quarter and year ended September 24. Annual income fell 87 percent on revenue of $55.1 million. This revenue of $55.1 million was down 10 percent from fiscal 1988 revenue, while revenue for the fourth quarter declined 35 percent from the same quarter a year ago. SEEQ suffered a loss of $2.4 million in the fourth quarter, which compares unfavorably with income of $2.3 million for the same quarter a year ago and income of $1.7 million for the prior quarter. The company attributed its poor revenue and earnings performance to events in manufacturing and marketing. Over the past two years, SEEQ has been trying to convert from a single-product, engineering-oriented facility to a multiple-product, manufacturing-oriented company. Additionally, the company has experienced some price and volume pressures associated with the current business environment. SEEQ had indicated a few weeks earlier that the company would report a loss for the fourth quarter as a result of a "precipitous" decline in orders for its Ethernet product family.

Silicon General

Financial results for Silicon General's first fiscal quarter of 1990 include only the continuing operations of its semiconductor business, because the company is in the process of spinning off its telecommunications business as a separate company. Revenue of $9.1 million represented an increase of 5 percent, and income increased 88 percent over the same quarter last year. Net earnings of $425,000 included an extraordinary tax credit of $73,000. Revenue for the telecommunications business for the quarter were $5.1 million, with income of $12,000. A company spokesperson said that demand for Silicon General's semiconductor products continued to be strong in the areas of defense electronics, industrial power conversion, and automotive electronics.

Texas Instruments (TI)

TI reported a decline in third quarter revenue and net income compared with both the corresponding quarter last year and the immediately preceding quarter. Third quarter revenue of $1,539 million represented a decrease of 2.5 percent over last year's third quarter and a decrease of 1.6 percent over the prior quarter. Income registered a sharper decline of 31 percent and 39 percent over the same quarter a year ago and the previous quarter, respectively. Jerry Junkins, TI chairman, president, and CEO, commented that "electronic end-equipment production in the United States remained sluggish, with pronounced weakness in the computer and defense segments. In Europe... slowing was experienced in consumer products and computers." Mr. Junkins observed that the slowing growth rate of the semiconductor market is particularly evident in memory products. He attributed the decline in net sales billed to lower semiconductor billings, which were down 6 percent. Profits were negatively affected by lower prices, primarily in memories, and by higher depreciation in semiconductors. Third quarter results also include royalty income of $28 million compared with $21 million for the same period a year ago. TI will continue to invest in global deployment of the company's submicron CMOS processing capability, however, and capital spending for 1989 is pegged at $850 million.

Unitrode Corporation

Unitrode announced third quarter results that showed a small increase in income on a lower level of revenue when compared with the immediately preceding quarter. Revenue from continuing operations for the quarter were down 5 percent and 3 percent, respectively, from the same quarter last year and the prior quarter. Income of $244,000 represented a 33 percent decline from the like quarter a year ago but a 4 percent increase over the second quarter. Net income included a modest gain from the sale of the Passive Components Division, and revenue of $37.2 million included $3.3 million in sales from that division, which was sold to AVX Corporation in mid-October. Howard Wasserman, president and CEO of Unitrode, noted that two of the company's divisions, Integrated Circuits and Powercube, posted a record quarter in sales and profits. New orders, particularly in the Semiconductor Products Division, strengthened over the prior quarter.

Weitek Corporation

Revenue of $12.8 million for Weitek's most recent quarter reflects strong growth of 38 percent and 11 percent over the same quarter last year and the prior quarter, respectively. Income of $1.8 million grew 64 percent over last year's similar period and 10 percent over the preceding quarter. For the tenth consecutive quarter, Weitek's revenue and net income have increased substantially. The company's book-to-bill ratio remains above 1.0.

Western Digital (WD)

For its first fiscal quarter, Western Digital reported a loss of $2.7 million on sales of $224.9 million. Compared with the corresponding period last year, sales dropped 9 percent while earnings went from net income of $12.9 million to a loss. Factors contributing to the quarterly loss were primarily a drop of 57 percent in sales of imaging products, mainly to the reseller channel; a loss of production time at WD's board-manufacturing plant in Puerto Rico due to Hurricane Hugo; and currency losses resulting from the strength of the dollar. In terms of the company's communications business, although revenue was flat, that segment remained substantially profitable, while the company's total storage business improved on its already profitable performance. WD expects to break even next quarter in its systems logic business. The company achieved its best level of bookings in five quarters, according to WD chairman, president, and CEO, Roger Johnson.

Xicor, Inc.

Xicor reported third quarter financial results for the quarter ended September 10. Revenue of $21.2 million was essentially flat compared with the same period a year ago, but income declined 77 percent to $863,000 from $3.8 million for the third quarter of 1988. The company attributed the impact on its operating profits to continued declines in selling prices. Xicor president Raphael Klein also said that bookings had not yet recovered from the summer sluggishness and that price erosion continues. He took the opportunity to warn that Xicor may report a loss for the fourth quarter, although he expects the company to be profitable for the year.

VLSI Technology

VLSI Technology reported record revenue and net income for its third fiscal quarter, ended October 1. Company chairman and CEO Alfred J. Stein attributed the strong financial performance for the quarter to both a strong backlog from the preceding quarter and new orders, resulting in record production revenue for ASIC and Logic Product Divisions. Other factors contributing to increased operating profits were improved manufacturing productivity at the San Jose, San Antonio, and Tempe fabs and higher utilization and production at the San Antonio fab. The company expressed cautious optimism about its future prospects.

ZyMOS Corporation

Record third-quarter revenue of more than $10 million for ZyMOS represented a 57 percent increase over third quarter 1988 and an 18 percent increase over the prior quarter. However, the company recorded a loss of $500,000—up from a second quarter loss of $324,000 but substantially down from the $1.6 million loss before an extraordinary gain for the like quarter a year ago. The increase in revenue is attributed primarily to increased standard product sales, while the loss is mainly the result of continued investments in R&D and expenses in new product introductions.

Patricia Galligan

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DSP AND THE WAVE OF NEW RISC PRODUCTS

INTRODUCTION

The major news topic of the last six months in the semiconductor field has been the reduced-instruction-set computer (RISC) processor. Every major semiconductor and computer company now has a stated position on RISC in its product lines. Although much of the news is market posturing, there can be little question that the new RISC microprocessors represent a significant next generation for general-purpose computing. Independent of instruction set size, they embody the latest thinking from both computer science and market demand in today's VLSI technologies. Such opportunities for a completely fresh start on a processor architecture occur only rarely. Some suppliers are taking better advantage of the chance than others.

Any change in the general-purpose microprocessor market is important to digital signal processing (DSP) because it is consistently estimated that half of the volume of the integrated circuits used in DSP are conventional microprocessors. Their low price, wide familiarity, and variety of support tools always make them an attractive alternative to the higher-performance digital signal processor (DSMPU) solution. In addition, many of the mips and mflops performance figures of the new RISC processors are close to those expected only from digital signal processors. Even a casual glance shows RISC's architectural similarities to DSMPUs, such as deep data pipelining, the Harvard-style separation of instruction and data memories, and multiple execution units. RISC processor manufacturers are even talking about the same embedded controller markets that have been the domain of high-performance DSMPUs and about things like real-time operating systems.

What does this mean for the suppliers and users of single-chip DSMPUs in the future? We will explore that question in this newsletter. In addition, we will review some of the basic performance requirements for digital signal processors and see how these are met by the major new RISC processors. Next, we will look at the latest generation of high-performance DSMPUs and see how both are moving to solve some common new systems requirements. Comparing the two types of processors leads to some strategies for DSMPU makers to protect and expand their markets in the face of this potentially strong competition.

DSP REQUIREMENTS AND THE NEW RISC PRODUCTS

Historically, signal processors have been distinct from general-purpose microprocessors because of the following three major requirements:

- Higher precision
- Higher speed
- Special functions operating on large amounts of data

Table 1 lists these requirements with some of the architectural or implementation techniques used to meet them. The first two columns indicate which of these techniques has generally been used in current-generation CISC microprocessors and in the first- or second-generation DSMPUs. The next two columns show the RISC processors and the latest (or third generation) of high-performance DSMPUs. Following the historical requirements are the additional DSP requirements considered to be important today as the result of larger, more complex systems.

Just looking at the relative predominance of the Xs over the Os in Table 1 confirms the general trends: New CISC microprocessors have few attributes other than precision to make them suited for DSP, whereas even the first-generation DSMPUs are a significant improvement. New higher-performance DSMPUs are complete in their use of such techniques, while RISC, for its own performance needs, has used more than even the early DSMPUs. The Xs and Os represent only rough averages across a number of products. Table 2 shows some of the specific features and performance parameters for four representative RISC products. Three high-performance DSMPUs are included for comparison on the same basis.

Table 1

Product Overlap in Meeting DSP Requirements

DSP Requirements	Implementation Technique	Products: CISC	DSP-1&2	RISC	DSP-3
Historical DSP Requirements					
High precision	8-bit	X	O	X	X
	16-bit	X	X	X	X
	32-bit	X	O	X	X
	Floating-point	O	O	X	X
High speed	Pipelined data path	O	X	X	X
	Parallel operation				
	Data memories	O	X	X	X
	Instruction memory	O	X	X	X
	I/O controller	O	X	O	X
	Address generators	O	X	O	X
	Fixed and floating point	O	O	X	X
	Loop counters	O	X	O	X
	Full processors paralleled	O	O	X	X
	Memory speed-size hierarchy				
	Instruction caching	O	O	X	X
	I/O buffering	O	O	X	X
Special processing	Complex address generation				
	Vector	O	X	O	X
	2-D	O	O	O	X
	Arithmetic				
	Multiply-accumulate	O	X	X	X
	Saturation	O	X	O	X
Large amounts of data	Large memory space	O	O	X	X
	High-speed I/O	O	O	O	X
	Real-time control	O	X	X	X
New DSP Requirements					
High-level languages		X	O	X	X
Operating systems		X	O	X	X
Industry standard functions		X	O	X	O

Source: Dataquest
March 1989

Table 2

Major New RISC and DSMPU Feature and Performance Summary

	RISC				DSP		
	Motorola 88100	AMD 29000	SPARC 7C601	Intel i860	TI 320C30	AT&T 32C	Motorola 96002
Precision							
Integer	8-32	8-32	8-32	8-32	16, 32	8-24	32, 64
F-P	32, 64	Ext	Ext	32, 64	32, 40	32, 40	32, 96
Speed							
Cycle time (ns)	50	40	30	30	60	80	75
Execution unit data pipelines							
Integer	1	1	1	1	2	1	2
F-P	2	N/A	N/A	2	S	1	S
I/O	1	1/2	1	1	1	2	2
Concurrent data pipelines	3	3/2	2	4	3	3	3
Parallel processors	Y	N	Y	Y	Y	N	Y
Memory hierarchy							
Integer RF	32	192	136	32	16	22	10
F-P RF	S	N/A	N/A	32	S	4	S
Data cache	Ext	Ext	Ext	Y	N	N	N
Inst. cache	Ext	Ext	Ext	Y	Y	N	Y
Special processing							
Address generation	N	Y	N	Y	Y	Y	Y
Multiplier-accumulator							
Integer	N	N	N	N	Y	Y	Y
F-P	Y	N/A	N/A	Y	S	Y	Y
Address space (bits)							
Data 1	30	32	40	32	2x10	2x9	32
Data 2	-	-	-	-	12	10	S
Instruction	30	S	S	S	24 (S)	24 (S)	32
I/O bandwidth (MB/sec)	80	50	66	132	132	50	106
Interrupts	Y	Y	Y	Y	Y	Y	Y
Context switch	Y	Y	Y	Y	Y	N	Y
High-level language	Y	Y	Y	Y	Y	Y	Y
R-T operating system	Y	Y	Y	N	Y	N	N

Ext = External
N/A = Not Applicable
Y = Yes
N = No
S = Shared

Source: Dataquest
March 1989

Precision and Speed

Precisions are at rough parity now. DSMPUs tend to preserve more bits for accumulation, but RISC processors often have greater word length flexibility, which can be useful for DSP image data. RISC meets the precision need. Basic data pipeline cycle times are shorter for RISC processors, and the difference is real for small vectors. Nevertheless, address generation times in the RISC integer ALU and data memory bottlenecks reduce performance for most signal processing operations below that of the DSMPUs. As the number of separate pipelines in the execution units and the concurrency figures show, however, the differences may not be large. Note that the 64-bit data busses of the i860 give it higher large-vector performance than the DSMPUs due to concurrency. Thus, RISC can meet many DSP speed requirements now. So-called vector processors are being considered by RISC suppliers now to provide multiport address generation for large real data memories to increase DSP and vector performance, so the gap may narrow in the future. NEC has even announced such a vector processor for its V-series product line, which employs traditional complex-instruction-set computer (CISC) architectures. RISC processors for the moment seem to lead DSPs in providing for paralleling of complete processors.

Memory Hierarchy

RISC processors have large data register files that, for most functions, equate to the much larger separate data memories on the DSMPUs. Concurrent load/store I/O operations on the RISC processor can reduce this size difference; however, speed may degrade quickly due to I/O bottlenecks. The large number of registers or accumulators on the DSMPUs reflect the desire to support high-level language compilers. Caching of instruction memory is used in both RISC processors and DSMPUs, although the modes of operation are much different. A low-cost, low-complexity solution is possible with a RISC processor that is sufficient to meet signal processing needs. Data caching is handled overtly with partitioned memories and programmed control in DSMPUs rather than "automatically" as in RISC processors. The large on-chip data cache on the i860 with its 128-bit bus is a real performance booster for signal processing operations. Overall the RISC memory hierarchy may seem ill suited for signal processing, but it can be scaled down and be cost and performance effective for large DSP systems.

Special Processing

The addition of vector processors to RISC processors may more nearly even the score, but now DSMPUs clearly excel at the concurrent and complex address generation needed in large data spaces for signal processing. This extends to I/O with DMA controllers as well as for on-chip memory. The concurrent multiply-accumulate arithmetic function so central to DSP is not common in RISC except in the floating-point execution units. This directly affects DSP speed performance on the RISC processors.

Large Amounts of Real-Time Data

The important address space change for RISC is to separate data and instruction spaces for higher performance. DSMPUs have increased the size of both spaces in order to handle the larger programs from high-level languages and the graphics and image data bases. DSMPU memory spaces have become more linear (like RISC) as they have gone off-chip. Thus, RISC processors can meet the separate and large memory space requirements of current signal processing systems. DSMPU I/O bandwidths remain higher than RISC processors and generally can be more fully utilized, but RISC I/O rates exceed many early DSMPUs and can be sufficient in many DSP systems.

RISC processors have interrupts, stacks, and other context-switching hardware assists, but they often lack the deterministic response times necessary for real-time DSP. Cypress Semiconductor is moving to improve this in its implementation of the SPARC architecture, and it seems likely that others will also. RISC processors, likewise, have the more complete high-level language support but not in a real-time operating system environment.

TODAY'S HIGH-PERFORMANCE SYSTEMS AND THEIR MARKETS

This growing similarity between digital signal processors and general-purpose RISC microprocessors results from manufacturers of these products recognizing the needs of an increasingly common high-performance system. Figure 1 is a block representation of such systems. It represents functional blocks of the typical new high-performance systems and their varied CPU processing and software requirements. Typically, some physical process that generates a large amount of data is analyzed or controlled by computations on the data. The computations are altered by operator controls, often interactively, from results that are presented on a display. The display itself often involves much processing, as does the final output result on some peripheral device.

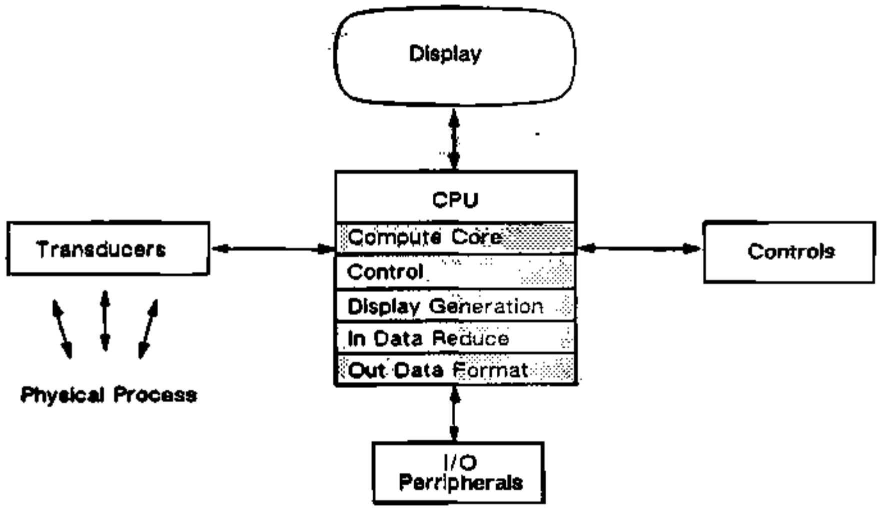
For economic reasons, and because not all processing is simultaneous, a single CPU is desired. Speed is important because of the large amount of data, the fact that the system is interactive, and the fact that it often must be real time in the strictest sense for closed-loop control purposes. The speed must be in I/O as well as arithmetic functions to support displays and the data collection.

Large amounts of high-level language applications code are used, often running under UNIX. This user- and third-party-supplied software accommodates industry standards processing and standard I/O peripherals, drivers, and formats. The high-level language improves maintainability, but often it is used initially because it allows the function to be transported in to get the system operating in a minimum amount of time. Critical time to market is improved.

Typical applications that use these systems are listed in Figure 2. Frequently, they are referred to collectively as high-performance embedded controller systems. Note that high-performance workstations in this context are a subset with less demanding real-time I/O.

Figure 1

New High-Performance Systems and Their Varied CPU Processing and Software Requirements



0003271-1

Source: Dataquest
March 1989

Figure 2

Important High-Performance Markets for RISCs and DSMPUs

- Medical Tomography Imaging
- Ultrasound Imaging
- Communications Instrumentation
- Vibration Testing
- Electrical, Chemical, and Mechanical Design, Simulation, and Analysis Workstations
- Image Scanning and Electronic Publishing

0003271-2

Source: Dataquest
March 1989

THE COMPETITIVE THREAT AND NEW DSP STRATEGIES

Few significant quantity shipments of RISC processors occur today, except for workstation shipments, and it will be two years before the important product families and markets can be confirmed. However, the prudent DSP product strategist cannot wait for market erosion to react.

Dataquest believes that certain DSP performance issues are important ones for DSMPU suppliers trying to maintain their markets. DSMPU suppliers must continued to do the following:

- Accommodate the real-time nature of DSP operations—The first requirement is to continue to accommodate the real-time nature of the processing while adapting to the need for operating system and high-level language benefits. This can be done through integrated hardware assists and real-time software function libraries that support industry standards and device independence yet do not get in the way of the other real-time processing required. Developing a standardized library of real-time functions and a suite of DSP performance measures, like the recent SPEC benchmarks, would help.

- Support greater memory flexibility

  - Even with the larger data bases and programs of DSP systems today, the memory hierarchy needed always will be different from the more general-purpose data processing system. The need for large, multiported nonvirtual memory always will exceed the RISC on-chip register file. Continued attention to this memory distinction will protect DSP markets.

  - Vector processors that provide concurrent address generation for arrays are expected to be added to both CISC and RISC microprocessors, but DSMPUs always should be able to exceed the performance achieved in a linear memory, particularly for 2-D functions and transforms like the FFT.

- Develop workable multiprocessor languages and interprocessor protocols—Paralleling complete processors to increase computing power is everyone's candidate for the next major leap in performance, yet progress has been very slow in systems that can be used today. Because DSP is so amenable to partitioning between parallel processors, it can take the lead in simple, workable languages and interprocessor communications conventions.

- Emphasize high-bandwidth, real-time I/O—A final area of emphasis for DSP should be input/output (I/O). Graphics and imaging have made I/O dataflow an issue for all processors; however, the serial telecommunications interfaces, complex multiplexing/demultiplexing, and high real-time bandwidths should allow important product distinctions.

DATAQUEST ANALYSIS

Dataquest believes that if DSP suppliers are successful in providing this special DSP performance, their growth will continue and they will remain an important portion of the semiconductor processor market. The discussion here has centered only on the high-performance, higher-cost devices, but they represent a major growth area now and the dominant products of the future. Failure to act could bring a repeat of the generation-earlier contest between DSP array processors and general-purpose minisupercomputers. In spite of FORTRAN library support and parallel processors, the array processors lost vital market share to the more general-purpose minisupercomputers when they had the same floating-point multiprocessor parity. The near demise of Floating Point Systems, the leading array processor company, at the hands of Alliant and Convex closed out the first significant generation of DSP high-performance systems. The parallel between those rival minicomputer systems and today's rival microprocessors bears careful attention by suppliers of DSP integrated circuits.

Robert E. Owen

- Encouraging companies with cross-licensing agreements to introduce MCA products quickly and offering assistance to third-party vendors in order to increase the use of MCA

- Squeezing PC-clone vendors by lowering prices to make MCA PCs more attractive

- Seizing every opportunity to discredit the viability of EISA, as members of the EISA group introduce MCA products

However, Dataquest believes that IBM will reduce its licensing fees for MCA technology only as a last resort.

In the near term, we expect sales of MCA-based PCs to increase due to the creditability given to a new bus structure by the PC-clone manufacturers. In our opinion, IBM's influence, EISA's late entry, and fragmentation within the EISA ranks will hinder the acceptance of EISA systems. Compaq's strong influence and determination ensure that MCA systems and EISA systems will coexist in the market, at least in the intermediate term, with MCA products gaining market share as other vendors offer MCA systems. EISA will survive as a bridge, to extend the use of the current installed base of XT and AT machines. In the long term, however, Dataquest believes that EISA will not meet the challenge of future performance and expandability requirements and that this market will become a shrinking niche market, serviced by only a few surviving vendors.

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Ken Pearlman
Robert Charlton

IBM

Dataquest believes that IBM holds the winning hand in this card game. It is in a good position to influence the outcome of the EISA/MCA challenge and can sway the business community to embrace MCA. Our analysis is based on the following factors:

- EISA may not be available from PC manufacturers for 9 to 18 months. This gives IBM time to introduce products that can take advantage of MCA, and to establish a user base. The sooner useful MCA applications hit the market, the greater the market share MCA will capture.

- Although it has stated that the royalty structure will remain in place, IBM always has the option of changing its mind, if it becomes beneficial.

- Companies that have a universal cross-licensing agreement in place with IBM may not be required to pay the same royalty fees as companies that do not. This makes it more attractive for those companies to manufacture MCA-based PCs.

- It is being debated whether EISA or MCA, in the current configurations and environment, is technically superior. We believe that the issue is really which architecture will perform best in the future.

  - An expected requirement is the ability to expand to a 64-bit data path and handle processing speeds above 40 MHz.

  - ESIA will have problems with both the physical accommodation of a 64-bit bus and the electrical noise associated with high-speed processors.

  - IBM has the time and the option to redesign the current MCA to eliminate the debate and to clearly differentiate performance before the first EISA machine is even shipped.

- Most importantly, whereas MCA exists now, EISA is, at present, vaporware.

Compaq

Compaq Computer will hold an estimated 3.4 percent U.S. market share of personal computers shipped in 1988. Compaq is also the leader of the EISA consortium, and we believe that it holds enough market share and following to make EISA a viable product. It was the first company to introduce an 80386 PC and continues to be a leading force in the industry.

Dataquest believes that Compaq will follow through and introduce EISA regardless of how the rest of the PC industry reacts to extended bus architectures. In fact, Compaq has announced that, as of April 21, it will sever its relationship with Businessland. Businessland has stated that it may back only MCA technology; although Compaq denies that this caused the rift, many analysts believe otherwise.

EISA Consortium

Dataquest believes that the EISA Consortium is very serious. It is well organized and well supported by the members. Nevertheless, it faces an uphill battle against MCA with obstacles that IBM will exploit at every opportunity.

The first obstacle is that the EISA standard is being formed by a group of competitors anxious to increase their own market shares in an extremely competitive market. Even with the common interest of EISA, it is hard to believe that any group of competitors with a common goal will stay together. Any fragmentation in the ranks will be quickly noted by IBM.

A second obstacle is one of economics. Members of the EISA consortium will hedge their bets and will develop, or already have developed, MCA PCs, and will actively market them. This is partially due to the effort they have already put into cloning MCA systems and partially due to the fear of being caught without an extended architecture product if EISA stalls. Tandy, for example, is shipping MCA products now. John Roach, president and CEO of Tandy, stated at Dataquest's PCIS Conference that he would be ready to satisfy his customers whether they wanted MCA or EISA product. Dell also has announced that it has MCA systems. Companies with MCA systems that are shipping now, or will be very shortly, are ALR, Dell, Mitac, Olivetti, and Tandy.

The Winners and the Losers

The Winners

Dataquest believes that, provided Apple Computer can capitalize on its stable NuBus platform, it will be a clear winner as a result of the chaos caused by multiple PC bus standards. Corporations vacillating between the Apple and the IBM product will purchase Apple because it has a viable 32-bit bus technology without competitive confusion. Other winners will be the third-party board manufacturers that will sell their products to both buses—MCA and EISA. Board vendors view the two standards as expanded opportunities. They see the MCA and EISA markets as a larger total market that offers increased opportunities for selling their products. Certainly, Microsoft will win as it is hardware independent and will sell products to both MCA and EISA-based PCs.

The Losers

The losers will be the public, which ultimately will pay the price for this confusion, and the manufacturers, which must invest limited funds into both standards. Designing two products is costly due to development time, distribution and revision changes, service, and repair.

DATAQUEST CONCLUSIONS

Dataquest thinks that IBM will react strongly to the introduction of EISA in the following ways:

- Introducing applications—possibly at Fall 1989 Comdex—that use the unique characteristics of the microchannel architecture

Dataquest does not agree that this issue is strong enough to dissuade businesses from purchasing a different bus architecture, for the following reasons:

- Because older systems are passed down intact to areas that were previously devoid of PCs, businesses do not have surplus boards available.
- The new systems probably contain standard features that were options on older systems.
- The third-party board manufacturers have added new features and functions to their products, which makes upgrading attractive.

These factors were amply demonstrated when the PC AT system was introduced. Imagine placing a 10MB, 85ms hard disk drive running on an 8-bit controller into the AT, or doing CAD/CAM with a CGA monitor driven by the original color card in an effort to save money.

Although backward compatibility is feasible with EISA, Dataquest believes that in a business environment, the bus layout will not significantly alter sales—provided support products, third-party boards, and peripherals are competitively priced and readily available. The total system price and the support product availability will ultimately determine which product will sell.

An important underlying issue is the question of who sets the standards for PC compatibility. Until now, IBM has been the standard, the model for the PC clonemakers. IBM has had control over the direction of this industry, even as it loses market share. Will the EISA consortium, led by Compaq, be capable of breaking from this tradition to establish and maintain a new standard? Whose EISA machine will define the compatibility standard for the other consortium members? Will it be Compaq's or will it be the first EISA machine on the market (if it is not Compaq's)? The answer lies in the ability of Compaq to lead and to maintain the support, cooperation, and respect of the consortium members.

EISA Second Sources

Many companies selecting PCs prefer to have multiple sources for the same product. The number of PC manufacturers supporting the EISA bus makes the EISA PC attractive for this reason. Dataquest believes that this is an especially critical area to watch—to ensure that the EISA bus is identical from one PC to another.

The potential exists for one manufacturer to "improve" on features to leverage market share, as in the case, for example, of expanded memory. A prominent group of companies developed an approach to use memory in protected mode to "stretch" real mode memory so that larger spreadsheets could be manipulated. Instead of staying with this scheme, another company developed a similar but different scheme with different features. Now, both Expanded Memory System (EMS) and Enhanced Expanded Memory System (EEMS) memory management techniques exist.

MCA

MCA Delivery Time

IBM has been shipping MCA bus PCs since April 1987. Dataquest estimates that 1.5 million MCA-based systems will be installed by the end of 1988. Thus, companies that expect to have new applications for their PCs do not have to wait for a PC with the MCA bus to be developed.

Dataquest believes that third-party manufacturers of application hardware initially will concentrate their resources on MCA-based PCs, simply because of the large marketplace into which they can sell product. Strong development of products using the MCA bus will place the EISA bus in a catch-up mode.

MCA Backward Compatibility

MCA's disadvantage is that is is not compatible with the nearly 33 million MS-DOS PCs shipped since 1983. However, Dataquest does not view this as a strong justification for not purchasing the MCA PC for the reasons stated earlier. Those reasons are: the requirement to use existing PCs intact, the desire to upgrade to the new features and functions offered by third-party boards, and the fact that certain features are now standard on new PCs.

MCA Second Sources

Several companies have announced plans to ship MCA PCs or have announced that they are already shipping them. These companies, which are members of the EISA consortium, have stated that, one way or another, they will satisfy the customer. The argument that there is only one vendor for MCA has therefore been eliminated.

Apple's success is another illustration that shows the fallacy of the argument that companies are reluctant to purchase products from a sole source. Although it has a completely noncompatible bus and operating system and is the only company producing the product, Apple holds the number two spot behind IBM with an estimated 14.5 percent of the 1988 U.S. market.

MARKET PARTICIPANTS

To examine the success or failure of EISA or MCA, the participants must also be examined.

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NEW DSP PRODUCTS AND TRENDS AT ISSCC '89 AND CICC '88

SUMMARY

Significant new products were shown in all digital signal processing (DSP) segments at the major semiconductor conferences during the last year. Most new DSP products were in the video and image special-function segment. Recent product, architecture, and technology trends continued with programmed, functional block, and application-specific solutions coexisting. Reduced-instruction-set computing (RISC) processors and their floating-point coprocessors invited comparison with high-performance signal processors.

INTRODUCTION

The first public awareness of significant new integrated circuit products usually comes through papers presented at the International Solid State Circuits Conference (ISSCC) in February or the Custom Integrated Circuits Conference (CICC) in May. This certainly has been true for DSP, where whole sessions are usually devoted to the topic. An important part of Dataquest's DSP research is coverage and interpretation of new products and related technologies that are described at these two conferences. We also will be reporting on signal processing technology advances and products introduced at the International Conference on Acoustics, Speech, and Signal Processing (ICASSP) in April.

Of obvious interest are the new DSP microprocessors (DSMPUs), microprogrammable building blocks (MPDSPs), special-function DSPs (SFDSPs) for video and imaging, and application-specific circuits for DSPs (ASDSPs) in fields such as telecommunications. But related products like analog/digital converters, high-performance microprocessors, and coprocessors also affect DSP markets. Both conferences provide a guide to the latest design methodologies that can be important in fitting DSP techniques to new application needs rapidly. New semiconductor technologies described often impact DSP products early because of their need for the highest speeds and high density. Our purpose here is to collect those items that seem important for a thorough understanding of DSP product and technology directions. Completeness of coverage is considered more important than details and comparisons of specific products, due to the preliminary nature of this early information.

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DSP Microprocessors

Only one truly general-purpose, single-chip DSMPU was described at either conference; it was an upward-compatible, third-generation enhancement from Mitsubishi. However, Mitsubishi's new product's speed at 40ns per instruction cycle for 24-bit floating-point is noteworthy. The 24-bit (16E8) precision is an increase over the initial 18-bit (12E6). Other differences are a shared on-chip data and instruction cache and shared external memory space, in addition to the normal external instruction-only and data-only memories. Caching is increasingly being seen in DSPs, and here it includes a novel clock-scaling circuit to allow it to be easily loaded from slower external memory.

Although described as video processors, a 24-bit integer unit also from Mitsubishi and a 16-bit integer processor from NEC are really full-function programmable DSMPUs. Both are impressively fast, and as Table 1 shows, they have all the functions of the general-purpose Mitsubishi device except the serial telecommunication interface. The chief distinction between the video processors and the DSMPU is the richness of address generation capability, a welcome addition for most applications on a DSMPU, along with the faster speed. Prices will be higher for these two larger-size chips.

Special-Function DSPs

Video Processors

The special function receiving the most attention this year, as it has for the past several years, was video (see Table 2). This follows from the increased interest in HDTV and the establishment of ISDN video compression standards. The most flexible product is the 24-bit integer processor from Mitsubishi (also shown in Table 1). The three data execution units supported by two large dual-ported memories with three address generators driven by the 48-bit instructions provide very high performance. The data precision is high enough for transforms, yet the instruction set also makes it data byte efficient. Address generation is two-dimensional both on- and off-chip. Performance figures were given for a large number of video functions, but full attention was given to the video codec requirements for transforms, vector quantization, and motion compensation.

Table 1

Significant New DSP Microprocessors (DSMPUs) at ISSCC '89

Features	Mitsubishi	Mitsubishi	NEC
Precision	24-bit FP (16E8) & integer	24-bit integer	16-bit integer
Instruction Cycle	40ns	50ns	25ns
Arithmetic Element Stages			
ALU	1	1	1
MPY	1	1	1
ACC	0	1	1
Address Generators	2	3	4
Memories			
Instruction			
Internal ROM	4Kx32	-	-
Internal RAM	-	512x48	512x32
External	60Kx32	16Kx48	-
Data & Instruction			
Internal RAM	64x32	-	-
External	4Kx32	-	-
Data			
Internal RAM 1	512x24 (DP)	512x24 (DP)	128x16
Internal RAM 2	-	512x24 (DP)	128x16
External 1	60Kx24	64Kx24	1Mx16
External 2	-	-	1Mx16
Input/Output			
Serial	1-bit	-	-
Parallel	24-bit	24-bit	16-bit
Technology			
Process	CMOS	CMOS	CMOS
Feature Size	1u	1u	1.2u
Transistor Count	300K	538K	220K
Pin Count	135	177	176
Die Size (mm)	7.0 x 8.6	13.8 x 15.5	14.0 x 13.4

Notes: FP = Floating-Point, DP = Dual-Port

Source: Dataquest
April 1989

Table 2

Significant New Special-Function DSPs (SFDSPs) at ISSCC '89 and CICC '88

Company	Function	Instruction Cycle Time	Precision	Transistors
Video				
Mitsubishi	Broad, microprogrammable	40ns	24-bit	538K
NEC	Broad, microprogrammable	25ns	16-bit	220K
MicroElectronics Center	2-D FFT	100ns	11-bit	152K
Bellcore	2-D DCT	70ns	12-bit	73K
Toshiba	Codec	41ns	8-bit	288K
Kodak	Color correction	70ns	14-bit	94K
Image				
LSI Logic	FIR filter	50ns	8-bit	240K
	Template match	50ns	1-bit	94K
	Rank value	50ns	12-bit	140K
	Delay line	50ns	8-bit	110K
Siemens	MAC	40ns	18/32-bit	340K
	Correlation	40ns	32-bit (FP)	90K
Sony	16 MAC array, selectable	50ns	12-bit	124K
NEC	MAC (BiCMOS)	5ns	16-bit	20K
Fast Fourier Transform (FFT)				
Plessey	FFT, weighting	25ns	16-bit	500K
Filter				
Fujitsu	Adaptive filter	100ns	16-bit	42K

Notes: DCT = Discrete Cosine Transform, FP = Floating-Point

Source: Dataquest
April 1989

The NEC chip is a 16-bit integer processor (also shown in Table 1) and is correspondingly faster than Mitsubishi's at 25ns. It compares with a simpler three-stage pipeline, 70ns version presented two years ago. The seven stages of the newest chip are in a sequence that is useful for most video tasks. NEC has provided for multiprocessor synchronization, because even with these data rates, more than one processor may be necessary for real-time performance.

These two programmable processors, with their writable control stores for instructions, are contrasted with the video processors from Toshiba and Kodak, which are fixed in function. Toshiba's video codec uses the time-compressed integration format for HDTV conversion in either direction. The link may be either analog, 400-Mbps digital, or video disk. For an established format, it offers functional flexibility in one large but potentially high-volume part. Kodak's processor serves a more narrow function—it provides the digital processing from color filter CCD arrays to create correct three-color video signals. The slower speed is acceptable because of the smaller number of pixels in current CCD arrays.

Image Processors

Video processing generally is seen as a subset of image processing that accommodates in some manner the specific real-time bandwidth requirements of video signals and makes use of the sequential raster nature of data and its storage. For more basic functions like multiply-accumulate, the distinction may not be meaningful. Sony's processor containing 16 multiplier-accumulators (MACs) and adders and NEC's BiCMOS MAC are described as video building blocks, while Siemens' products are aimed at "real-time images." The Siemens two-chip set and the Sony processor are programmed processors but fit together like building blocks. The input MAC is integer for 6-bit neighborhood data, while the arithmetic processing unit is 32-bit floating-point for full image 2-D operations like correlation. There are three concurrent floating-point data execution units and concurrent I/O. Sony's processor's limited functions, all based on the inner product operation, can be combined in systolic arrays to boost the 1.04 Giga-operations per second (GOPS) for a single chip. NEC, in one-fourth the chip area and with 65 percent of the power consumption, achieves 0.2 GOPS or one-fifth the performance—more of a BiCMOS test vehicle than part of any video or imaging product strategy.

Fast Fourier Transform (FFT) Products

With the flurry of new FFT chips recently introduced by Austek, Honeywell, TRW, UTC, and Zoran, interest was high in the new PDSP 16510 from Plessey. Its most notable feature is that it will do a full 1,024-point complex transform using only internal memory and in less than 100us. Most other products use large, fast, and expensive external memories and/or multiple processors to do transforms this large. Plessey's version is also very flexible in transform size, real or complex data type, use of data buffers, and selection of weighting functions. The 13.1 x 13.3mm area will make it not be cost competitive with DSMPUs for small transforms; however, in the many applications requiring midsize transforms, this product will be very attractive in price, size, and complexity of design. Plessey's FFT was the most significant pure DSP product introduced at ISSCC '89.

General–Purpose Microprocessors

Coprocessors

The major public product announcement at ISSCC was of course Intel's i860, and it was of not just a little interest to the DSP community. The hype was about RISC, UNIX, and standalone operation, but competitors' concerns were about a high-performance $750 coprocessor, and that is how we have compared it in Table 3. The significant trends among the coprocessors are toward multiple, fast pipeline stages; multiple execution units including I/O; and wider-than-32-bit data paths. All are moves toward DSP-like performance in a standard microprocessor system. This was particularly evidenced by the concurrent multiply-add and the vector address generation capability of NEC's new coprocessor for the V60, 70, and 80 series.

RISC Processors

RISC processors are the engines that drive coprocessors with high clock rates and wide 64-bit busses. A Digital Equipment Corporation spokesperson said in his session 7.1 presentation that a vector processor was a future part of this (non-VAX) family. The Matsushita chip, with its four parallel execution units, clearly rivals the i860 in power, and it, too, has features for multiprocessing.

Building Blocks

Multipliers are the traditional regular-function, medium-complexity test vehicles for any new technology, so it is not surprising to see some appear now in gallium arsenide (GaAs). Seldom are they significant in commercial DSP markets. However, Honeywell's GaAs multiplier introduced at ISSCC clearly was designed for DSP because it does a full 16-bit complex multiplication (four multiplies and two additions) and does it in only 8ns. Mitsubishi's 32-bit floating-point building block is highly pipelined with five 10ns stages and is self-timed. This technique, where data is passed from stage to stage only when the processing is complete, is bound to see wider use as multiple variable-length data pipelines become common. Mitsubishi does not use this technique in its purest form, but the company has a head start at learning about its use. This product was the most significant DSP circuit/architecture innovation presented at ISSCC '89.

Table 3

Significant New General-Purpose Microprocessors and Building Blocks (MPDSPs) at ISSCC '89

	Functional Unit	Pipeline Delay	Pipeline Depth	Precision
Coprocessors				
Intel i860*	Integer ALU	30ns	1	32-bit
	FP ALU	30ns	3	32/64-bit
	FP MPY	30ns	3	32/64-bit
	I/O	60ns	1-3	64-bit
NEC	FP ALU	50ns	8	32/64/80-bit
	FP MPY	50ns	9/11/12	32/64/80-bit
GE	32-bit Integer or			
	FP ALU or MPY or MAC	25ns	3	32/64-bit
	I/O	25ns	1	32-bit
Digital	FP ALU or MPY	20ns	4/5	32/64-bit
RISC Processors				
Digital (7.1)	Integer ALU	20ns		32/64-bit
Matsushita	Integer ALU	50ns		24-bit
	FP MPY	50ns		64-bit
	FP MPY	50ns		64-bit
	I/O	50ns		64-bit
Digital (7.3)	Integer ALU	28ns		32-bit
	I/O	28ns		64-bit
HP	Integer ALU	33ns		32-bit
Digital (7.5)	Integer ALU	40ns		32-bit
	I/O	40ns		64-bit
Building Blocks				
Honeywell (GaAs)	Integer MPY (complex)	2ns	3	16-bit
Mitsubishi	Integer & FP ALU	10ns	5	32-bit
	Integer & FP MAC	10ns	5	32-bit

Notes: ALU = Arithmetic Logic Unit, FP = Floating-Point, MAC = Multiplier-Accumulator, MPY = Multiplier

*Intel's i860 processor is considered a standalone RISC processor with integrated floating-point and 3-D graphics. For purposes of this comparison, we will focus only on the floating-point portion of the i860.

Source: Dataquest
April 1989

Applications

It is always interesting to check on the migration of DSP techniques into chips for complete applications. There is a concern that all of the high-volume applications will be met this way and that there will be no lasting market for the general-purpose programmable solutions. Oki's modem chip showed that this high-volume application's requirements can be met with a DSMPU core and specialized on-chip A/D and D/A peripheral circuits.

Panel Discussions

The regular "Future of DSP" panel session was less partisan and more penetrating than usual. A major topic was questioning the need of the latest large, full-featured DSMPUs. Is there a place for other than "lean and mean" (simple and fast) processors? As part of that topic, the usual floating-point versus integer discussion ensued, but this time it ended differently than usual. AT&T virtually acknowledged that floating-point had been put in its DSP-32 because it was the next step and not because it was clearly justified. And sure enough, AT&T said, the most successful application had been graphics transformations, not a traditional DSP function at all.

CICC '88

Products

At last year's Custom Integrated Circuits Conference, the DSP products were all special-function products, as one might expect, and there was more information about DSP-specific design methodologies. Video and imaging dominated again. For example, Bellcore's discrete cosine transform chip does 16 x 16 pixels in real-time for video coding. It is a multiplierless design using only additions and ROM lookup tables for compactness.

The MicroElectronics Center (MEC) 2-D FFT array of chips processes 256 x 256 pixels in real-time at a 30Hz rate. It uses the long-forgotten shift register method of FFT data sequencing to advantage.

Two papers by LSI Logic introduced a family of 20-MHz image-processing chips that has since grown to six and increased in speed. They were the most significant DSP papers presented at CICC '88 because in one short span of time LSI has made available a complete processor and memory building block set for imaging. This came from a thorough product line plan, fast turnaround design tools, and a commitment to provide what was needed even if it resulted in large chips. The FIR filter, for example, has 64 MACs and is 1.4cm on a side. Rarely is there such a complete product thrust into a market that is in an early development stage. The commercial battle line is clearly drawn now between programmable processors and functional blocks in this DSP application area.

Fujitsu described an adaptive filter that offers improved I/O and multichannel processing over a DSMPU. It is unusually well supported with design software and documentation.

Design Methods

CICC papers have more discussion of design tools than circuit design details, and the silicon compiler session always includes DSP because DSP data processing is more regular and amenable to description and synthesis. The University of California at Berkeley and IMEC in Belgium are both centers of much of this compiler work, and their progress is steady, with effects being seen in commercial products at Philips and LSI Logic. No company is visible yet that has made silicon compilation a cornerstone of its DSP product strategy.

DATAQUEST CONCLUSIONS

What did these two important conferences say about the major DSP issues being watched today? They confirmed first that general-purpose microprocessors in the form of RISC and their coprocessors are getting function and performance levels close to high-end DSMPUs. Secondly, in the growing area of video/image processing, a special-function DSP segment, there are still new product examples of programmable, functional block, and application-specific implementations. These three forms may continue to coexist with no clear indication of a single product "best" strategy.

The product trends for each of the segments were as follows:

- DSMPU—Little new; the third generation is still being digested.
- SFDSP—Video/image is the function getting the most attention recently.
- MPDSP—No major products except at new technology frontiers.
- ASDSP—Core DSP processors are expanding into this area more than compilers/design tools are adapting to DSP.

The architectural trend is to separate highly pipelined data execution units for higher performance and more run-time assists to control them. One micron is the new technology norm, and BiCMOS' impact, if any, is yet to be felt in DSP.

Generally, DSP integrated circuit progress is strong and healthy, but one feels a little cautious when all of the excitement is about general-purpose processors with speeds and precisions that were only so recently the sole domain of DSP.

Robert E. Owen

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THE INVISIBLE DSP IC MARKET: GATE ARRAY, CELL-BASED, CUSTOM, AND SILICON COMPILER DESIGNS

SUMMARY

Application-specific digital signal processors (ASDSPs) constitute a large and rapidly growing segment of the general application-specific integrated circuit (ASIC) market. The major suppliers are broad-based ASIC firms that provide little DSP support, rather than the traditional DSP IC companies. By supporting the DSP designer better, DSP-focused suppliers can secure some of this market, which is nearly equal in size to the DSP microprocessor (DSMPU) market.

INTRODUCTION

DSMPUs, building blocks, and special-function DSP chips (SFDSPs) constitute a very visible market because of the large marketing promotions for these devices. Suppliers and users alike advertise the successful incorporation of these ICs into end products. Almost totally invisible are the custom ASDSPs developed by product manufacturers for their special DSP needs.

ASDSPs are a portion of the broad ASIC market and include all of the same techniques in their design: gate array; cell based—standard cell, as well as extensions to a microprocessor core; full-custom; or silicon compilation. However, they are distinct within DSP IC markets from the SFDSPs such as modems and FFT chips, which are designed and marketed broadly for specific functions rather than specific "applications."

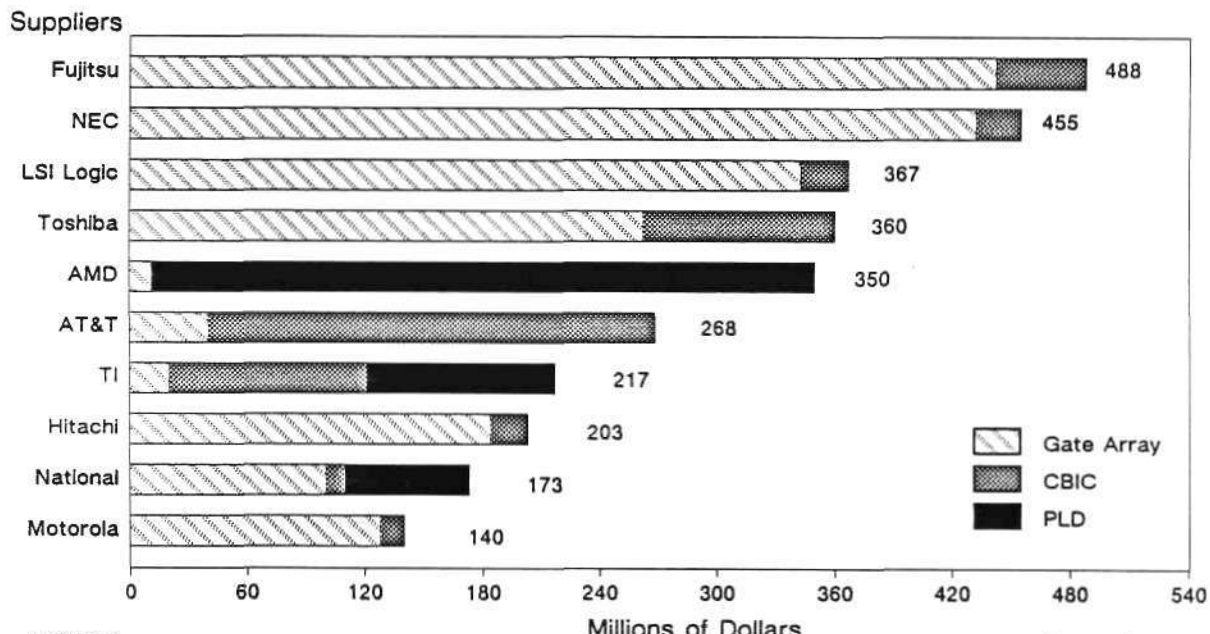
These invisible ASDSP chip sales are very substantial, estimated at $131 million in 1988, or roughly the same as the $158 million for the highly visible DSMPUs. For many domestic ASIC suppliers, 20 to 30 percent of their output is DSP related, with some companies approaching 50 percent. The invisibility comes from the proprietary nature of the business, not its lack of market importance. This newsletter looks at what is happening in this market with the thought that its invisibility may be hiding DSP business opportunities and important trends. We first review the major general ASIC suppliers and their marketing positions toward DSP. Then we examine the major DSP suppliers and their involvement with ASDSPs.

PRODUCTS AND DSP MARKETING POSITIONS OF MAJOR ASIC SUPPLIERS

The general ASIC market was $7.4 billion in 1988, nearly 20 percent of the total IC market, with a compound annual growth rate (CAGR) of 16 percent. Figure 1 shows the worldwide sales for the major suppliers in all technologies (MOS, bipolar, and BiCMOS) and design types (gate array, cell-based, etc.). Estimated North American ASIC consumption by application market is shown in Figure 2. Note the prominence of the communications and military areas, major DSP markets.

Figure 1

Estimated 1988 Worldwide ASIC Ranking



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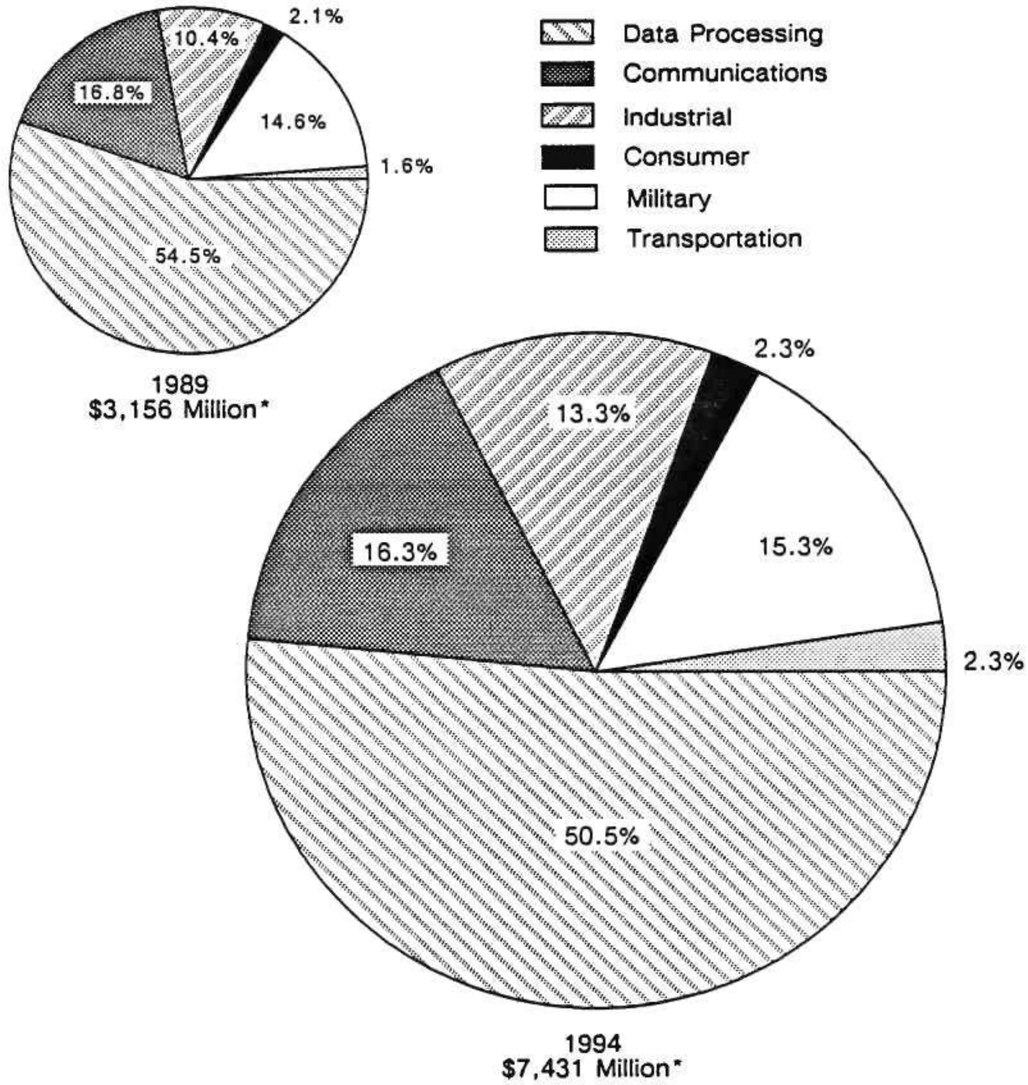
Source: Dataquest May 1989

Figure 2

Estimated North American ASIC Consumption by Application Market—Total (1989 and 1994)



*Excludes Full-Custom ICs

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Source: Dataquest May 1989

Gate Arrays

The largest ASIC segment is gate array designs, at $2.9 billion in 1988. The ranking five suppliers are the top four overall ASIC companies—Fujitsu, NEC, LSI Logic, and Toshiba—plus Hitachi. None, with the exception of LSI Logic, have significant design aids for DSP users. The closest thing is macrofunctions of the AMD Am2900 series building blocks, which are popular in DSP. LSI Logic, the top CMOS gate array supplier with an estimated 25 percent DSP business, has the MACGEN compiler for generating multiplier-accumulators of varying precision and arithmetic formats. Although backed up with a full arithmetic and functional simulator, it still lacks specific DSP features like overflow saturation and coverage of the often complex address generation and microprogramming functions needed for a full processor.

Cell-Based Designs

The smallest but fastest growing segment of the ASIC market is the so-called standard cells segment. In 1988, revenue was $1.3 billion, with AT&T, Texas Instruments, Toshiba, NCR, and VLSI Technology as the top-ranked suppliers. Growth was 43 percent last year. Here again, DSP support has been limited mostly to Am2900 series building blocks.

Full-Custom and Silicon Compilers

The second largest ($2.5 billion) portion of the ASIC market in 1988 was still the full-custom segment, but it is declining at a 3 percent annual rate. Silicon compilation, however, counters the overall figure with strong growth. DSP accounts for nearly half of all silicon compiler applications because of its acceptance by large communications and military systems companies. DSP support is a natural fit for silicon compilation, with its emphasis on high-level functional design, but even leader Silicon Compiler Systems, Inc., provides no specific DSP support.

The motivation for a full-custom design is often proprietary design protection and cost, but it also can be the high performance that DSP requires. The largest custom suppliers are NEC, Matsushita, Sharp, and Toshiba. Although much of their output is for consumer products (e.g., ultrasonic autofocus controllers for cameras), the companies are often solving DSP problems. That trend should continue as consumer products become smarter. Philips, the large European consumer products firm, estimates that half of its custom silicon output is for DSP functions.

MAJOR DSP SUPPLIERS' ROLES WITH ASDSPs

Dominant DSP supplier Texas Instruments has surely leveraged its position with application-specific designs, but these designs have been mostly full-custom done with internal design resources. One that became visible is the TMS 320C20, now a standard product, which grew from specific speech processing requirements at ITT. But Texas Instruments does not actively encourage ASDSPs, particularly those that involve users in any active role in their design. The new TMS 320C30 has a modular layout and a future as a processing core, but it is not a major thrust at this time.

Number two DSP supplier NEC has produced a myriad of DSP designs in most DSP applications, such as speech recognition, signal encoding and image processing, as well as in more experimental areas like data-flow processors. Most have been cell-based designs to keep development costs low and design times short. However, these devices have been mostly for internal telecommunications requirements, with no public attempt to secure ASDSP business using the cell libraries.

Similarly, Fujitsu has supplied a large internal telecommunications need with cell-based designs. It has had less commercial success with standard products. Perhaps because of this, Fujitsu has now made available its processing cores and cell-based peripherals and memory configurations in the MB8220/232 product line.

AT&T, a major internal ASIC and DSP supplier, has not used its limited commercial success with standard parts to expand its ASDSP business. Motorola and Analog Devices have no ASIC programs in DSP, even though Motorola's 56200 was a silicon compiler design that could presumably have been the start of an application-specific filter business.

TRW LSI Products is understood to have replaced much of its loss of merchant market share with custom DSP designs using its own design teams. There are no tools for public use. AMD's lack of participation in the general ASIC market has kept the company from capitalizing on the Am2900 series building blocks.

DATAQUEST CONCLUSIONS

The distinction between DSP and general-purpose data processing is becoming blurred, but clearly a large portion of the fastest growing segment of the IC business, ASICs, is DSP related. Dataquest expects ASDSP to be a $181 million market in 1989 (see Table 1). The major participants in this business are the traditional ASIC suppliers rather than the DSP IC firms. Business is being secured in spite of not having device libraries or support tailored to DSP designer needs. At this time, users are limited to sophisticated users who do not require much support.

The major DSP suppliers, although they do high-volume, full-custom, application-specific designs, have not pursued this business either. Because their own standard products have usually been custom designed, they have not internally developed the libraries or tools that would assist them in the public ASDSP market. They also might view an aggressive ASDSP program as eroding the programmable solutions with their standard products in which they have made such an extended investment. This explains their cautious approach of expanding from a programmable core processor for ASDSPs. Within large IC companies, DSP and ASIC are often separate divisions, with many organizational forces working to impede cooperation on a workable strategy. Even in a narrowly focused company like LSI Logic, the DSP effort has been an attempt to establish a viable standard product line (something new for the company) rather than to strengthen its position in the ASDSP market.

Table 1

Application-Specific DSP (ASDSP) Market
(Millions of Dollars)

Estimated		
1986	1987	1988
$68	$98	$131

CAGR 1986-1992
37.6%

Forecast			
1989	1990	1991	1992
$181	$250	$340	$461

Source: Dataquest
May 1989

The ASDSP market is understandably undersupported at this time. Because both general ASIC suppliers and DSP firms have been growing rapidly, they have had other more important tasks. Each type of company would have to master a new set of skills to solidify a position, but as competition increases, some company will likely move to claim ASDSPs as its own. ASIC houses would seem to have a head start, but DSP manufacturers may have the strongest motivation.

As DSP increasingly becomes possible on general-purpose, particularly RISC, processors, a quick-response, application-specific approach to the remaining diversified DSP market will be necessary. Cell-based designs seem the best design approach today, besides being a good basis for any long-term plan for DSMPUs, or special-function or building block DSP standard products.

Robert E. Owen

Semiconductor Industry Service
Analog Newsletters

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Research Newsletter

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THE ANALOG IC MARKET: A BAROMETER FOR THE SEMICONDUCTOR INDUSTRY

SUMMARY

It is well known that the analog IC market neither grows as fast nor suffers the same severe downturns as the digital market. Less well known is that the difference in growth rates between the total monolithic IC market and the analog market 1) is periodic and tracks the IC industry ups and downs, and 2) has provided a leading indicator for every downturn over the past 16 years.

Over the past 16 years, most IC market forecasts have predicted the decline of the analog segment of the semiconductor market. In reality, the analog IC market not only has kept pace with the semiconductor market in general, but it has offered a stable benchmark by which the state of the IC industry can be measured.

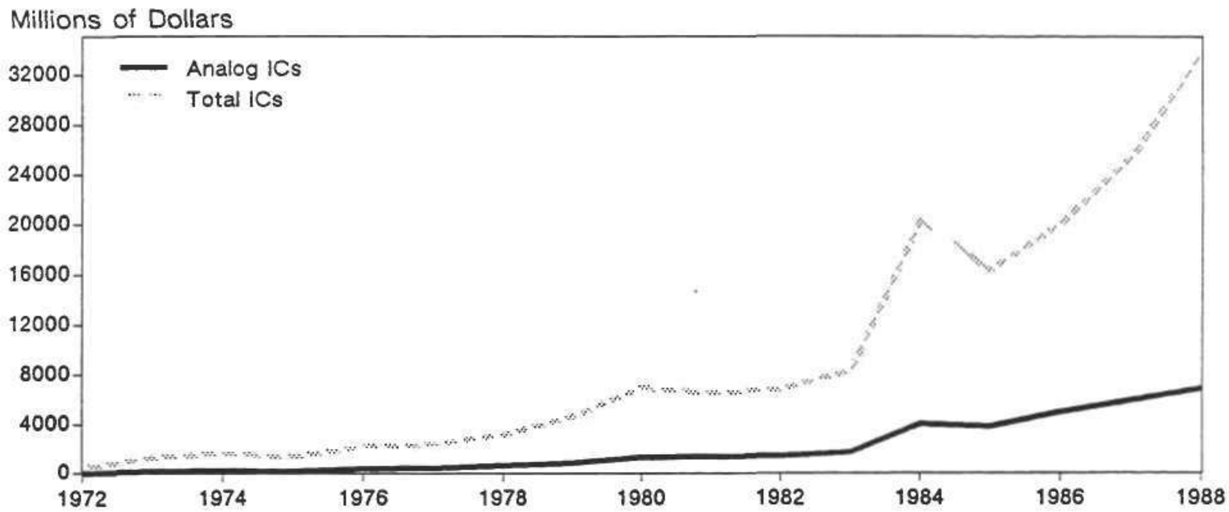
This newsletter provides a new look at analog IC market growth and how it relates to the total market.

THE ANALOG BENCHMARK

The line graph in Figure 1 shows both total monolithic IC consumption and analog IC consumption over the past 16 years. The curves are similar in shape, differing mainly in magnitude, which suggests that the analog market tracks the total IC market. By using the World Semiconductor Trade Statistics (WSTS) data shown in Figure 1, a bar chart can be constructed (see Figure 2) that shows monolithic analog IC sales as a percentage of the total monolithic IC sales. The important point shown by this bar chart is that analog sales have consistently remained at about 20 percent of the total monolithic IC market. This is a surprising result because, despite significant changes in both analog and digital products, the analog proportion of 20 percent has remained virtually unchanged over the 16-year period. Using the fact that the analog portion of the market has remained at approximately one-fifth of total sales suggests that the consumption curve of Figure 1 can be redrawn, multiplying analog sales five times for comparison. This has been done in Figure 3.

Figure 1

Analog IC Sales versus Total Monolithic IC Sales



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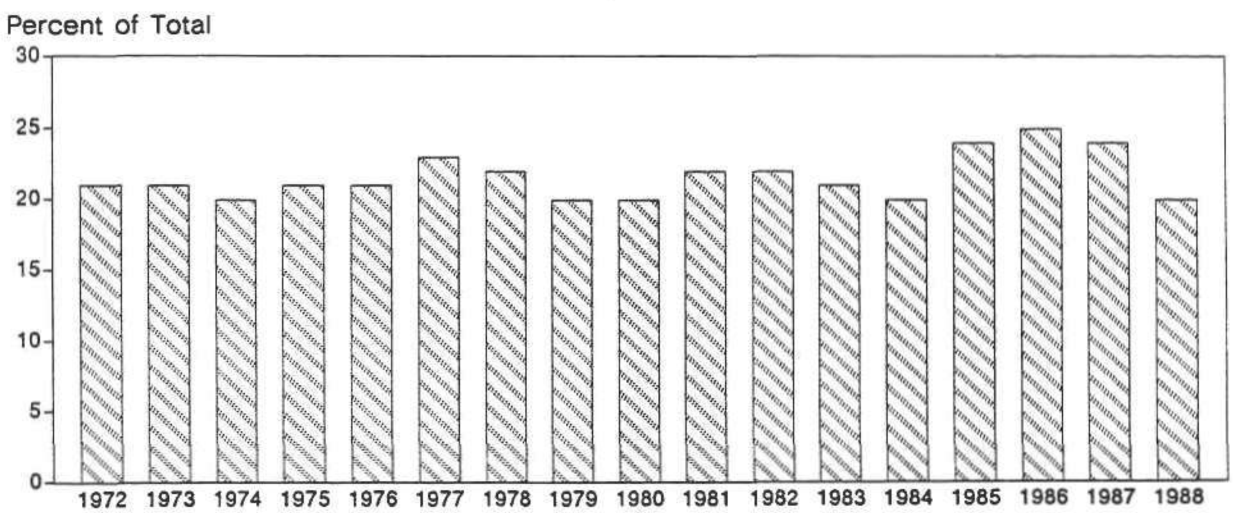
Source: Dataquest
January 1989

Figure 2

Analog IC Sales As a Percentage of Total Monolithic ICs



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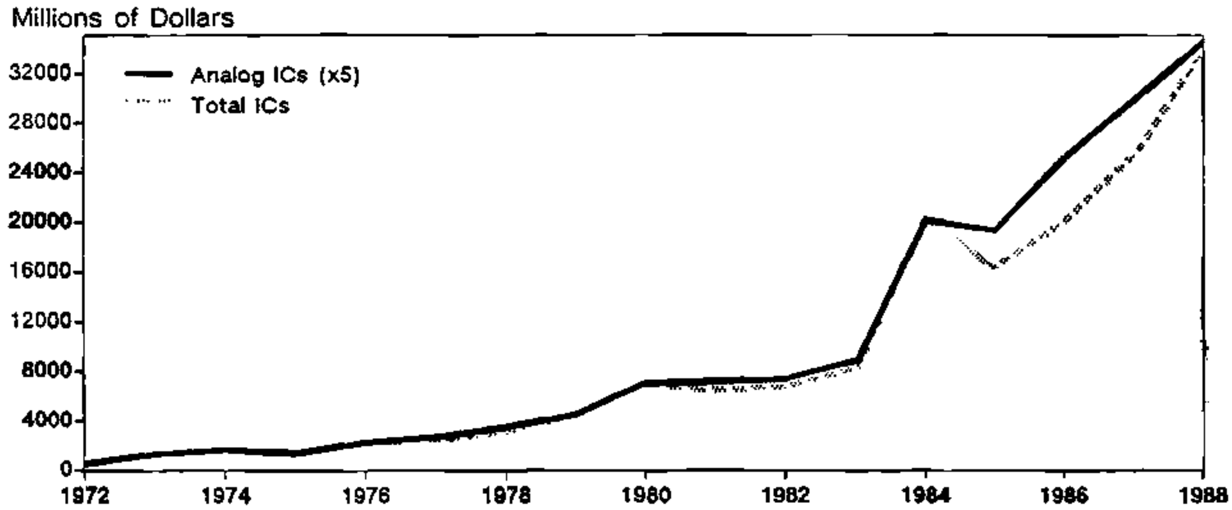
Source: Dataquest
January 1989

Figure 3

Total IC Sales versus Five Times Analog Sales



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Source: Dataquest
January 1989

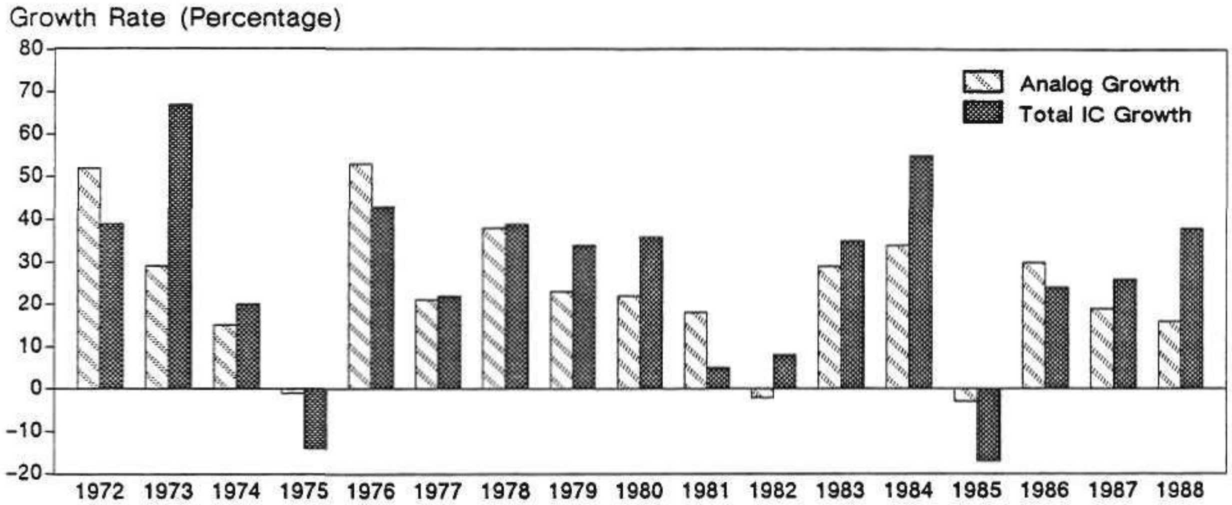
Figure 3 shows how closely the analog market tracks the total IC market. The analog curve is not only similar in shape, but it is a smoother curve that more closely defines the long-term market trends. These curves diverge greatly at two important periods—strong growth (boom) periods and weak market (bust) periods.

Please note that Figures 1, 2, and 3 use WSTS data to isolate monolithic ICs. This WSTS data represents only the reported sales of SIA participants, so the year-to-year growth rates can be distorted. Japanese companies joined this trade association in 1984, which is why the growth is so large in this year (although it was an exceptional year). WSTS data is used to establish the relationship of analog to total ICs in monolithic form only and not for absolute numbers or growth rates.

Taking sales data and plotting it as growth rates over 16 years, as illustrated in Figure 4, shows these growth characteristics more graphically. While it is well understood that the analog market shows smaller growth rates and declines than the total market, the less obvious long-term result of this pattern is that the analog market growth during the bust period compensates for the lower growth during the boom period. This is why analog IC sales remain at a nearly constant 20 percent of total IC sales.

Figure 4

Growth Rate Comparison
(Total ICs versus Analog ICs)



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Source: Dataquest
January 1989

GROWTH RATES COMPARED

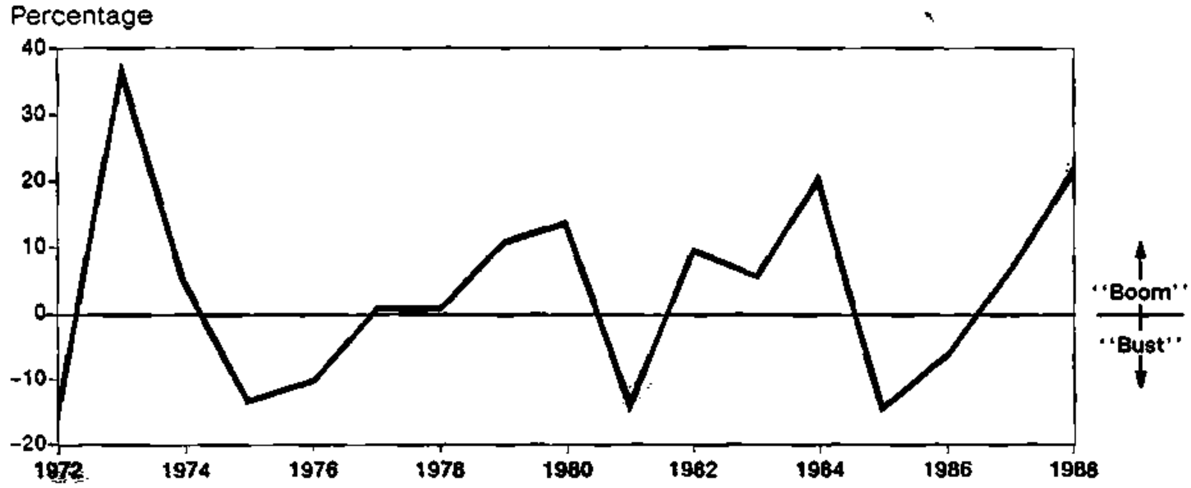
The fact that analog IC growth lags the total growth in periods of strong growth and leads in periods of slow (or negative) growth suggests a periodic nature to these comparative growth rates. By plotting the total IC sales growth minus the analog growth by year over the same 16 years, the periodic nature of their relative growth is dramatically illustrated (Figure 5). This graph defines normal boom periods as being above the zero axis and bust periods as being below. The slow markets of 1975, 1981, and 1985 are clearly defined, as are the strong years of 1973, 1979, and 1984.

This graph may lead to the conclusion that an industry downturn can be predicted when the total-to-analog growth rates get too far apart. An analog lag of more than 10 percent seems to signal an approaching downturn as it did in 1974, 1980, and 1984 (and again in 1988).

Note that Figures 4 and 5 are derived from Dataquest information that includes worldwide data but does not identify monolithic ICs separately from total ICs. These curves are essentially the same as those derived from the WSTS data used in Figures 1 through 3 but are used to prevent concern about the growth rate distortions that could result from the WSTS data.

Figure 5

Growth Rate Difference by Year
(Total IC Growth Minus Analog IC Growth)



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Source: Dataquest
January 1989

How can the different growth rates forecast a change? By showing when the total IC market is growing faster than the analog market, the graph defines a period of an imbalance in market demand (a boom period) and the following adjustment (a downturn). Analog components do not exist in a vacuum. They provide interface, conversion, and signal-processing functions found in all electronic equipment. Even products considered to be digital can contain analog ICs in the power supply and output functions. Any product handling electronic signals such as audio, radio, TV, and telephone equipment must have analog ICs. In addition to this broad market application, analog ICs have shorter lead times, less pricing volatility, many suppliers, and few high-demand glamour circuits.

In an ideal IC market, one in which supply equals demand, prices remain relatively constant, and end-product markets have little variability, both the total and analog growth curves should track. However, distorted buying patterns caused by chip shortages, long lead times, and "hot" electronic products can lead to the total-to-analog growth rate difference shown in Figure 5. Past occurrences of this large growth rate difference have led industry observers to conclude that the analog IC market was declining. In fact, as we have seen, the large difference in growth rates was not signaling the decline of analog as much as it was indicating a forthcoming market downturn.

FORECAST

Dataquest has forecast a slowdown in the second half of 1989, using other forecasting techniques. The same conclusion may be drawn by interpreting the growth rate difference curve of Figure 5 as a leading industry indicator. The fundamental assumption for this interpretation is that analog will remain at a constant 20 percent of IC sales (as it has over the past 16 years). This leads to the conclusion that the average value of the difference curve of Figure 5 must remain constant (at zero) over time. When a demand difference as large as we saw in 1988 occurs, a correction (total industry slowdown) can be expected within the next one to two years to maintain this zero value.

DATAQUEST CONCLUSIONS

The movement of the analog IC market should be of interest to more than the suppliers and users of analog ICs. Analog IC products are important to all areas of electronics. It is this broad functional utility that ties analog so significantly to the whole IC market. But it is the analog market's unique pattern of stability that makes it a suitable benchmark to measure the changes in the total IC market. While the periodic pattern that shows up in Figure 5 may not always remain a viable forecasting method, it does fit the past patterns of industry changes. The analysis of analog IC growth patterns can provide a useful leading indicator of the general health of the IC market.

Gary Grandbois

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SEMICONDUCTOR SENSORS: KEY COMPONENTS IN SMART PRODUCTS

INTRODUCTION

Senses provide a window to the world outside ourselves. Without sensory input, not only humans, but also powerful logic elements such as microprocessors are not in control of "real-world" processes and events. This newsletter describes electronic sensors and their markets, focusing particularly on semiconductor sensors, their advantages, and their potential for growth.

Sensor Defined

An electrical sensor is a device that creates an electrical signal (an analog) proportional to the intensity of a particular physical phenomenon. Some of these phenomena are light, force, pressure, displacement, temperature, moisture, acidity/alkalinity (pH), chemical concentrations, electrical fields, magnetic fields, and sound. The term transducer, from the Latin "to lead across" (in this case, to transfer energy from any form to an electrical form), is sometimes used interchangeably with sensor. Using Dataquest's definition, sensor covers all sensing elements and ICs that provide electrical signals in response to nonelectronic physical phenomena.

SENSOR INDUSTRY

The sensor industry is very fragmented. More than 200 U.S. sensor companies alone vie for equally broad markets. The result is that most sensor companies are relatively small, with niche-oriented products and diverse sensor design technologies. The wide range of sensor types, technologies, packages, interfaces, and suppliers makes the sensor marketplace a very amorphous one. In fact, the term sensor has been applied to products ranging from the basic sensor element (a slug of silicon, for example) to complex sensor modules or systems. Market-size estimates can vary greatly due to this latitude in product definition.

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SENSOR MARKET

Dataquest defines a semiconductor sensor as a component-level product, either a chip or an IC (monolithic or hybrid) composed of a semiconductor material (silicon or gallium arsenide). For nonsemiconductor sensors, only the sensing element and any mechanical interface and packaging are considered to comprise the sensor. Dataquest estimates the total 1988 worldwide sensor market to be $3.2 billion. Figure 1 shows the breakdown of this market by sensor technology. In 1988, about 60 percent of the sensor market was supplied by nonsemiconductor sensors. These products include thin-film strain gauges, ceramic infrared sensors, thermocouples, and linear voltage-differential transformers (LVDTs). By 1995, it is expected that 60 percent of the market will be supplied by semiconductor sensors. The semiconductor segment of the market can be further split into optical and nonoptical sensors. Figure 2 shows sensor consumption by region.

Figure 1

Sensor Market by Technology
(Captive and Merchant Suppliers)

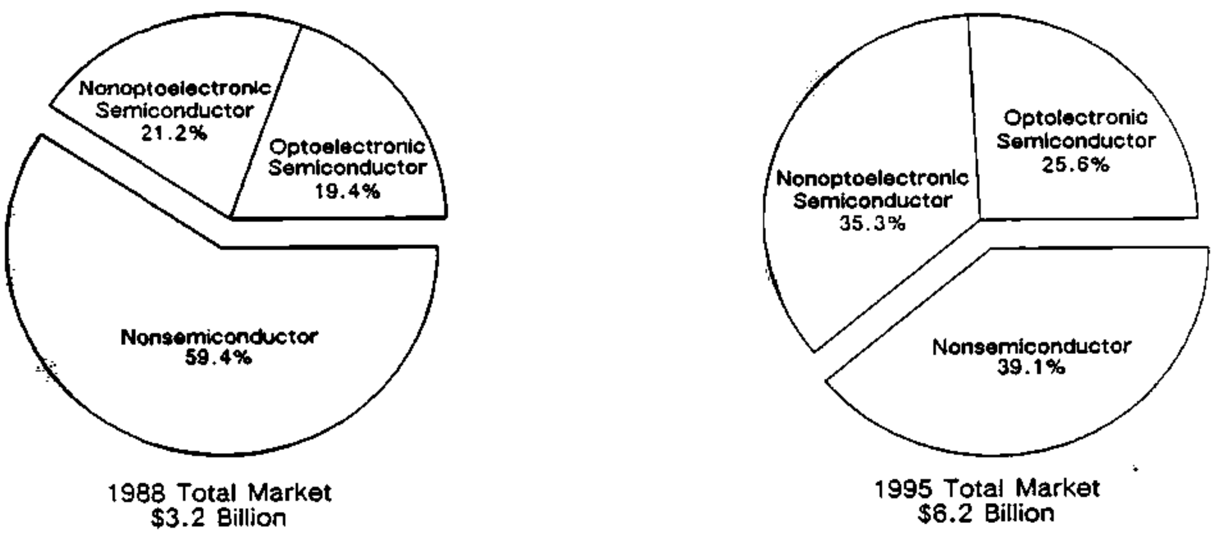

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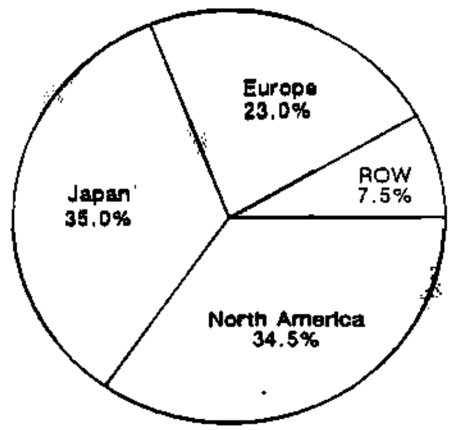
Figure 2

Sensor Consumption by Region



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Source: Dataquest
February 1989

Microprocessors, Automobiles Drive Sensor Market

Microprocessor-based electronics promise efficiency, automation, comfort, and safety as programmed logic replaces human interface in everyday products. Electrical sensors are the key to having "perception" capabilities in these automated systems. But electrical sensors and controls can do more than merely automate products and processes. They provide the sensory input essential to improved performance, efficiency, and safety. Automobile engines, suspensions, and braking systems, as well as electric motors and air-conditioning systems, are examples of products that have been improved by sensor technology. These high-volume consumer and automotive products demand inexpensive yet rugged sensors. Semiconductor sensors can meet these stringent requirements.

The automotive market is the largest single market for sensor products. Automobiles now use 2 to 7 sensors per automobile (33 million automobiles manufactured per year). At present, sensors are found in automobile engine control applications. Comfort and safety applications will be the next growth areas for automotive sensors. The average number of sensors per vehicle is expected to increase to 12 by 1995, with semiconductor sensors dominating these new applications.

SEMICONDUCTOR SENSORS

Silicon has become an important sensor material because of its impressive advantages over other materials. These advantages include the following:

- Excellent mechanical properties
- Excellent electrical sensing properties
- Extensive semiconductor R&D "coattails"
- Ability to integrate signal conditioning on sensor

The nature of silicon is well suited to sensing. Silicon has a resistance that varies with strain, a property that is used in force, pressure, and acceleration sensors. Magnetic fields can create voltage differences in semiconductor material that has a current flow (Hall effect).

Semiconductor junctions are sensitive to light, strain, and temperature. In addition, MOS devices are sensitive to electric fields and the presence of ions. Although rugged, silicon sensors have a limited upper temperature of about 125° Celsius. Although gallium arsenide (GaAs) devices have the potential to extend this upper limit to 400° Celsius, processing and cost constraints have limited GaAs sensor developments.

Besides having excellent physical properties, semiconductor sensors borrow and build on the extensive R&D efforts made by IC manufacturers. This "free ride" on IC R&D developments gives semiconductor sensors substantial advantage over other sensor types. The learning-curve expectations for IC prices and developments can be applied to semiconductor sensors as well.

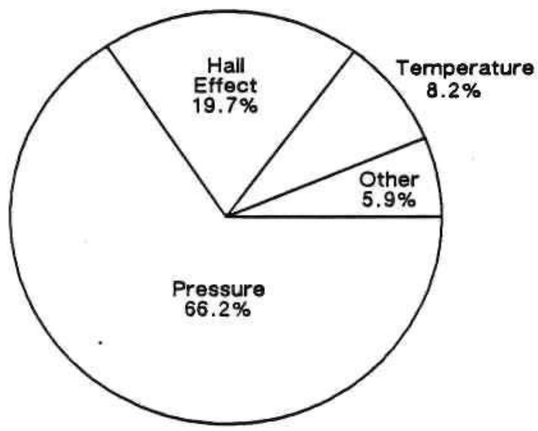
Since the sensor is fabricated on semiconductor material using standard IC processes, additional circuitry can be fabricated on the same chip. The additional circuitry can include other sensors, amplifiers, or linearization functions. A sensor combined with active circuitry can overcome environmental problems, such as noise, temperature, and power-supply variations as well as correcting any deficiencies of the sensor element itself.

SENSOR CONSUMPTION BY SENSED PHENOMENON

Figure 3 shows the semiconductor sensor consumption by type (excluding optoelectronic sensors for simplicity's sake). Pressure sensors are very much the dominant type of semiconductor sensor. The reason can be seen in Figure 4. Semiconductor pressure sensors have penetrated their market much more effectively than have other semiconductor sensors.

Figure 3

Nonoptoelectronic Semiconductor Sensor Consumption by Type



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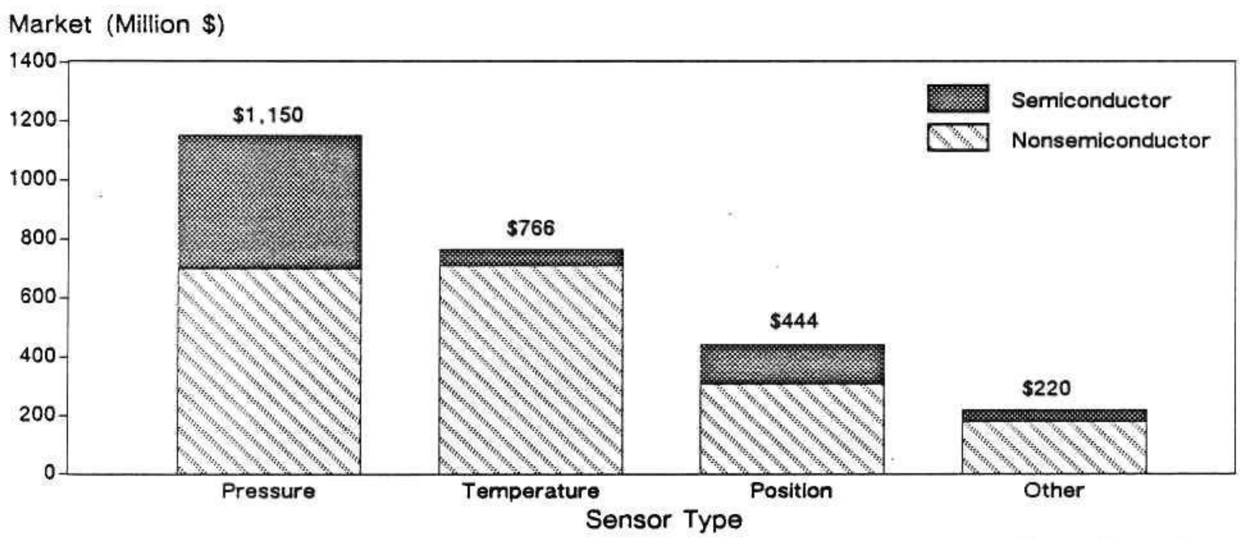
Source: Dataquest February 1989

Figure 4

Nonoptoelectronic Semiconductor Sensor Market Penetration



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Source: Dataquest February 1989

NONCAPTIVE U.S. SUPPLIERS

Table 1 lists U.S semiconductor suppliers that supply nonoptoelectronic sensor ICs into the merchant market. The total merchant market for nonoptoelectronic semiconductor sensors exceeds $300 million.

Table 1

Estimated Nonoptoelectronic Sensor Shipments by U.S. Semiconductor Sensor Suppliers

Company	1988 Sales ($M)
Kulite Semiconductor	$ 27
Sprague Semiconductor	18
Honeywell	16
Motorola	12
Sensym	9
IC Sensors	7
NovaSensor	7
National Semiconductor	4
Analog Devices	4
Others	41
Total	$145

Source: Dataquest
February 1989

HALL-EFFECT SENSORS

Twenty percent of the nonoptoelectronic semiconductor sensor market is for Hall-effect sensors, which develop a voltage output relative to the magnetic field sensed. Hall-effect sensors determine position or displacement by sensing the variation in a magnetic field. Brushless DC motors depend on Hall-effect position sensing for operation.

Hall-effect devices have been available for many years, being based on a century-old sensing concept. They have become important for a number of reasons. By being both noncontact and a nonoptical, they are largely immune to the effects of dirt and corrosive materials. They also share the low cost of manufacturing and the ease of integration common to all semiconductor products. Hall-effect ICs combine the basic Hall-effect sensor with signal-conditioning circuitry, such as amplifiers and comparators. Although a Hall-effect device normally provides analog output, the comparator function makes the device a switch by providing only a two-state output. These "digital" Hall-effect sensors are found in keyboards, motor controllers, and tachometers.

SEMICONDUCTOR PRESSURE SENSORS

The traditional thin-film strain gauges have been successfully challenged by silicon, micromachined, piezoresistive strain gauges. Piezoresistive means simply that resistance changes in relation to strain.

These products use IC diffusion and etching developments in the fabrication of pressure sensors that offer new levels of performance, repeatability, and cost-effectiveness. Micromachining is the technique of selectively etching a silicon wafer in three dimensions to create thin silicon diaphragms. Silicon diaphragms exhibit near-ideal mechanical elasticity with an absence of hysteresis (mechanical memory). Thousands of pressure sensors, along with signal-conditioning circuitry, can be fabricated on a silicon wafer using standard IC equipment and processing.

TEMPERATURE SENSORS

Silicon temperature sensors make use of the temperature sensitivity of the PN junction. This simple sensing element has a predictable characteristic that can be linearized and conditioned right on the sensing chip.

IC temperature sensors have had limited success in displacing other temperature-sensing devices. This is due to the limited operating temperature range of silicon. Silicon devices, at best, operate over the temperature range of -55° to +125° Celsius. The upper range is simply too low for the monitoring of most thermal processes, including the temperatures found in automobile engines.

OPTOELECTRONIC SENSORS

Light sensing is used in control applications, fiber-optic communications, image detection, machine vision, and video. Semiconductor optical sensors include discrete photodetector products, such as photodiodes and transistors, and IC image sensors, such as charge-coupled devices (CCDs) combined with photodiode arrays. CCD image sensors are available in linear and area arrays and are vital to imaging and machine vision applications. Silicon photodetectors are widely used in fiber-optic data transmission and fiber-optic sensors, optical encoding/decoding, and position sensing. This $620 million market will have strong growth in consumer and communications applications.

CHEMICAL AND BIOLOGICAL SENSORS

Semiconductor chemical sensors are emerging only now. One application of a transistor as a chemical sensor has been dubbed the chemFET. This device is similar to the standard MOSFET except that modulation of channel conductivity is provided by chemical ion concentrations rather an applied voltage. A semipermeable membrane selectively passes the ions being measured into the gate oxide position of the chemFET. Channel resistance of the FET device is altered by their presence.

Biological sensors generate voltage or resistance changes in silicon in response to the presence of biological agents. Semiconductor chemical and biological sensor applications accounted for an insignificant portion of the sensor market in 1988. This market will develop in the early 1990s as reliable and inexpensive sensors are introduced.

DATAQUEST CONCLUSIONS

Sensors are the missing link in the next decade of electronics development. The sensor market is poised for standardization, consolidation, and growth. Automotive and consumer applications will provide the impetus for sensor standardization, which will result in lower-cost devices that will, in turn, develop the market further.

Upcoming newsletters will focus on specific semiconductor sensors. Micromachined silicon pressure sensors, Hall-effect sensors, and optoelectronic sensors will each be the subject of an individual newsletter in the months to come.

Gary Grandbois

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ANALOG AT ISSCC '89
ISSUES, PRODUCTS, AND PROCESSES

INTRODUCTION

The International Solid-State Circuit Conference (ISSCC) was held in New York City on February 15 through 17 this year. Although the sessions covered all IC types, this newsletter focuses on analog IC design trends, with highlights of selected sessions. These are followed by tables showing process technology by product type, by presenting company, and by leading analog suppliers.

SESSION HIGHLIGHTS

Data Converters

The Data Converter Papers

Five of the six papers were devoted to new designs for A/D converters (ADCs). The sixth described a D/A converter. Of these six presentations, five were devoted to CMOS converters and the other to a bipolar design. This preponderance of CMOS ADCs is a remarkable change from a decade ago. In 1979, only 23 percent of the converter papers described CMOS devices; the rest were divided into 46 percent bipolar, 23 percent NMOS, and 8 percent PMOS. A less dramatic fact is that 60 percent of the data converter papers this year were from U.S. sources, down only slightly from 77 percent in 1979. This is one of the few areas where U.S. suppliers seemingly have maintained a strong position.

None of the ADC papers was on fully parallel flash converters. The complexity, chip size, power requirements, and resolution limitations of flash converters as well as the limited speed capability of the successive approximation technique have pressed the multistep, subranging technique to the forefront of new designs. Four different papers on this technique were presented.

The first two papers (by NTT and Sony) were remarkably similar in describing 40-MHz, 8-bit, CMOS subranging ADCs that incorporate on-chip sample-and-hold (S/H) circuits. These circuits were fabricated in 1.0- and 1.4-micron CMOS processes, respectively.

The third paper (from National Semiconductor) also covered a 40-MHz 8- to 10-bit CMOS ADC. This design used a recycled remainder technique to time-multiplex a single 4-bit flash converter in successive conversion steps. This ADC did not incorporate the S/H function on the chip. The device was fabricated with a 2.0-micron CMOS process.

Signetics presented a paper on a 12-bit bipolar subranging ADC with fuse trimming. This device uses a complex four-step quantizer that successively determines the least significant bits (LSBs) while correcting errors that may have been created in preceding steps. Conversion time is stated to be 500ns.

A 13-bit, 160ns ADC was presented by SGS-Thomson. This device uses a combined resistor string and capacitive array in a successive-approximation converter to obtain the 13-bit resolution. The resistor string provides the 4 most significant bits (MSBs) while the capacitor array provides the 9 LSBs. This structure normally leads to a converter with good differential linearity and poor integral nonlinearity. To combat this, a multitapped single resistor element was incorporated to improve the integral nonlinearity of the device. The part was processed in 1.2-micron double-metal CMOS process.

In the last converter presentation, Philips laboratories presented a design technique that can be used to provide multiple matched current sources for CMOS A/D converters.

Standardization on the CMOS process for A/D converters is apparent from these papers. BiCMOS, as a data converter process, was conspicuously absent from the presentations. Dataquest believes that, along with CMOS, BiCMOS will be a significant process for data converter designs.

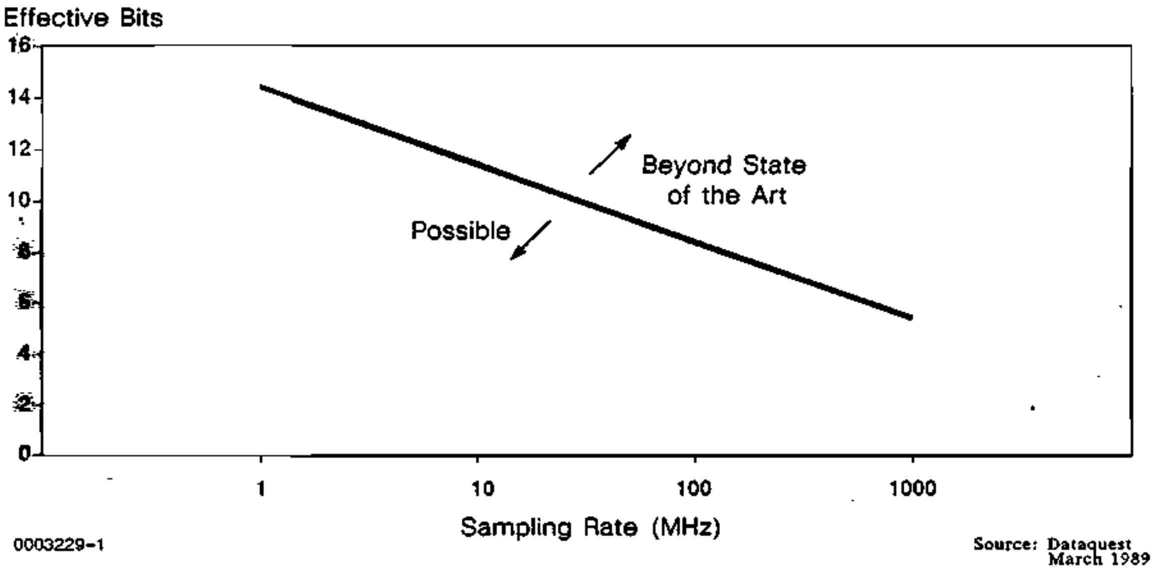
BiCMOS was more evident in the amplifier session. National Semiconductor presented a paper on a sample-and-hold amplifier that settles to 10 bits in 15ns. Video speeds were maintained from the combination of bipolar amplifiers and fast MOS switches despite the fact that a closed loop configuration was used for increased accuracy.

The Limits of Data Converters

One of the panel discussions focused on the performance limitations of data converters. Conversion rate limitations were the main focus. The relationship between sampling rate and resolution was also discussed. Factors that can limit sampling rate include package capacitance and inductance, time delay of silicon interconnects, comparator delay, input capacitance, rise/fall time uncertainty, finite bandwidth, induced noise, and inherent noise. The point was made that high sampling rates (>1 GHz) and high accuracy (>6 bits) are mutually exclusive parameters. Although sample-and-hold circuits can solve many of the time-dependent problems, 250 MHz seems to be the fastest rate that can be achieved presently with an S/H ADC system. Figure 1 illustrates the present frontier of A/D converter performance.

Figure 1

A/D Converter Performance Limit



Resolution to 20 bits and beyond are predicted as oversampling and digital correction techniques are used. Resolution beyond 20 bits and usable bandwidths beyond 500 MHz both seem beyond the present state of the art.

Amplifiers

One of the product highlights of the amplifier session was an op amp with a 10-GHz unity gain bandwidth. This device, presented by Hughes Research Laboratories and offering a fourfold improvement over previous designs, was fabricated in a GaAs MESFET process that created an insulated backgate. Previously, backgating effects had hampered the performance of other MESFET amplifier implementations considerably.

Analog Standard Cells

A panel discussion important to analog observers was titled "Analog Standard Cells . . . A Powerful Tool Whose Time Has Come?". The presence of the question mark in the title gave emphasis to the many concerns and questions involving analog ASIC technology. No one on the panel or in the audience questioned the usefulness of the analog standard cell concept; implementation is the problem. Implementation of analog standard cells is hampered by the availability of CAD tools and by the fundamental nature of analog circuits and their markets. Although some panelists believed that available digital layout tools and analog simulation tools can be used, no one suggested that true integrated tools are available at this time.

Additional discussion developed around the point that even if the design tools existed, analog standard cell libraries would not be viable. Some of the concerns expressed about analog cells were as follows:

- Process dependency of parameters
- Process/library inflexibility required to be truly "standard"
- Variation in performance demanded by fragmented markets (This requires many similar cells or constant modification.)
- Number of analog functions needed (The market may be limited for a limited library.)
- Sensitivity to physical layout
- Cumulative performance degradation of interconnected cells
- External passives needed
- Testability

Although no concerns developed on whether or not the time will come eventually for analog standard cells, a common opinion seemed to be that we do not yet have true libraries of analog standard cells. The present libraries are not truly standard because the cells are constantly being "tweaked" and new cells are constantly being added.

Imagers and Sensors

This session was largely devoted to CCD imaging sensors designed for color video, HDTV, and imaging applications. These products are key to many of the high-volume consumer, medical, and industrial applications of the future.

A number of papers indicated that the standard CCD imagers are being refined in resolution and performance. A 1.3-million-pixel imager was presented by Matsushita. One problem in reducing pixel size is that noise and image smear increase; however, an advanced technique, the BAsed-Stored-Image-Sensor (BASIS), provides a means to combat the degradation that occurs when pixel size is reduced. Canon, Inc. presented a paper on a 310,000-pixel BASIS Imager that has an amplification function within each pixel. Noise and smear can be reduced and dynamic range increased by this technique. Processed in BiCMOS, this imager shows great potential for highly integrated image-sensor systems in the future.

Despite the importance of these products to the future of electronics, the session was rather poorly attended. Although 60 percent of the papers presented were of U.S. origin, we can expect imaging technology, along with most optoelectronic technology, to be dominated by the Far East.

Telecommunications

A complete telephone circuit on a single chip was presented by SGS-Thomson. This IC was able to combine line interface, power supply, ringer, audio driver, and dialing functions as a result of the capabilities of the bipolar-CMOS-DMOS (BCD) process used. The audio portions of the circuit use 30V bipolar circuitry, the logic uses 12V CMOS, and the ringer/driver circuits use 60V DMOS drivers.

STATISTICS ON PRESENTATIONS

The geographic origin of the papers presented in the analog and digital sessions differed. The analog sessions contained 26 papers, 14 of which (54 percent) were of U.S. origin. The digital sessions saw the reverse trend where 57 percent of the papers were of non-U.S. origin. At the 1979 conference, 75 percent of the analog papers were of U.S. origin. The United States has not lost market share in analog circuits as rapidly as in digital, and this fact is reflected in the paper origins.

Table 1 lists the number of papers presented at each session and the process technology used. This table displays the preferences in process technology relative to product type.

Table 2 lists the number of papers presented by each participating company or organization and the process technology used.

Table 1

Number of Papers by Product Type and Process

	Process						
	Bipolar	CMOS	BiCMOS	BCD	DMOS	GaAs	Other
Analog Sessions							
Data Converters	1	5					
Amplifiers	2		1			1	
Imagers and Sensors		1	1				3
Analog Processors	1	3	1		2		
Telecommunications ICs		7		1			
Digital Sessions							
Static RAM	1	3	4				
Floating-Point Processors		6					
Microprocessors		4					1 NMOS
High-Speed BiCMOS ICs			7				
Nonvolatile Memories		7					
Data Communication ICs	1	4				1	
Digital Video Processors		7	1				
Gate Arrays	2	2	1			2	
High-Speed Digital ICs	4	1				1	
Dynamic RAM	7						
Total	12	57	16	1	2	5	4

Source: ISSCC Proceedings

Table 2

Number of Papers by Company and Process

Organization	Number of Papers: Total	Number of Papers: Analog	Process: Bipolar	Process: CMOS	Process: BiCMOS	Process: BCD	Process: GaAs
Alcatel Telephone	1	0		1			
AT&T Bell Labs	4	1		4			
Canon Inc.	1	1			1		
Carnegie/Mellon Univ.	1	1		1			
Cypress Semiconductor	1	0		1			
Delft Univ. (Netherlands)	1	1	1				
Digital Equipment Corp.	4	0		4			
Eastman Kodak	2	1		1			
Elec. & Telecom Inst. (Korea)	1	0					1
Fujitsu	2	0	1	1			
General Electric	1	0		1			
Hewlett-Packard	2*	1	1	NMOS			
Hitachi	9	0	1	3	4		
Honeywell SPT	1	0					1
Hughes	1	0					1
IBM	5*	0	2	2			2
Intel	2	0		2			
Krysalis	1*	0		1			
Magnavox	1	1	1				
M.I.T.	2	2		1			
Matsushita	2	1		1			
Mitel Semiconductor	1	1		1			
Mitsubishi	7	0	1	6			
National Semiconductor	4*	2		3	1		
NEC	5	1		4	1		
NTT	4	1		2	1		1
Oki Electric	1	1		1			
Philips/Signetics	8*	5	2	2	3	DMOS	
Plessey Semiconductor	1	0		1			
Rockwell Corp.	1*	0					1
Ruhr University	1	0		1			
SEEQ Inc.	1*	0		1			
SGS-Thomson	3	3		1		2	
Siemens	4	1	1	2	1		
Silicon Systems	2	2		2			
Sony Corp.	3	1		3			
Texas Instruments	4	0		2	2		
Toshiba	5	0		4	1		
Univ. of California	2	2		2			
Western Digital	1*	0		1			

*Some papers were jointly developed by two or more organizations; therefore, totals from this table will not match Table 1.

Source: ISSCC Proceedings

Table 3 takes the data from Table 2 and orders the companies using Dataquest's 1988 ranking by analog IC market share. These are the top 15 analog suppliers in descending order of rank.

Table 3

Presenting Companies by Market Share

Organization	Number of Papers		Process*				
	Total	Analog	Bipolar	CMOS	BiCMOS	BCD	GaAs
Toshiba	5	0		4	1		
National Semiconductor	4	2		3	1		
Sanyo	0	0					
NEC	5	1		4	1		
Philips/Signetics	8	5	2	2	3	DMOS	
Texas Instruments	4	0		2	2		
Motorola	0	0					
Matsushita	2	1		1			
Mitsubishi	7	0	1	6			
SGS-Thomson	3	3		1		2	
Sony Corp.	3	1		3			
Hitachi	9	0	1	3	4		
Analog Devices**	0	0					
Rohm	0	0					
AT&T Bell Labs	4	1		4			

*An important result of this ordering is the fact that five of the top six analog suppliers presented BiCMOS papers (and only one of the following nine did).
**A paper on BiCMOS sample/hold amplifiers was deleted from the conference.

Source: ISSCC Proceedings

DATAQUEST CONCLUSIONS

The most notable occurrence at this conference was the widespread presence of BiCMOS technology. Although CMOS has become a dominant technology in the IC world, its rapid move into the digital marketplace has not been mirrored in the analog marketplace. Bipolar has held a good share of the market and will continue to do so for some time. New analog products will be increasingly developed in MOS technologies, however. As this conference has demonstrated, BiCMOS has particular value in combining the performance of bipolar analog with CMOS switching and logic elements.

The variations in BiCMOS feature size presented at the conference ranged from 0.5 micron (Hitachi SRAM) to 1.5 microns (Siemens). CMOS feature size ranged from 0.5 micron (Sony DRAM) to 3.0 microns (UCLA linear).

Many of the analog product types for which BiCMOS is especially attractive were absent from the conference papers. These products include power ICs, interface ICs, and mixed-mode ASIC. CMOS/BiCMOS penetration of analog designs may be considerably greater than the presentations at the ISSCC indicate.

Gary Grandbois

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BiCMOS: A HIGH-PERFORMANCE COMPLEMENT TO CMOS

INTRODUCTION

The BiCMOS process technology has become one of the hottest topics in the IC arena. It was the dominant theme of this year's International Solid-State Circuit Conference (ISSCC) for both analog and digital ICs. BiCMOS has been most often discussed in terms of digital products, especially gate arrays and static RAMs. In fact, BiCMOS is a crucial technology for three of the highest growth areas in analog ICs: mixed-signal ASICs, smartpower ICs, and data converters. This newsletter will focus on the analog BiCMOS process, its present state, and its potential.

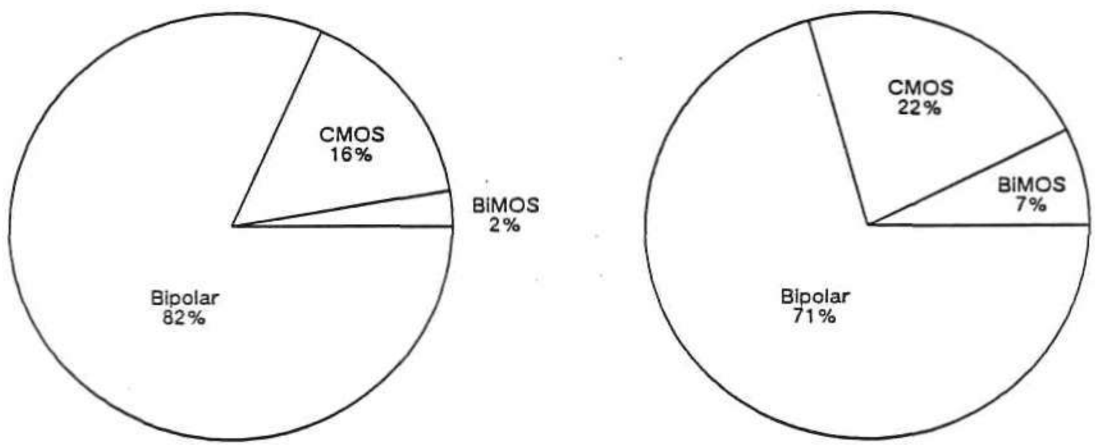
BiCMOS FORECAST

Analog ICs and the BiCMOS process are intertwined. BiCMOS has been around the analog IC world for more than a decade. Although the 1988 analog BiMOS, including BiCMOS, IC sales exceeded $148 million, the major BiCMOS developments and growth are only beginning.

Figure 1 illustrates Dataquest's estimates of analog revenue by process for 1988 and 1993. These numbers represent the percentage of total revenue provided by ICs fabricated with these processes. In this and all the following figures, BiCMOS is used to represent all BiMOS products (bipolar PMOS, bipolar CMOS, and BCD products). As Figure 1 shows, revenue from products using BiCMOS processing are expected to increase sixfold over the next five years. Bipolar-processed ICs will show growth in revenue during the five-year period, but this growth will drop by 10 percent of the total, losing substantial ground to MOS-processed ICs.

Figure 1

Sales by Process Type



1988 = $7.2 Billion

1993 = $13.1 Billion

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Source: Dataquest
March 1989

Why BiCMOS?

Although many analog products are still simple functional blocks that can use a single process technology, most new designs are for larger-scale devices that require multiple analog functions or mixed analog-digital subsystems. The needs of these complex subsystem chips are not well served by either a bipolar or a CMOS process. Table 1 lists some important functions and the preferred process.

Table 1

Bipolar and CMOS Compared

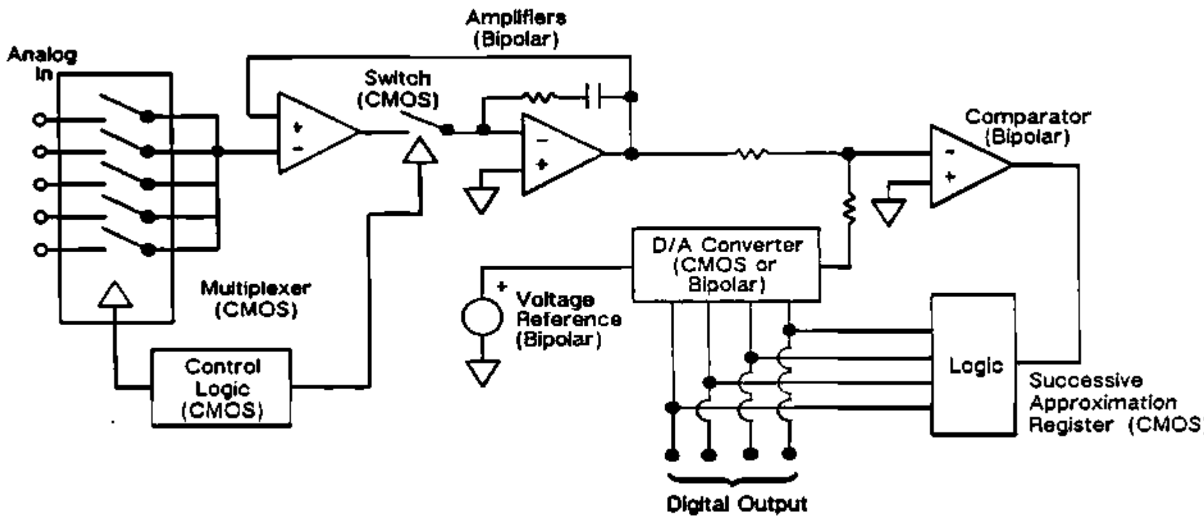
Functions	Bipolar	CMOS
Precision Amps	X	
Fast Amps	X	
High Impedance		X
Voltage References	X	
Analog Switches		X
High-Current Outputs	X	
High-Voltage Outputs	X	
Dense Logic		X
Low-Power Logic		X
Memory		X
ECL Interface	X	

Source: Dataquest
March 1989

Although complex ICs can and have been made with either of these technologies, performance compromises can be very severe. Bipolar cannot provide a useful analog switch nor CMOS a stable reference. As an example, Figure 2 shows the functional blocks comprising a data acquisition circuit. Note that an optimal circuit, designed around discrete function blocks, would require both bipolar and CMOS devices. To minimize performance trade-offs, integration of this system would best be done with a process that combined both bipolar and CMOS devices.

Figure 2

Data Acquisition System



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Source: Dataquest March 1989

Not only data acquisition, but mixed analog/digital ASICs, telecommunications ICs, and smartpower ICs would benefit from BiCMOS capabilities. Smartpower ICs especially require the current, voltage, and interface capabilities offered by bipolar devices. The extreme voltage requirements of some smartpower devices have pressed development beyond the BiCMOS process into bipolar-CMOS-DMOS (BCD), a process that combines high-voltage DMOS transistors with bipolar and CMOS devices.

Although the value of BiCMOS in power and interface circuits is largely accepted, its value in signal-handling and data-conversion circuits is questioned by a number of linear CMOS advocates. Although linear functions implemented in CMOS have improved greatly over the last decade, there is still a significant performance gap between bipolar amplifiers and references and the CMOS equivalents. BiCMOS provides a means to generate state-of-the-art circuits without requiring design "breakthroughs" in CMOS, and high-performance circuits can be implemented rapidly and easily with BiCMOS by less skilled designers. This is not a trivial consideration. The pool of highly skilled analog IC designers (often pegged at 200 worldwide) is a limited resource that cannot be stretched to accommodate the needs of growing markets.

BiCMOS Suppliers

A list of suppliers of ICs using BiCMOS processing is presented in Table 2.

Table 2

BiCMOS Suppliers

Supplier	ASIC	Smartpower	Converter
Analog Devices	X	X	X
AMCC	X		
AT&T	X		
Barvon	X		
Fujitsu	X	X	
Harris	X	X	
Hitachi	X	X	
Honeywell SPT			X
International Rectifier		X	
IXYS		X	
LSI Logic	X		
MIETEC	X		
Motorola	X	X	
National	X	X	X
NEC	X		
Philips	X	X	X
Sony		X	
SGS-Thomson		X	
Siemens	X	X	
Sprague		X	
Toshiba	X	X	
Ricoh		X	X
Telefunken		X	
Texas Instruments	X	X	X

Source: Dataquest
March 1989

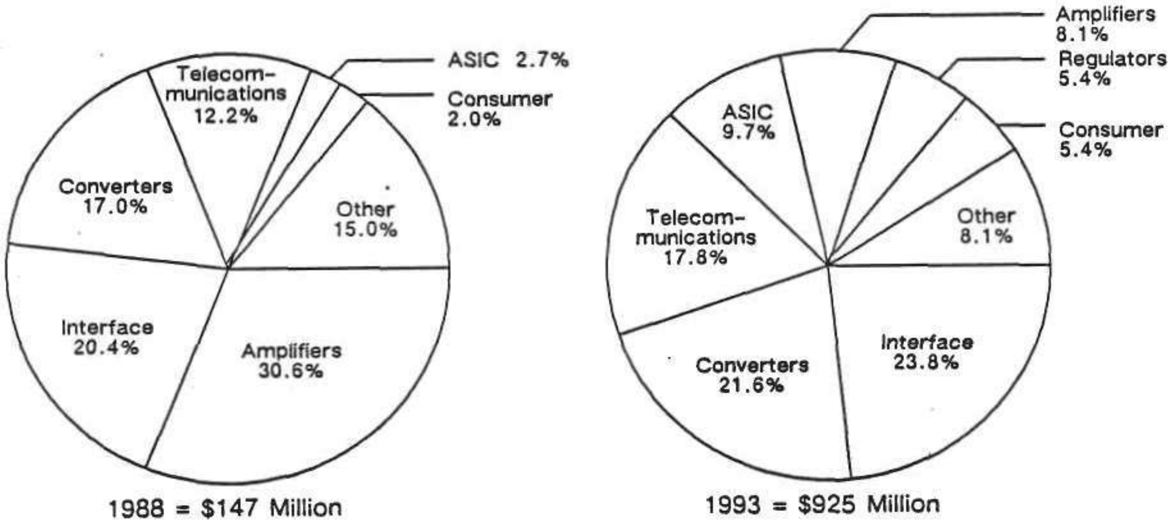
BiCMOS by Product

Figure 3 shows the BiCMOS sales by product type in 1988 and Dataquest's estimate of the sales in five years. We expect the major gainers to be the converter, interface, analog ASIC, and telecommunications IC markets.

Each of the three main product types is displayed by process type in Figure 4. This is done to illustrate the present state of the process technology (1988) and to contrast with the forecast changes by product as depicted in Figure 5 (1993).

Figure 3

BiCMOS Sales by Product



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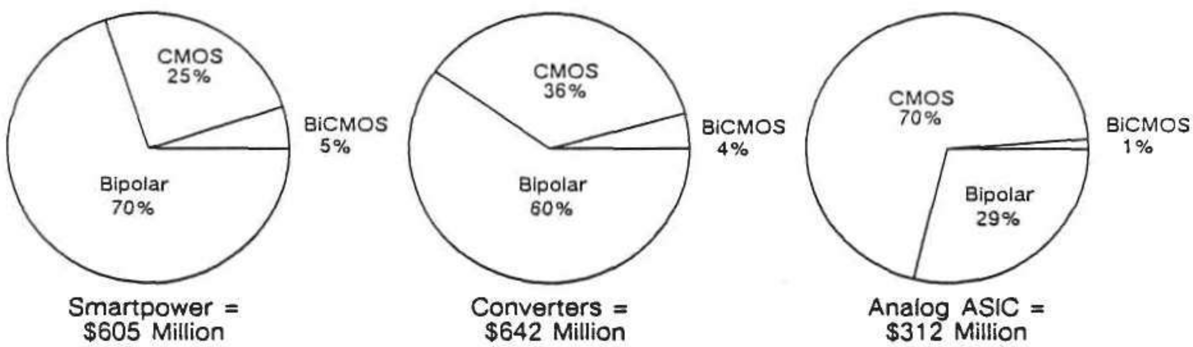
Source: Dataquest March 1989

Figure 4

Product by Process in 1988



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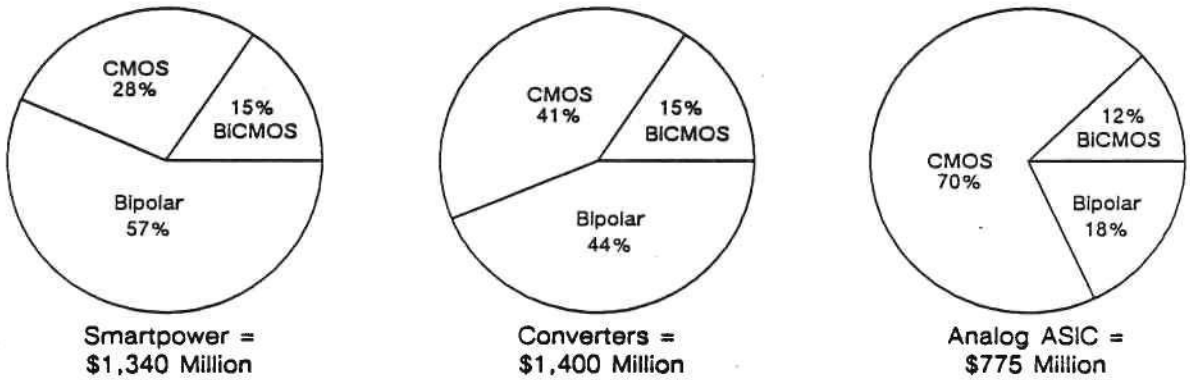
Source: Dataquest March 1989

Figure 5

Product by Process Forecast for 1993



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Source: Dataquest
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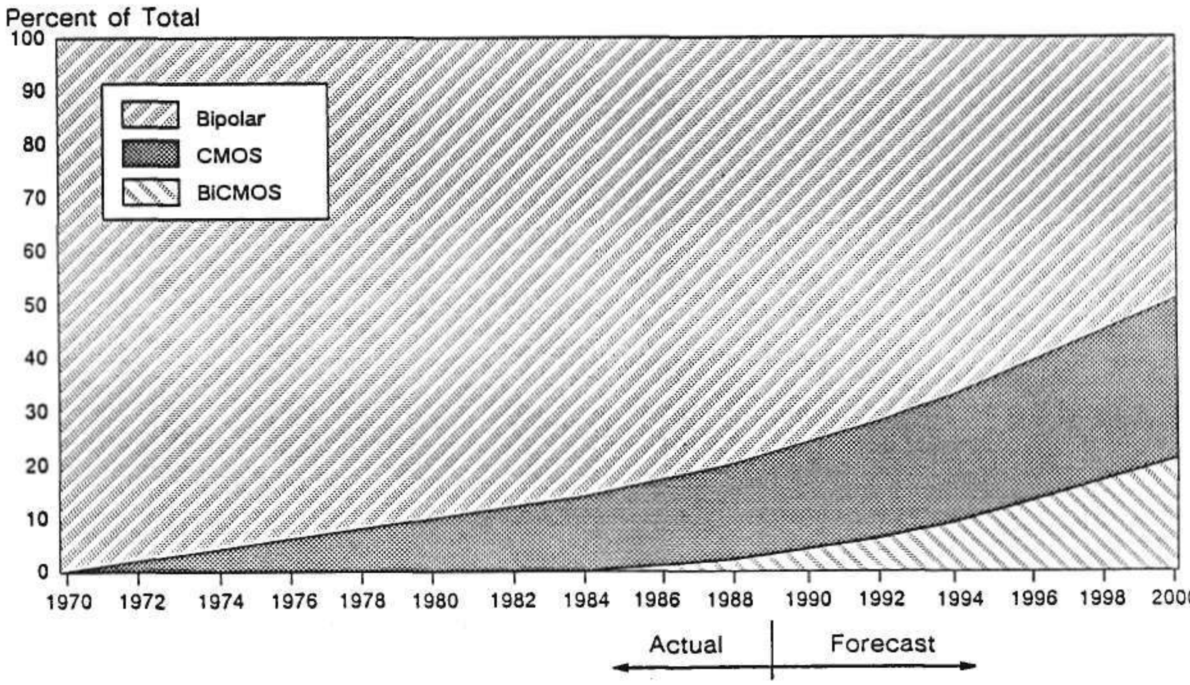
THE FUTURE OF BIPOLAR

Dataquest believes that CMOS and BiCMOS will continue to take market share from bipolar processing technology for analog ICs. Figure 6 shows this trend over a 30-year span, including the expected changes through the coming decade. Although bipolar will be dropping as a percentage of total analog IC revenue, its future is hardly bleak. Bipolar processing is in a very dominant position in the analog world. Dataquest estimates that it will lose approximately 3 percent per year in share of market to the MOS processes in the coming decade. As the analog market growth is expected to average 15 percent over the next five years, this still leaves the revenue for the bipolar segment increasing at a 12 percent compound annual growth rate.

Figure 6

Analog Process Changes over Time



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Source: Dataquest
March 1989

DATAQUEST CONCLUSIONS

BiCMOS is at the frontier of new high-performance products in the analog and mixed-mode markets. Dataquest believes that the opportunities represented by this process lie in high-performance analog systems, telecommunications ICs, ASICs, and power ICs. Although BiCMOS will take its place alongside CMOS as an important analog process, it is not likely to overwhelm either the CMOS or bipolar process within the next decade. Some of the limiting factors include the availability of CAD tools, increased costs, and demonstrated reliability.

The importance of BiCMOS over the next decade is twofold. First, it can provide new levels of performance and integration for analog ICs. This is the reason it is being developed and offered. The second important point is that BiCMOS will greatly reduce the dominance of the bipolar process in the 1990s. We predict that the emergence of BiCMOS, combined with the continued growth of CMOS, will drop the analog bipolar process to a minority role (less than 50 percent of the market) by the turn of the century.

Gary Grandbois

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AMPLIFIER IC FORECAST: CLOUDS ON THE HORIZON

INTRODUCTION

Operational amplifiers (op amps) represent one of the earliest and most substantial portions of the analog IC market. This venerable product seems to have reached a mature state in its product life cycle, which is reflected not so much in decreasing revenue as in decreasing importance. Amplifier sales will not decline in volume in the foreseeable future. On the contrary, amplifier revenue will continue to increase, although at a lower rate than that of the analog market in general.

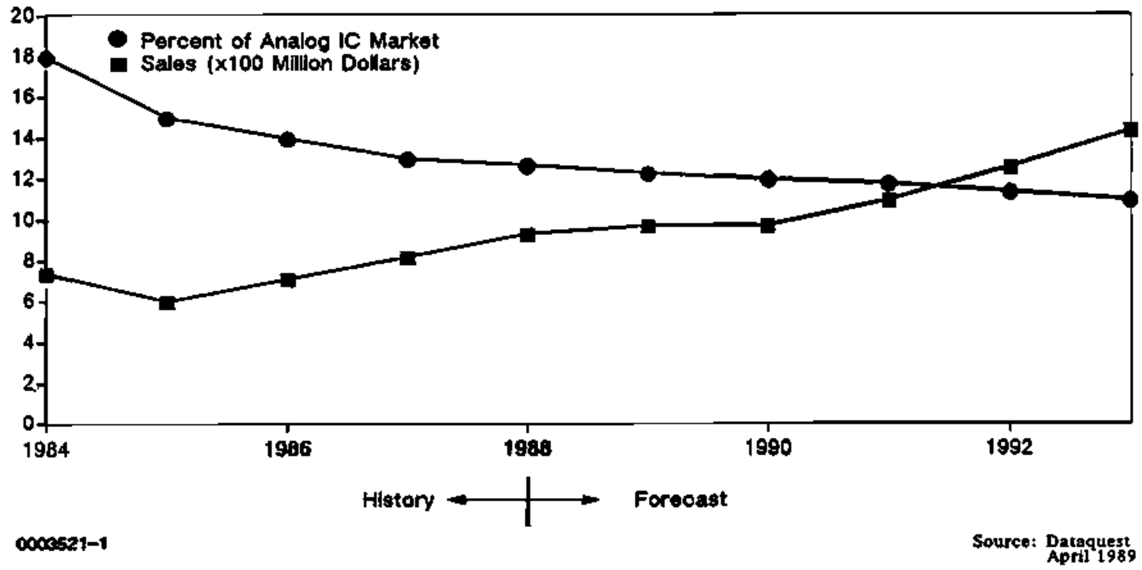
With regard to product families such as amplifiers, the concept of a complete life cycle (birth to death) is not always applicable. Products, like people, have limited life spans. Families, whether of the human or product variety, have widely differing aging profiles that may or may not include a stage of decline. Dataquest sees no period of decline for amplifiers within its forecast period.

TRENDS

Figure 1 shows the state of the amplifier market during the past five years and the forecast growth for the next five years. Note that two recent trends are continued into the forecast. First is the fact that amplifier sales will continue growing. Second, because this growth is not expected to be as fast as that of the general market, amplifiers will account for a decreasing portion of the total analog IC market.

Figure 1

Amplifier Historical Trends and Forecast



In the past, amplifiers grew at about the same rate as the total analog IC market because of their broad end-market distribution. The recent decline in market share has been caused by several factors, including the following:

- Digital signal processing (DSP) reducing the need for analog signal processing
- Higher levels of integration in market-specific products
- Mixed-mode ASICs

The demand for specialty products and higher levels of amplifier performance in video, telecommunications, industrial, and military applications is helping to counter this decline in analog market share.

DATAQUEST'S AMPLIFIER FORECAST

Dataquest expects the world amplifier market to increase from $935 million in 1988 to $1,440 million in 1993, a compound annual growth rate (CAGR) of 9.0 percent over the five-year period (see Table 1). This is approximately 3.4 percent less than the total analog market growth predicted for the same period.

Table 1

World Amplifier Forecast

Year	Revenue ($M)	Units	ASP*
1988 (Actual)	$ 935	2,180	$0.43
1989	$ 975	2,270	$0.43
1990	$ 975	2,320	$0.42
1991	$1,100	2,550	$0.43
1992	$1,260	2,900	$0.43
1993	$1,440	3,400	$0.42
1988-1993 CAGR:	9.0%	9.2%	(0.5%)

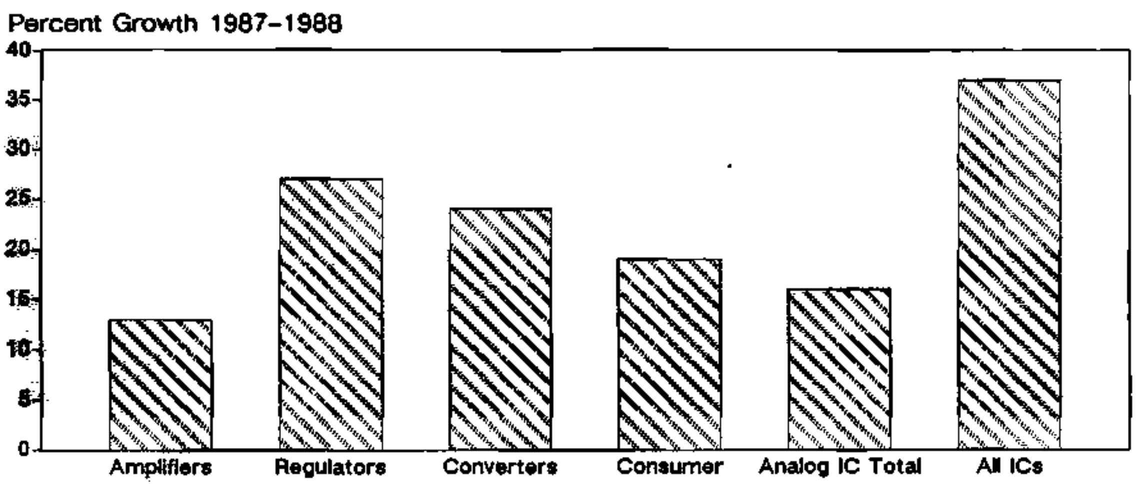
*ASP = Average Selling Price

Source: Dataquest
April 1989

The 1988 amplifier growth rate is contrasted with that of other analog products in Figure 2. Although the analog IC market increased 16 percent in 1988 over 1987, amplifiers grew only 13 percent. The CAGR of amplifier sales over the past five years (shown in Figure 3) was less than 6 percent. This CAGR was deflated largely by the 19 percent decline in revenue that occurred in 1985. The present trajectory of the amplifier market indicates projected growth from 2 to 5 percent less than that of the total analog IC market.

Figure 2

1988 Growth of Amplifiers versus Other Analog Products



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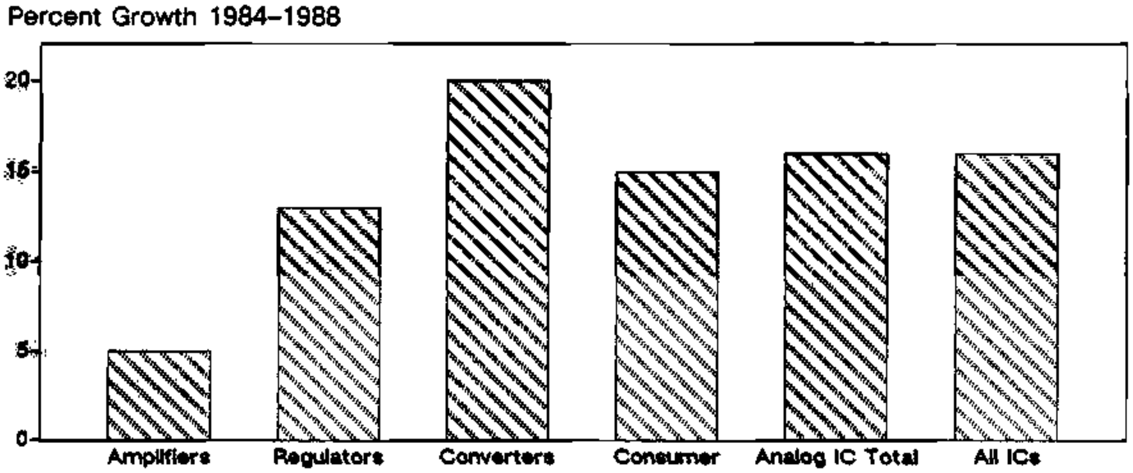
Source: Dataquest
April 1989

Figure 3

1984–1988 CAGR of Amplifiers versus Other Analog Products



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Source: Dataquest
April 1989

THE SILVER LINING—PERFORMANCE

Not all segments of the amplifier market are lagging the industry. Specialized product areas, particularly the performance niches of speed, power, and precision, represent growth areas.

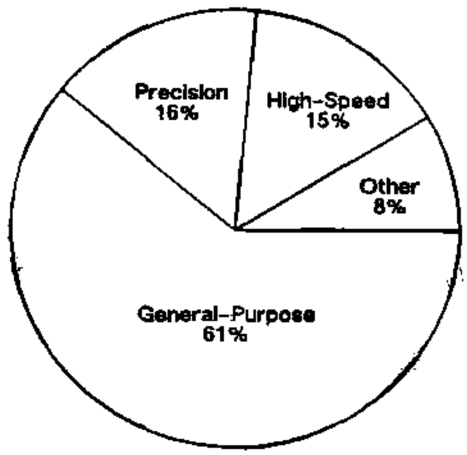
Dataquest divides amplifier performance into three categories—general-purpose, precision, and high-speed devices—as follows:

- High-Speed—Gain-bandwidth product >5 MHz; Slew rate > 10V/microsecond
- Precision—Vos <1mV; Gain >100,000; I_b <50nA
- General-Purpose—Everything else

Figure 4 shows 1988 amplifier sales by these performance categories. The amplifier market is dominated by the general-purpose type product, which constitutes approximately $565 million or 61 percent of the total world amplifier market. Precision and high-speed amplifiers meet more demanding and specialized application needs. The precision market for highly accurate ICs is the next largest; these amplifiers account for $150 million in sales or 16 percent of the total market. In general, there has been some movement from this category into the general-purpose sector as technology has improved. The high-speed category amounts to approximately $140 million or 15 percent of the world market.

Figure 4

1988 World Amplifier Market Share by Performance Category



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Source: Dataquest
April 1989

Of the three types of amplifiers illustrated, the fastest growth is occurring in the high-speed sector. Dataquest believes that high-speed amplifiers are growing at an approximate 18 percent rate, with sales that will increase from $140 million in 1988 to $320 million in 1993. Gallium arsenide amplifiers represent the ultimate in speed; recent improvements in performance should open this market greatly during the next decade. Precision amplifiers also should realize a relatively higher growth rate than general-purpose products. We expect precision amplifiers to grow at a 14 percent CAGR from $150 million in 1988 to $276 million in 1993. In total, we expect the amplifier market to grow about 9 percent between 1988 and 1993. This lower overall growth is due to the lower market demand for the larger, slower-growing general-purpose category, which is growing in the 7 percent range.

DATAQUEST CONCLUSIONS

The amplifier market represents a diminishing horizon for finding either new or growing markets. Specialty suppliers such as Linear Technology and Maxim Integrated Circuits have demonstrated that opportunities exist in high-performance and specialty products. GaAs amplifiers are at the high-speed frontier, whereas MOS technologies offer new capabilities in "smart" amplifiers.

The ubiquitous general-purpose op amp may be a product past its prime. Besides the market encroachment of mixed-mode ASICs and more highly integrated standard ICs, the "jelly bean" nature of general-purpose op amps, including fairly low-tech fab and process demands, large markets, large distributor sales, and commonly known part numbers, could make them an attractive target for emerging Rest of World companies that want to grab market share and tap a source of foreign currency in the 1990s. In the coming decade, the suppliers of specialty and high-performance amplifiers may have the more secure long-term position.

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HDTV
ANALOG ICs ARE MORE IMPORTANT THAN EVER

SUMMARY

The hottest topic in trade literature today is high-definition television (HDTV). Invariably, the articles imply that digital circuitry will replace analog signal processing, and that consequently, the analog content of TV will decline. Dataquest believes that neither analog IC content nor analog technology will be pushed into the background by the race to develop and market HDTV.

ANALOG OPPORTUNITY

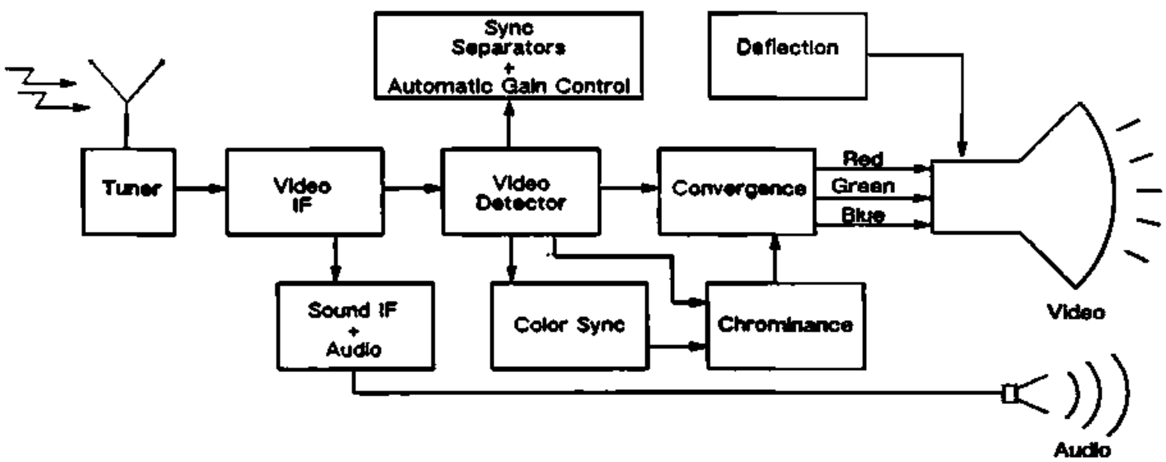
TV development is following two paths at this time. The first is to develop new broadcast and TV standards for HDTV. The second is to use digital techniques to improve display resolution and visual impact while still using today's standard video transmissions (NTSC, PAL, SECAM). Products such as improved definition TV (IDTV) or enhanced definition TV (EDTV) are examples of this direction. Either path toward picture improvement will involve digital signal processing, which will increase the use of data converters, as well as memory and DSP functions. The types of IC products used in these TVs can be anticipated, regardless of the broadcast format of the signal received.

THE ANALOG IC MARKET FOR TVs

Figure 1 is a block diagram of a typical analog TV of today. There are approximately 61 million color TVs manufactured worldwide per year. On average, each of these TVs uses $30 worth of semiconductors, $11 of which are analog ICs.

Figure 1

Analog
NTSC Color TV Block Diagram



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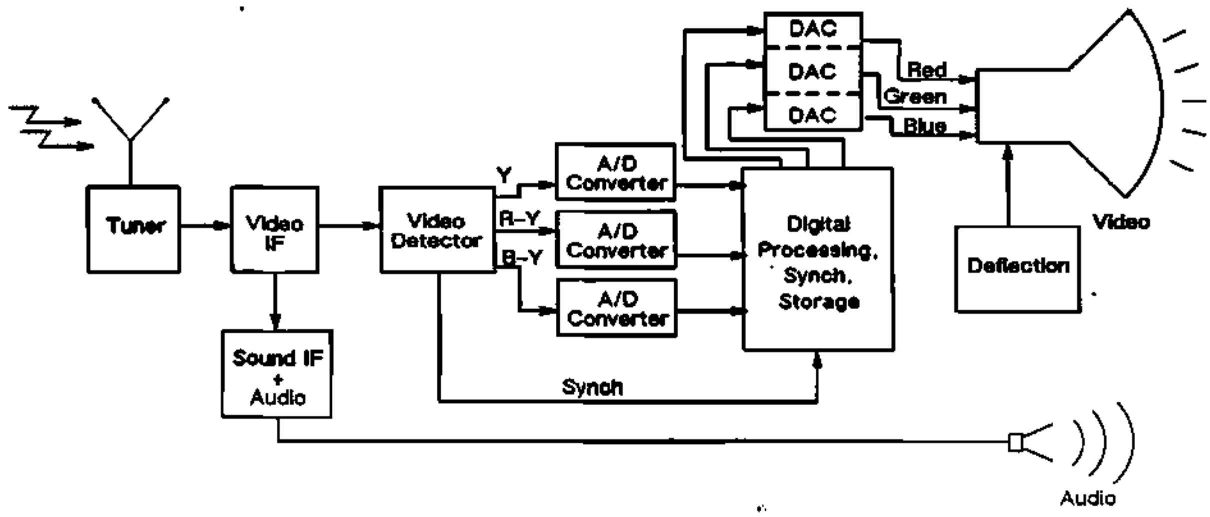
Source: Dataquest April 1989

An IDTV or HDTV will have a block diagram similar to that of Figure 2. Analog ICs will still be found in the tuner, audio amplifier, and video intermediate frequency (IF) sections. More importantly, four to six critical data converters also are needed. From one to three A/D converters (ADCs) are required to convert the baseband video into the digital data for processing within the digital system. On the output side of digital processing, a high-speed, triple 8-bit video D/A converter (DAC) would be needed to drive the video display.

Figure 2

Digital HDTV Block Diagram



0003621-2

Source: Dataquest
April 1989

Despite all the conflicting standards being proposed, HDTV systems are being implemented already. In addition to this move to HDTV, digital enhancement techniques will continue to be used to improve picture performance on upscale, compatible TVs. Both of these product offerings will increase the IC dollar content (both digital and analog) within the total television market. Table 1 and Figure 3 show the forecast sales of analog ICs into the TV market and the estimated value of the analog ICs per set. All IDTV, EDTV, and HDTV sets have been grouped together due to similar needs in ICs.

Table 1

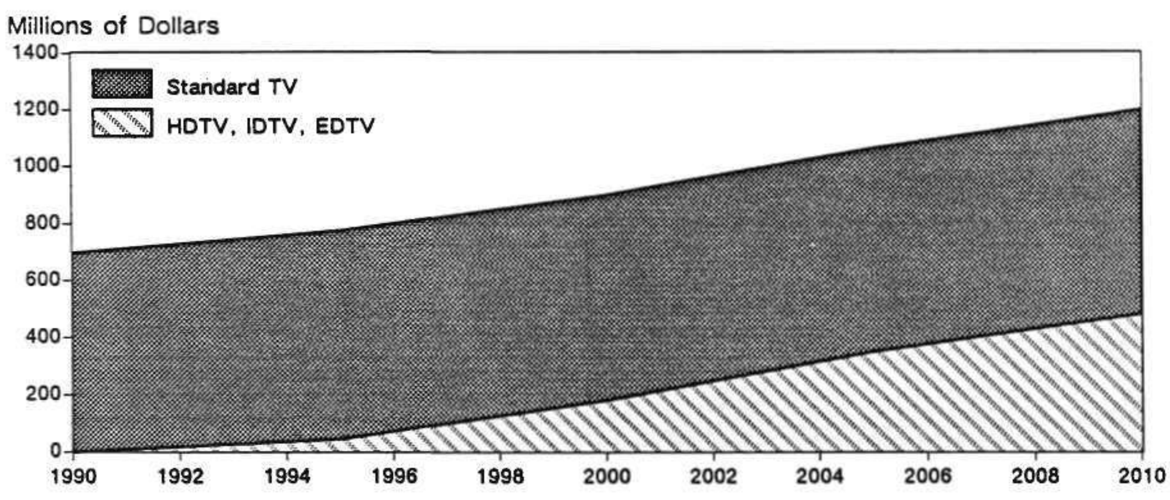
Forecast Sales of Analog ICs for Color TV (In Constant 1988 Dollars)

	Analog Content per Set		Analog IC Revenue ($M)		
Year	Standard	IDTV, HDTV, EDTV	Standard	IDTV, HDTV, EDTV	Total
1988	$11.00	-	$670	-	$ 670
1990	$10.50	$100	$699	$ 1	$ 700
1995	$10.00	$ 45	$730	$ 45	$ 775
2000	$ 9.00	$ 30	$720	$180	$ 900
2005	$ 8.50	$ 25	$714	$350	$1,064
2010	$ 8.00	$ 23	$720	$483	$1,203

Source: Dataquest
April 1989

Figure 3

Forecast Analog Content of TVs



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Source: Dataquest
April 1989

The forecast assumes that a major limitation to HDTV acceptance will be price and perceived value. Increased definition demands increased screen size and digital processing. Both of these factors will combine to drive the price of these sets into a range of two to five times the price of a conventional big screen (25- to 27-inch), CRT-type TV.

Data Converters for Improved Definition

Truly high definition will require D/A converters with 8-bit resolution for each of the three colors of the display. This represents a capability of 16 million colors.

The high-definition, high-speed triple 8-bit DACs are available today. These products will see a significant price decline—to $12 by the time HDTV becomes significant.

Philips recently has lowered the price for 8-bit, 40-MHz flash ADCs to less than $10 for large quantities. The March 1989 announcement speeds up the race for the digital TV market. The announced product (TDA8703) is specified to deliver 48.5dB signal-to-noise performance at 4.43 MHz (European TV color carrier).

U.S. suppliers have long dominated the data conversion IC market. The race to HDTV presents an opportunity for U.S. suppliers to leverage this position to regain market share in consumer products. The flip side is the danger that the loss of the consumer data converter market may lead to lost market share for present suppliers in nonconsumer markets as these low-cost, high-performance converters become available for broad applications. High-definition video is more than just TV. Military, medical, and computer markets (all strong markets for U.S. suppliers) have tremendous need for high-definition video products and represent a greater market than that of HDTV. Losses in any of these markets could be disastrous for U.S. suppliers.

DATAQUEST CONCLUSIONS

Whether HDTV is the next big IC market or the next over-hyped improvement (like "quadraphonic sound"), the news is generally good for analog IC suppliers. Any or all of the HDTV, IDTV, and EDTV possibilities represent sophisticated products that will increase analog dollar content per product rather than decrease it. The interesting paradox of the "digital revolution" is that it expands markets for specialty analog suppliers, especially those in the data converter area. As an example, the analog content of a CD player (DAC, amplifiers, motor controller) is significantly higher than that of the turntable it replaced. For those not yet positioned in the video data converter market, time and opportunity to develop these high-speed products still exist. These products reach beyond the consumer market for digital TV. They are key to all high-definition graphical information display markets.

Beyond the signal processing itself, further analog opportunities may develop in high-resolution, flat panel displays. These products will require complex analog driver ICs to interface to the video processor.

Gary Grandbois

Dataquest

Conference Schedule

1989

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Research Newsletter

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UPDATE ON ANALOG IC ALLIANCES

SUMMARY

The pattern of alliances continues, with factors such as trade, vertical integration, and technology facilitating the unions. The webs are tightly woven, and many of the unions in the analog world are not reported. This newsletter draws attention to some of the important unions that have taken place in 1988 and early 1989 (see Table 1). It also reports on some of the factors driving these alliances.

Table 1

Analog IC Alliances—1988 and 1989

Date	Company A	Company B	Type	Products
1988	Motorola	Seagate	Tech. exchange	Analog tech.
2/88	Thomson	Sipex	Joint venture	Power hybrids
2/88	Brooktree	National	Second source	Video DACs
2/88	Brooktree	Analog Devices	Joint development, second source	Video DACs
4/88	TI	Sony	Joint development	Audio filter
5/88	Comlinear	TRW LSI Products	Tech. exchange	Op Amps, data converters
6/88	AMD	Siemens	Second source	ISDN ICs
7/88	AT&T	GTE	Joint venture	Communications

(Continued)

Table 1 (Continued)

Analog IC Alliances—1988 and 1989

Date	Company A	Company B	Type	Products
8/88	PMI	SSM	Acquisition	Audio IC market
8/88	VTC	Grass Valley Group	Joint development	Video line drivers
8/88	Teledyne	Omnirel	Joint development and marketing	Smartpower ICs
9/88	Sil. Systems	Hayes	Tech. exchange	Design tools
9/88	Sharp	Hycom	Acquisition	Telecom manufacturing
10/88	Harris	Kawasaki Steel	Joint development	CMOS technology
10/88	Siliconix	Teledyne	Second source	Smartpower ICs
11/88	Harris	GE Solid State	Acquisition	General
12/88	Motorola	Cherry Semi.	Second source	Bipolar analog
1/89	AT&T	Intel	Joint development	ISDN, LAN ICs
1/89	Unitrode	ADDACON	Equity investment	Hybrids
3/89	Maxim	Supertex	Joint marketing	Power supply ICs

Source: Dataquest
April 1989

THE ALLIANCES

The alliances listed chronologically in Table 1 involve the following arrangements:

- Motorola and Seagate Technology—The agreement relates to internal use of Motorola's technology by Seagate, a major manufacturer of hard disk drives. (1988)

- Thomson and Sipex—Power Hybrid Systems, a newly formed subsidiary of Thomson-CSF and American Tractebel, began manufacturing a line of power hybrids in a plant belonging to Sipex, a Tractebel subsidiary. (2/88)

- Brooktree and National Semiconductor—Brooktree and National negotiated an agreement previously made between Brooktree and Fairchild; National will second-source four of Brooktree's video DACs. (2/88)

- Brooktree and Analog Devices—Brooktree and Analog Devices announced an agreement to provide customers with an alternate source for the video DACs. Also, the two companies will independently develop, manufacture, and market their own devices based on the Brooktree architecture. (2/88)

- TI and Sony—The companies agree to jointly develop an IC filter for digital audio. (4/88)

- Comlinear and TRW LSI Products—This is a technology exchange pact whereby Comlinear brings its design know-how in high-speed operational amplifiers and track/hold circuits to the party and TRW contributes its expertise in high-speed A/D and D/A converters. The companies are planning to combine a converter with an amplifier on a chip. (5/88)

- AMD and Siemens—This agreement involves the second-sourcing of 15 ISDN circuits. (6/88)

- AMD and Siemens—This is a technology agreement under which the companies will jointly develop, manufacture, and market microchips for data communications and telecommunications, with emphasis on ISDN. (6/88)

- AT&T and GTE—These two major suppliers of telecommunications have agreed to merge their manufacturing and R&D efforts in a joint venture in order to unify the marketing strengths of both companies against foreign competition in the United States.

  - The agreement also ensures that AT&T will continue as the dominant supplier of switches and future ISDN technology in the U.S. market.

  - The venture agreement provides for periodic control of the enterprise.

  - The manufacturing and research activities initially will be controlled by GTE, but the new enterprise will shift to AT&T in 1994. (7/88)

- VTC and Grass Valley Group—The Grass Valley Group is a manufacturer of professional audio equipment. The two companies are involved in the joint development of two 10-bit video line drivers meeting standards established by the Society of Motion Picture and Television Engineers (SMPTE). (8/88)

- Teledyne and Omnirel—This agreement involves the joint development and marketing of CMOS smartpower devices for military markets. The joint development will team Omnirel's high-density military power packages and discrete power MOSFETs with Teledyne's CMOS ICs, MOSFET drivers, and switch-mode power supply controllers. (8/88)

- PMI and SSM—PMI acquired SSM Audio Products of Santa Clara, California, a company that manufacturers analog ICs for audio and music applications. Through the acquisition, PMI gains entry into the professional audio IC market, while SSM gains financial and manufacturing resources. (8/88)

- Silicon Systems and Hayes—This agreement involves the exchange of internal design tools to support respective core businesses. Hayes expects to speed the development of semicustom and standard silicon designs for future products, and Silicon Systems gets insight from a market leader in telecommunications regarding what systems to implement in silicon. (9/88)

- Sharp Microelectronics Technology and Hycom—Sharp acquired Hycom in the fall of 1988. Hycom, a developer of communications and modem products, display systems, and advanced application-specific LSI and VLSI computer chips, now operates as a subsidiary of Sharp Microelectronics. (9/88)

- Siliconix and Teledyne—The companies are involved in a second-source agreement for switch-mode Smartpower ICs. Teledyne gets immediate manufacturing rights to ICs, and the agreement allows for future second-sourcing of parts developed by either company. (10/88)

- Harris and Kawasaki Steel—This is a joint development agreement in which Harris will provide CMOS technology to Kawasaki in exchange for financial and marketing support to Harris.

  - Some of the first parts were to be ASICs for digital signal processing, telecommunications, and industrial control applications.

  - Over the long term, the companies are expected to act as foundries for each other. (10/88)

- Harris and GE Solid State—Harris' acquisition of GE Solid State was finalized in November. The acquisition included GE, RCA, and Intersil facilities. All of these facilities included analog product and add to Harris' overall volume in analog. (11/88)

- Motorola and Cherry Semiconductor—The companies will become partners in technology (bipolar) and act as second sources for each other's devices. This agreement covers both custom and standard circuits and calls for establishing compatible manufacturing processes. (12/88)

- AT&T Microelectronics and Intel—This is a broad technology and product-development agreement covering ISDN and LAN ICs. AT&T will gain Intel's merchant market leverage, and Intel will gain network technology from AT&T. (1/89)

- Unitrode and ADDACON—Unitrode made a 50 percent equity investment in ADDACON, a manufacturer of high-speed, board-level, and hybrid circuit data converters for military and high-end industrial markets. (1/89)

- Maxim and Supertex—This agreement relates to the joint marketing of four devices in the 690 family of MPU supervisory circuits.
  - These chips perform supervisory functions including assurance of a constant power supply and protection against hardware and software malfunction.
  - The agreement is a continuation of a joint chip agreement that goes back to the conception of Maxim.

THE ISSUES

There are some underlying currents today that are fostering analog alliances. These include the pressure on Japan to buy American, the U.S. companies' need or desire to vertically integrate, and the natural alliance of large diversified houses with niche-oriented start-ups.

Japanese/U.S. Trade

Recent concerns over the inequity of trade between the United States and Japan have brought a new emphasis to doing business in Japan. Japanese companies are feeling pressured to purchase U.S. goods and are making steps to do just this. Recently, the EIAJ hosted a session for American companies wishing to do business in Japan. The meetings stressed that Japanese markets require different products than those destined for American markets and emphasized that the criterion for success in Japan would be to design and tailor products to specific Japanese market applications. Japanese companies now are examining U.S. products seriously and increasing their purchases of U.S. goods. This fact bodes well for analog suppliers, which have a significant opportunity in this market, if they offer the right products.

One of the easiest ways to establish long-term relationships, important to doing business in Japan, is through alliances. These alliances typically bring value to both parties. U.S. companies have impressive technology in the analog area, some of which is not available in Japan. With Japanese alliances, U.S. companies gain access to the Japanese market and internal company markets or financial backing.

Vertical Integration: Equipment/Supplier Alliances

More interaction is occurring between the circuit manufacturer and the equipment supplier. Alliances are being formed to offer insights from both sides of the business—component and equipment. These alliances often concern tools for semicustom circuit development. It is evident that the semicustom approach to circuitry offers many benefits to the equipment supplier. Semicustom products offer cost reduction and quicker entry to the market, especially valuable in highly competitive markets.

Established Company/Start–Up Company Alliances

An existing pattern that continues in the market, is the alliance of the broadly focused analog supplier with the very focused niche supplier or start–up company. This type of arrangement has been very successful because it allows the two companies to share their resources. Large companies gain expertise in fast–growth niche market areas. Small companies gain credibility from the alliance with the large supplier, financial backing, and, perhaps, access to foreign markets.

DATAQUEST CONCLUSIONS

It is obvious that company alliances benefit many parties. Through alliances, technology is advanced and marketing and financial assets may be shared. It behooves companies to investigate opportunities on an ongoing basis and to consider taking advantage of the many types of alliances discussed in this newsletter.

Barbara Van

Dataquest

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1989

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THE PRECISION MOTOR MARKET: ANALOG ICs TAKE CONTROL

SUMMARY

Motors are energy converters. They use the property of magnetic attraction or repulsion to convert electrical energy to mechanical energy. As motors are one of the most common electrical devices in everyday life, one often forgets about their presence. Because motors are quite obvious in supplying the mechanical power in items such as drills, saws, washers, dryers, garbage disposals, refrigerators, and air conditioners, one often fails to recognize their presence in electronic products. For instance, the average personal computer setup probably has more than a half-dozen motors (two for each disk drive, one cooling fan, and two or more stepper motors in the printer). The playback of any type of recorded information, analog or digital, also requires motors.

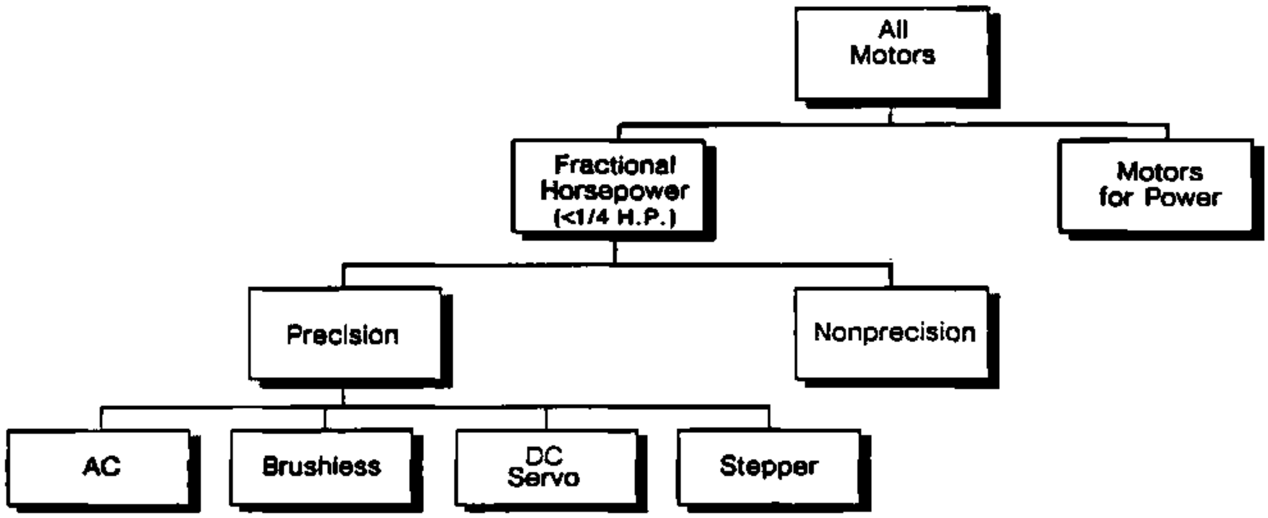
PRECISION MOTORS

The family tree shown in Figure 1 illustrates some of the main branches of motor categories in terms of power output, power source, and controllability. Although motor control runs the gamut from precision motors to massive motors (e.g., those used for controlling elevator position), the most significant market for IC motor control ICs is in the precision motor area.

Precision motors very often are found in consumer and office automation (OA) equipment. Table 1 shows some estimates, by motor type, of the consumption of electronically controlled precision motors.

Figure 1

Motor Categories



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Source: Dataquest
May 1989

Table 1

1988 Estimated Unit Consumption of Electronically Controlled Motors

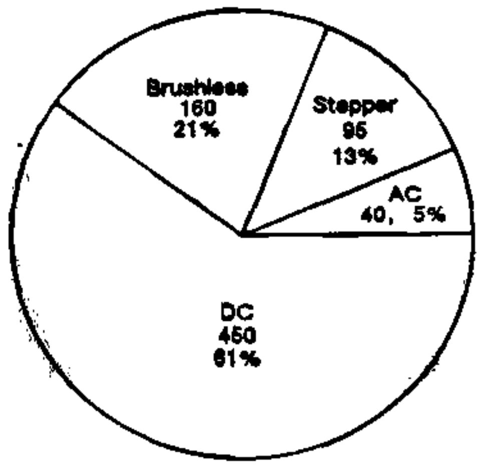
Motor Type	Number of Units (Millions)
Stepper Motors	
Printers	50
Fixed Disk Drives	9
Floppy Drives	30
Other	6
Brushless Motors	
Fixed Disk Drives	15
Floppy Drives	35
VCRs	50
Audio	25
Other	35
Servo DC Motors	
Disk Drives	11
Audio	60
VCRs	50
Other	54

Source: Dataquest
May 1989

Sales totals of "controlled" precision motors are plotted in Figure 2.

Figure 2

Precision Motor Market
(Millions of Units)



0004696-2

Source: Dataquest
May 1989

A motion that is controlled by motor design as well as the nature of the power supply and load is caused by simply connecting a motor to a power source. This imprecise electromechanical operation is acceptable for general motorized products, such as blowers and shavers, but not for precision products. Motor control devices provide a means of optimizing motor performance, precise positioning of mechanical functions (such as robot arms), precise speed control, or new control techniques that create improved types of motors (such as brushless motors). The type of motor used often is dictated by the application. Stepper motors are used for position control, brushless motors for speed control, and the DC Servomotor for either one, if the noise of the brush commutation does not affect the application.

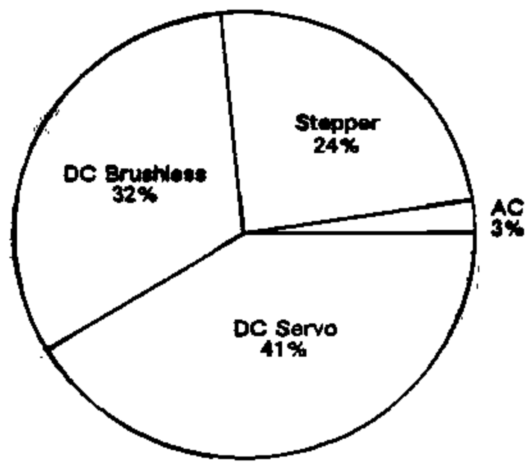
Accurate position control can be achieved by incrementing a stepper motor. Position control of a continuous-motion motor calls for complex control algorithms, such as PID (Proportional Integral Derivative), that use both position and speed information. These devices use this information to determine the motor trajectory for tighter control without positional overshoot and oscillation.

MOTOR CONTROL MARKET

The portion of the motor control market supplied by dedicated motor control ICs is estimated to be $134 million. At present, this represents about one-third of the potential market of $400 million. Control solutions implemented with discrete amplifiers, phase-locked loops (PLLs), logic, and other standard ICs supply the rest of the market. The sales of control ICs by motor category are shown in Figure 3.

Figure 3

IC Controller Sales by Motor Category

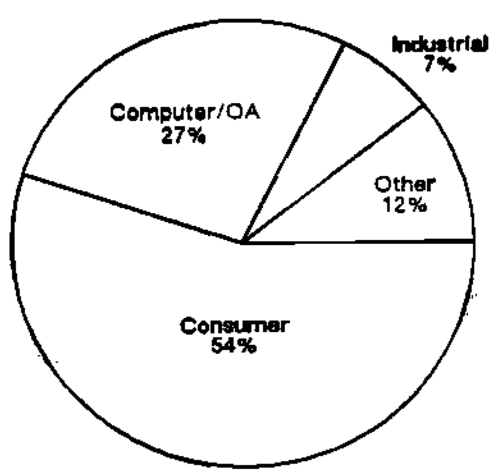


0004696-3 Source: Dataquest May 1989

The application markets for the controllers and motors are illustrated in Figure 4.

Figure 4

Estimated Controller Consumption by Market



0004696-4 Source: Dataquest May 1989

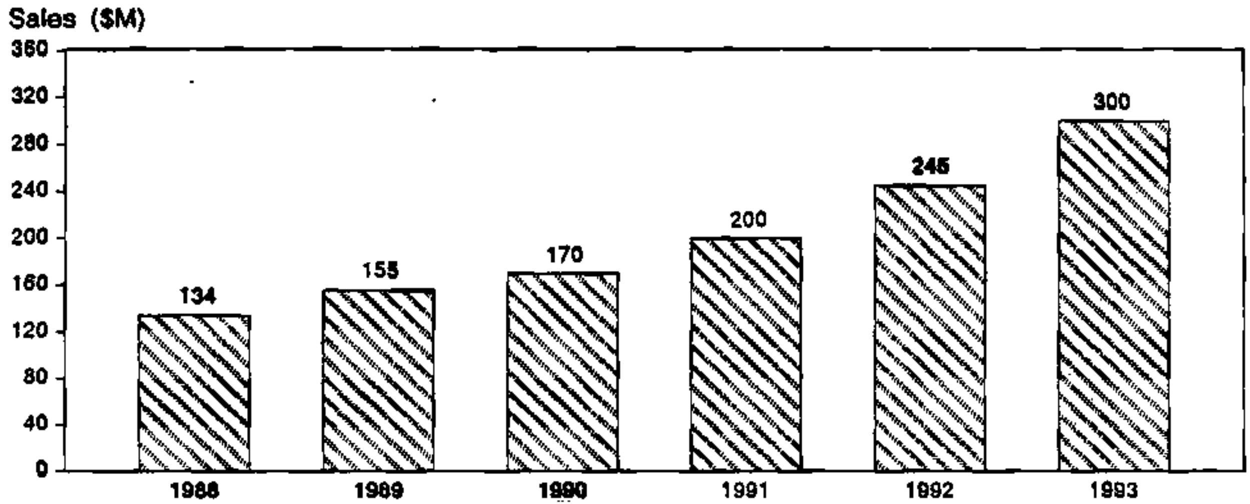
MOTOR CONTROL FORECAST

As shown in Figure 4, the motor control market is strongly linked to both the consumer market and the electronic data processing (EDP) market, and growth is strongly related to segments of these markets. Although the PC peripherals market is expected to slow somewhat over the next few years, the consumer market should continue to be strong. The new applications that motor controllers are being designed into are enhancing the growth of these markets.

Dataquest expects the motor control IC market to grow at 18 percent compound annual growth rate (CAGR) over the next five years. The forecast, shown in Figure 5, defines market growth by year over the next five years.

Figure 5

Motor Control IC Forecast
1988 to 1993



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Source: Dataquest
May 1989

MOTOR CONTROL SUPPLIERS

Table 2 shows a listing of motor controller/driver manufacturers and their participation in the different categories of motor control ICs.

Table 2

Motor Control IC Suppliers

Company	Motor Control ICs: Brushless	H-Bridge	Servo	AC	Stepper
Cherry Semiconductor			X		
Elantec			X		
Exar			X		
GE Solid State					X
Gold Star			X		
Hitachi	X				X
International Rectifier		X			X
LSI Computer	X				
Lambda Semiconductor		X			
Mitsubishi	X	X	X		
Motorola	X		X	X	X
National Semiconductor	X	X	X		
NEC			X		X
New Japan Radio			X		
Oki Semiconductor			X		
Philips			X		X
Plessey			X		
RIFA					X
ROHM	X		X		
SGS-Thomson	X		X	X	X
Sanyo	X		X		X
Siemens			X		X
Signetics			X		X
Silicon General			X		
Silicon Systems	X				
Solitron	X				
Sprague	X	X	X		X
Texas Instrument		X			X
Toshiba	X	X	X		
Unitrode	X	X	X		X

Source: Dataquest
May 1989

REGIONAL NATURE OF MANUFACTURERS

A review of the motors, markets, and manufacturers reveals four important points, as follows:

- The two major markets are consumer and computer peripherals (both dominated by Japanese manufacturers).

- The suppliers of precision motors are largely Japanese.

- Japanese suppliers dominate in motor control IC sales.
- The manufacturers of the end equipment are highly vertically integrated.

SILICON SYSTEMS/TDK

The recent acquisition of Silicon Systems by TDK Corp. can be viewed as a means for TDK to become further integrated in the disk-drive market. TDK supplies ferrite read/write heads, ferrite magnets for motors, and other components for disk drives (as well as the media). Silicon Systems supplies read/write amplifier ICs and motor control ICs for disk drives.

DATAQUEST CONCLUSIONS

Data storage, embedded control, consumer entertainment, and home automation products all depend on the control of precision motors. Because of the strong presence in this market of vertically integrated companies, participation in the precision motor control market may be difficult unless strong alliances are made with an original equipment manufacturer (OEM) and/or motor suppliers.

A less developed motor control market is that of high-power, low-precision motors (AC Induction Motors). This type of motor speed control has very important applications in home and industrial equipment. Large savings in power can be made by varying the speed of constantly running motors, rather than duty cycle (on-off) operation of motors. High-volume air conditioning systems are one important example of where power savings of up to 50 percent can be achieved.

From a technology standpoint, Dataquest believes that mixed-mode ASIC and Smartpower ASIC technologies will emerge as the best approaches for developing market, motor, and application-specific motor controller products for the coming decade.

Gary Grandbois

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Research Newsletter

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0003809

ANALOG ICs: OPPORTUNITY KNOCKS IN THE ASIA/PACIFIC MARKET

SUMMARY

Changes in the regional consumption and manufacture of integrated circuits are part of the dynamics of the semiconductor industry. Dataquest's 1988 sales data show that one region of the world, the Asia/Pacific area, was experiencing furiously paced growth in consumption. This growth is bringing it into parity with two of the three other major consumer areas, North America and Europe. This growth in consumption is not coupled to a corresponding growth in locally produced ICs and therefore represents a major opportunity for nonindigenous foreign suppliers.

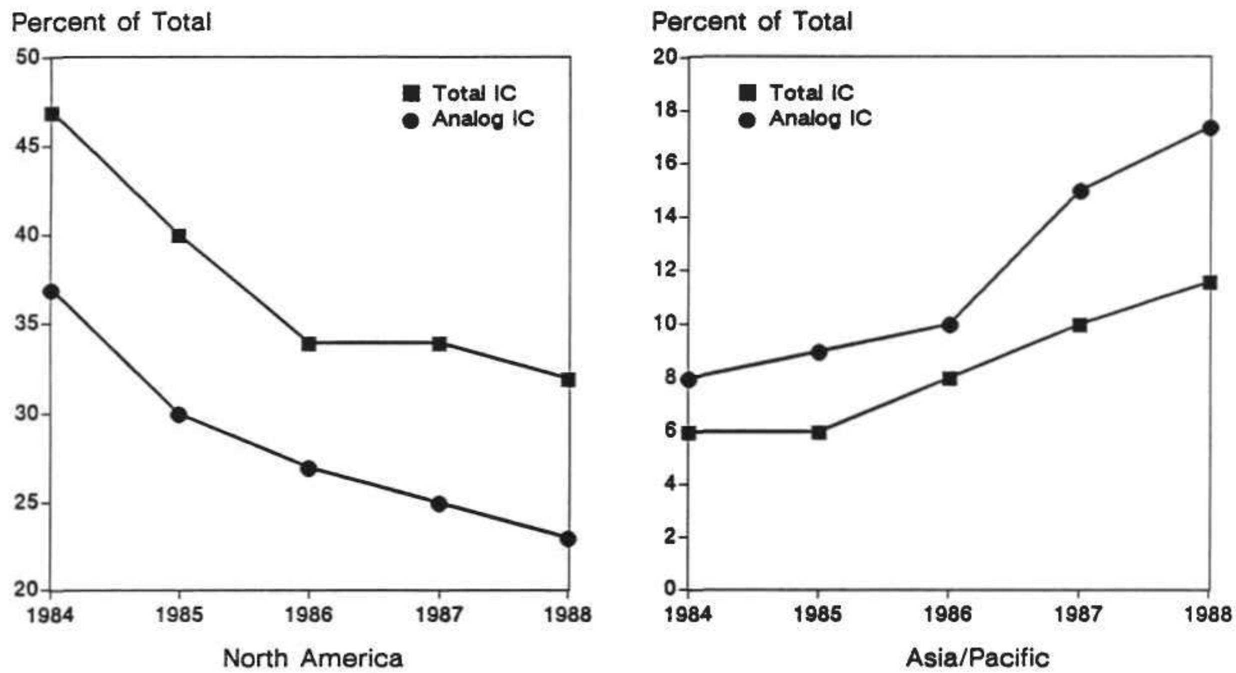
CHANGES IN CONSUMPTION

Consumption patterns for analog ICs have changed dramatically during the past few years. The two areas that have undergone fastest change, North America and the Asia/Pacific region, are shown in Figure 1. The curves show the percentage of total analog ICs and the percentage of all ICs consumed in each of these two areas. As Figure 1 shows, North America is notable in that the sales of ICs are dropping at a rapid rate. More important to analog suppliers is the fact that the North American analog IC market appears to be declining at a faster rate than the market in general. Just the opposite is occurring in the Asia/Pacific market, where analog ICs have had a compound annual growth rate (CAGR) of more than 50 percent since 1985 (see Figure 1). This analog IC growth is outstripping the general IC growth rate considerably in the Asia/Pacific marketplace. In 1988, sales of analog ICs to the Asia/Pacific market were $1.26 billion, 17.4 percent of all monolithic analog ICs sold worldwide.

The effect of the North American decline and Asia/Pacific growth in analog consumption is that they are becoming comparably sized markets. The trend in both of the curves is toward a 20 percent portion of the total analog market by the early 1990s. Plotting the four major sales regions by year, as is done in Figure 2, illustrates that three of them are converging on this 20 percent value, whereas the Japanese market remains flat at about 40 percent of the total.

Figure 1

Regional Consumption by Year

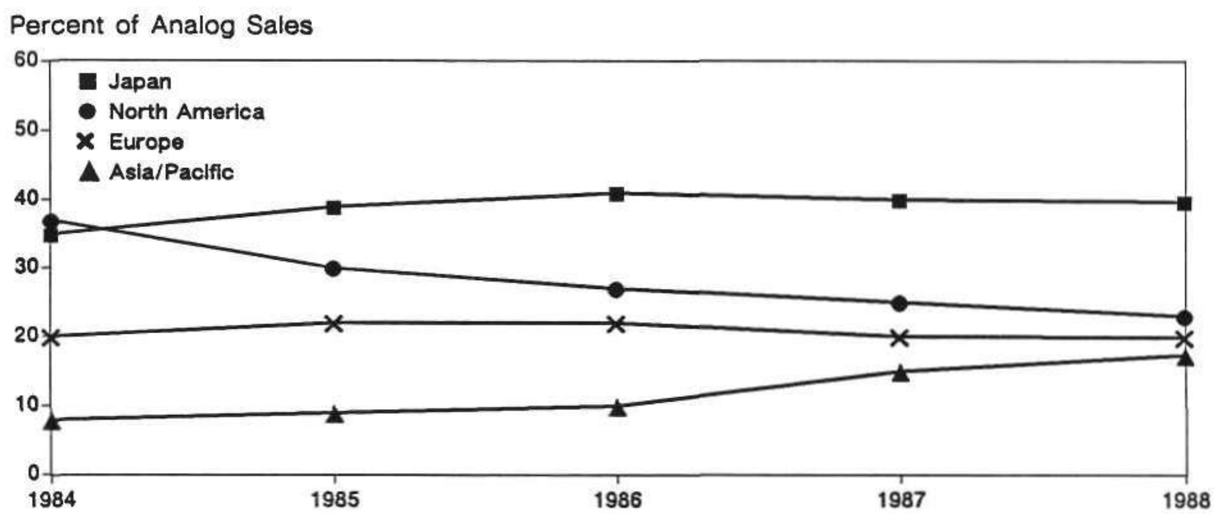


0003809-1

Source: Dataquest
May 1989

Figure 2

Analog IC Sales by Region



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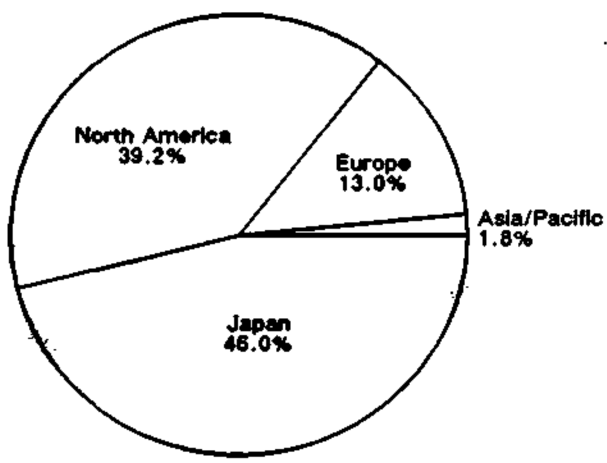
Source: Dataquest
May 1989

ASIA/PACIFIC PRODUCTION

Although the Asia/Pacific market accounted for more than 17.0 percent of analog IC sales, the region's production of analog ICs amounted to only 1.8 percent, as shown in Figure 3. An important characteristic to outside suppliers is that cultural pressure to buy locally produced products is not as formidable as in other world markets. Because the difference in the size of analog IC production and consumption in North America is widening, penetration of the Asia/Pacific market is crucial to counter the production decline that otherwise will follow the decline in consumption.

Figure 3

Analog IC Supply by Region of Origin



0003809-3

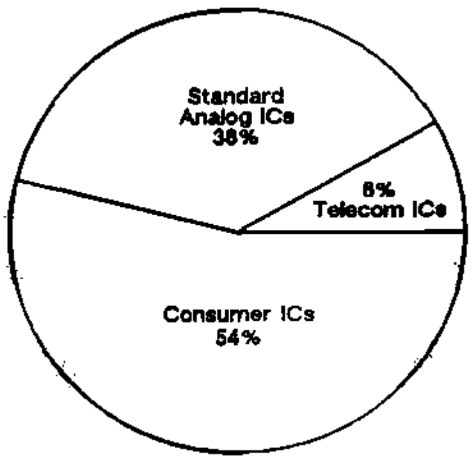
Source: Dataquest
May 1989

PRODUCTS

Figure 4 shows the Asia/Pacific market by product type. Although the market is strongly consumer-specific IC oriented, the broad spectrum of standard analog ICs is also consumed.

Figure 4

Asia/Pacific Markets by Product Type



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Source: Dataquest
May 1989

DATAQUEST CONCLUSIONS/RECOMMENDATIONS

Although the Asia/Pacific market is moving into parity with those of Europe and North America, this does not necessarily mean that purchasing is done in the region. Because many nonindigenous companies have manufacturing facilities only within this region, shipments may result from sales agreements made in other market areas. Nonetheless, the rapidly changing nature of analog IC consumption requires informed decisions on where sales and support efforts should be focused. The Asia/Pacific market deserves attention.

Gary Grandbois

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Research Newsletter

SIS Code: Newsletter 1989
Analog
0004257

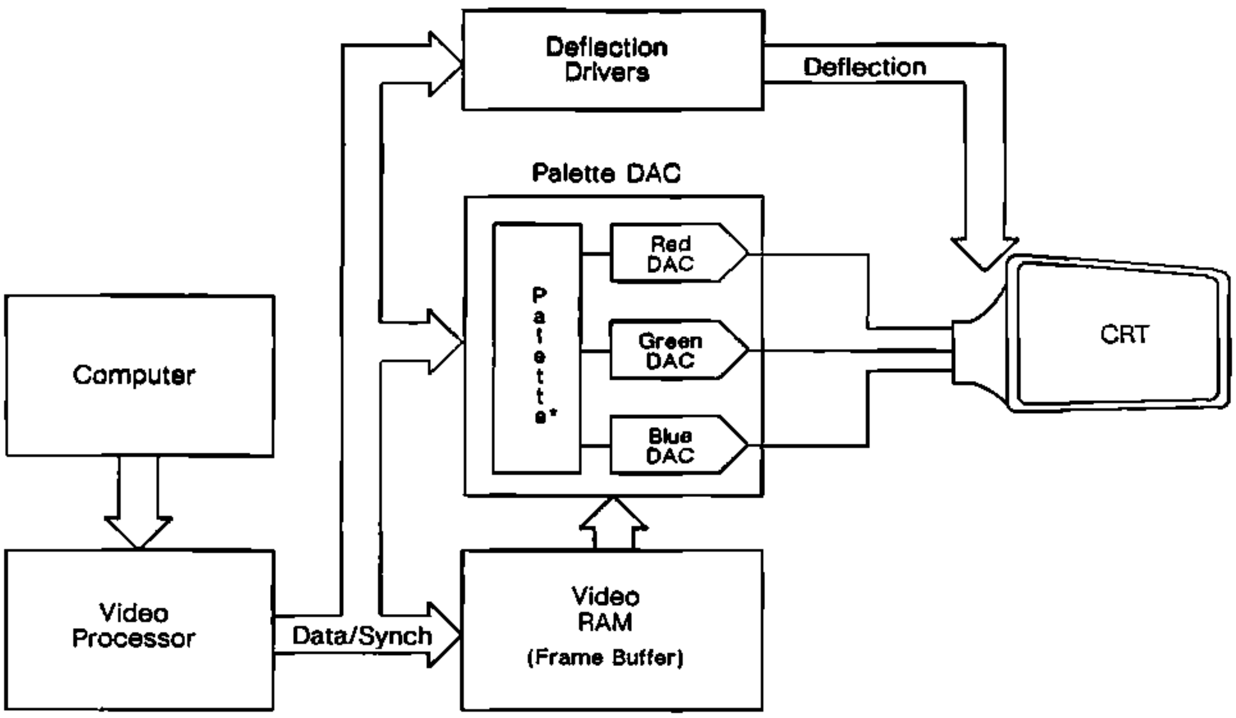
THE COLOR OF MONEY: ONE OF MANY HUES PROVIDED BY PALETTE DACs

OVERVIEW

A specialized digital-to-analog converter (DAC) that has become prominent in the graphics product market is known as the video DAC. Video DACs encompass a variety of products variously called RAM-DACs, palette DACs, and RGB DACs in addition to the more general term, video DAC. These products originated as high-speed, low-resolution DACs designed for creating images from computer-generated graphics data. As high-resolution computer graphics became more commonplace, the original hybrid triple DACs gave way to monolithic video DACs. More recently, these have been combined with RAM to create on-chip color lookup tables (CLUTs). This is the so-called color palette DAC, or RAMDAC. The introduction by IBM of the VGA graphics standard for PS/2 PCs, as well as the growth in graphics workstations, has greatly expanded interest in analog color graphics generation. As any color is created by combining the red, green and blue primary colors, analog signals are needed to modulate the intensity of the primary colors to create the wide range of hues needed for realistic graphics. Figure 1 shows a typical application of a triple DAC in a graphics application.

Figure 1

Palette DAC Application



*Also known as Color Look-Up Table

0004257-1

Source: Dataquest June 1989

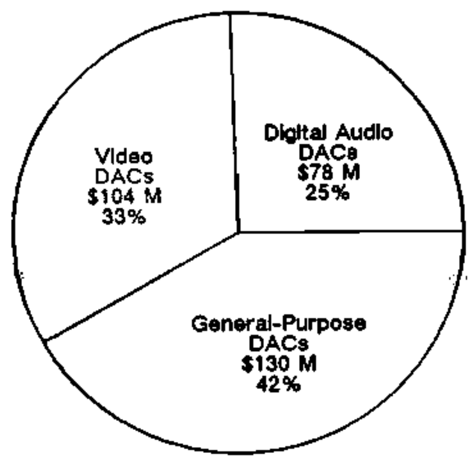
THE MARKET

The video DAC product market has exploded in the past year with rapid growth of workstation graphics products and the VGA standard in the PC arena. Video DACs have grown to a substantial portion of the monolithic DAC market, as shown in Figure 2. Presently, video DACs represent one-third of the market, and they are expected to grow to more than 41 percent of the monolithic DAC market by 1993.

Figure 3 shows unit sales breakdown by conversion speed. In 1988, the bulk of the video DACs consisted of lower-resolution applications such as VGA (640 x 480). This mix will change dramatically during the next five years, as the faster products needed for improved resolution become more available and at a lower cost. Super VGA (800 x 600) and other higher-resolution PC standards, such as IBM's 8514/A adapter and Compaq's noninterleaved graphics (both at 1,024 x 768 resolution), as well as the high-performance graphics used in workstations, will drive this resolution race. Figure 4 relates the conversion rate to the screen resolution in pixels (number of pixels per line times number of lines).

Figure 2

DAC Market by Segment



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June 1989

Figure 3

1988 Video DAC Unit Sales by Conversion Rate

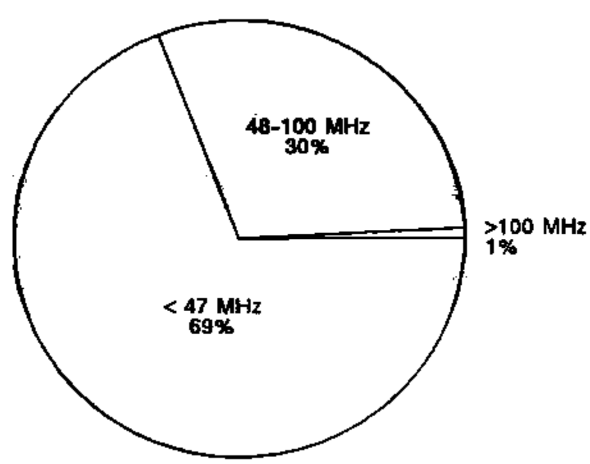

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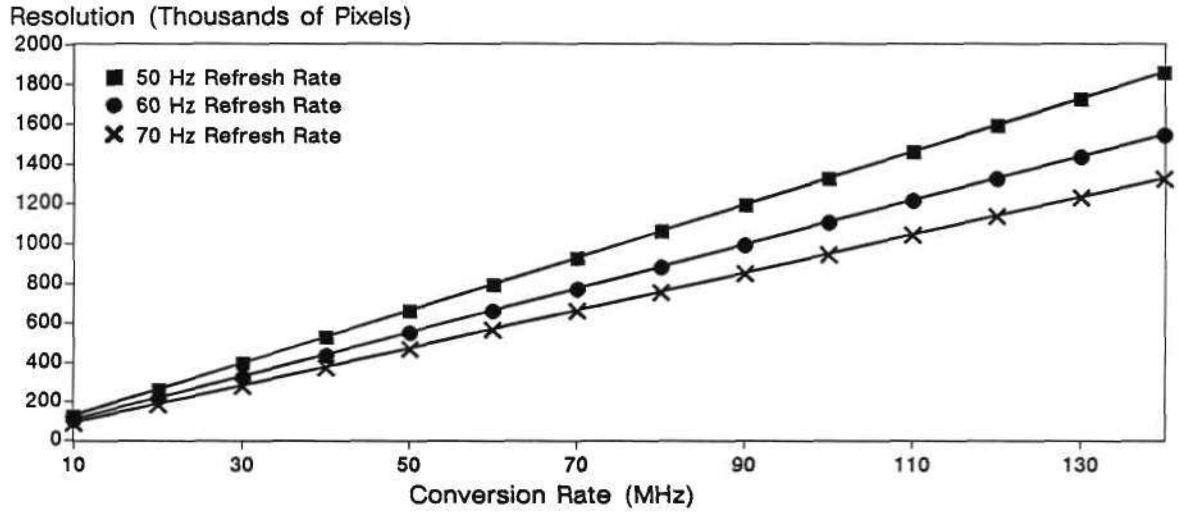
Figure 4

Video DAC Resolution versus Conversion Rate



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Source: Dataquest
June 1989

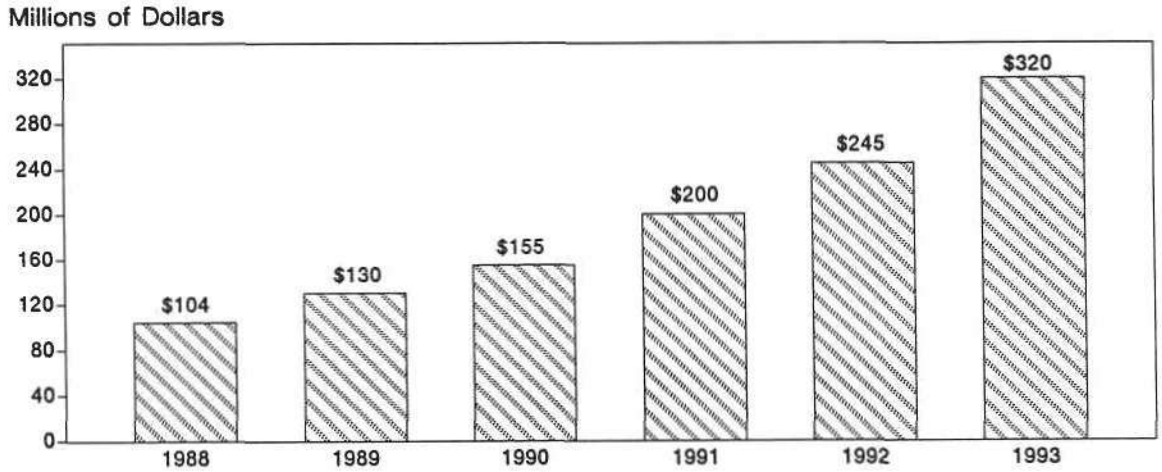
FORECAST

Growth in graphics workstations and greater graphics emphasis both in PCs and PC applications is widening the application of these products while pressing conversion speed higher. Figure 5 shows the anticipated growth in video DAC revenue from 1988 through 1993.

Although we forecast revenue to increase by a compound annual growth rate (CAGR) of 25 percent during this five-year period, we expect the number of units to grow even faster, by more than 41 percent CAGR (see Figure 6). Such growth may be a signal that significant price erosion can be expected.

Figure 5

Video DAC Revenue Forecast 1988–1993



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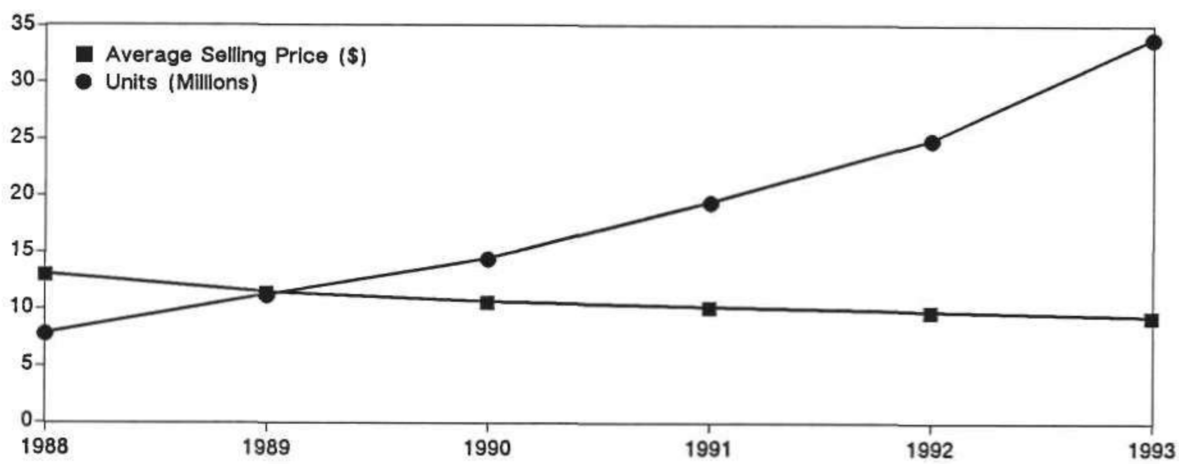
Source: Dataquest June 1989

Figure 6

Palette DAC Unit and ASP Forecast



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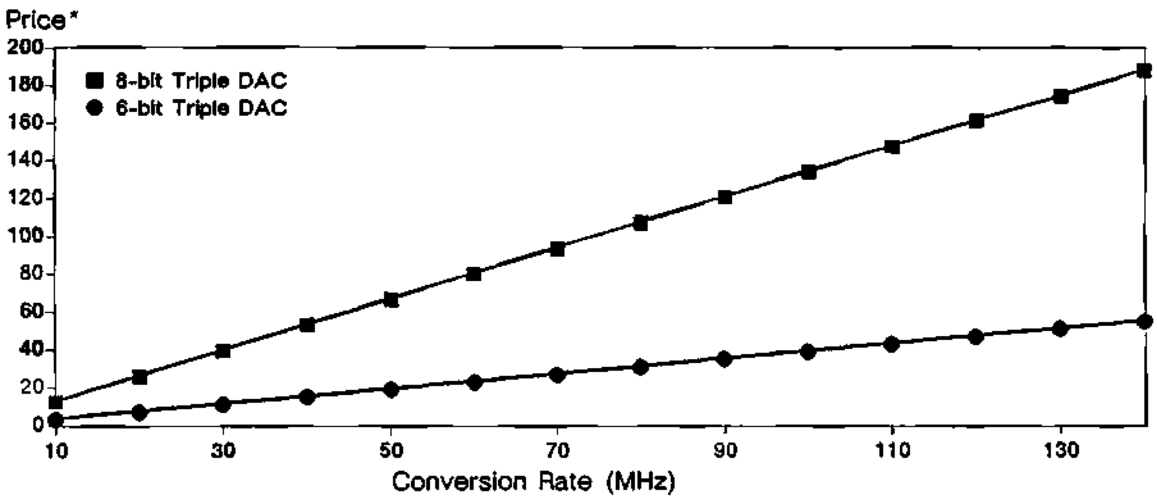
Source: Dataquest June 1989

PRICING

Video DAC pricing varies widely. Although pricing is related to the conversion rate, the product features, and the size of the lookup RAM (the palette), the conversion rate appears to be the dominant pricing factor. Figure 7 shows an approximate pricing curve for 8-bit and 6-bit triple palette DACs by conversion rate (1988 prices, 100 pieces). The 8-bit pricing curve can be described as approximating a price line of $1.35 per megahertz—at 100 pieces, large-quantity pricing is approximately one-half of this. The 6-bit palette DACs follow a similar trend line, but at approximately 40 cents per megahertz, also at 100 pieces.

Figure 7

Palette DAC Pricing versus Conversion Rate
(8-Bit Triple-Palette DAC, 100-Piece Price)
Approximate Trend Lines



*100-piece price
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Source: Dataquest June 1989

Palette DACs have seen considerable price erosion in the first half of 1989 as new suppliers have entered the market. Price erosion will occur for all of these products, but the 8-bit triples are expected to show the most dramatic changes as 8 bits becomes the graphics standard. Dataquest believes that the 8-bit products will show more than a 50 percent price decline during the next five years. This price erosion could be accelerated if high-definition video appears in the consumer market. These changes in product resolution will effectively mask the ASP erosion that would otherwise be expected if resolutions and product mixes (PC graphics to workstation graphics) remained constant.

SUPPLIERS

Suppliers presently in the video DAC market include the following: AMD, Analog Devices, Brooktree, Cirrus Logic, Harris, IDT, Inmos, Intech, Motorola, National Semiconductor, Philips, Signal Processing Technologies, Inc., Silicon Systems, Triad Semiconductor, and VLSI Design.

SUMMARY

This product is in one of the fastest lanes of IC growth. Being involved in computer graphics, CAD/CAM, high-definition TV, medical imaging, and other leading-edge product areas makes the future for these products bright indeed. With a large number of traditional DAC suppliers and many mixed-mode ASIC suppliers entering the market, however, the outlook is for fierce competition, eroding prices, and the palette DAC product's rapid evolution. Higher conversion rates and lower glitch energies will give improved definition, while larger palettes, overlay palettes, and other interface and control enhancements will add features to the product. Vendors not willing to invest in developing high-performance, highly integrated video products will find tough going in the market.

Gary Grandbois

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Research Newsletter

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POWER ICs: NONSMART POWER STILL DOMINANT

The power IC category offers a cross-section of analog ICs with high power or voltage output capabilities from many different product segments. Power ICs include amplifiers, pulse-width modulators, peripheral drivers, display drivers, voltage regulators, and consumer-specific ICs. Although power ICs have been available for decades, the relatively recent combination of logic with power drivers, labeled "smart power" (or "intelligent power"), is seen as one of the major new opportunities for analog ICs. Few IC segments have been as difficult to define and quantify as smart power. In order to shed some light on smart power products, we must restate the power IC definition and compare smart ICs with nonsmart ICs.

POWER ICs—A DATAQUEST DEFINITION

Dataquest defines a power IC as any IC that meets both functional and electrical output criteria.

Functional Requirement

A power IC either provides a power supply function to other electrical/electronic circuits or acts as an interface driver circuit for cables, optoelectronic, electromechanical, or electrochemical devices. Essentially, a power IC provides the activation energy for any electrical function. It is not a signal-processing element that happens to handle higher-than-normal voltages.

Output Requirement

A power IC must be capable of meeting or exceeding one of the following three requirements:

- Dissipate 2 watts
- Handle 1 amp of current
- Control voltages of 100 volts or more

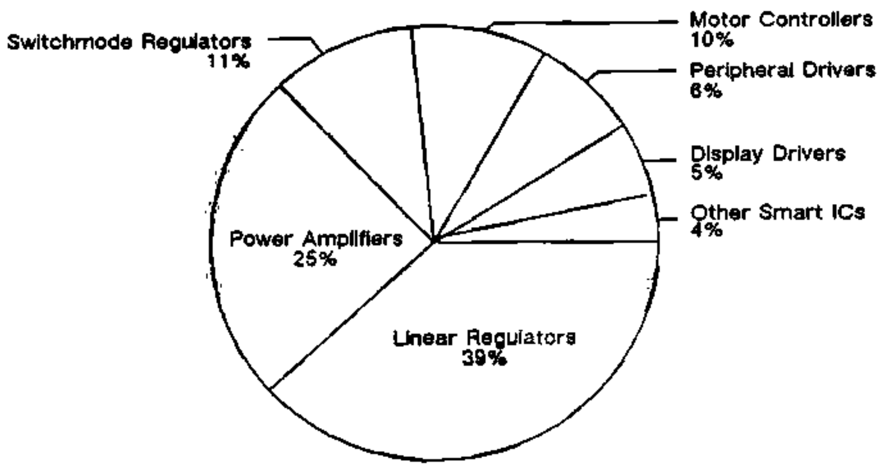
Although this definition includes most of the products promoted as power ICs in the past, it eliminates others. These include high-voltage versions of standard small-signal analog IC functions such as amplifiers, switches, multiplexers, references, and many telecommunications products.

POWER IC MARKET

Figure 1 shows the 1988 power IC market based on some of its major product types. The largest segments are the power portions of the linear voltage regulator market and the combined power amplifier segments of op amps and consumer ICs (audio power amps).

Figure 1

Power IC Market by Product Type



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Source: Dataquest July 1989

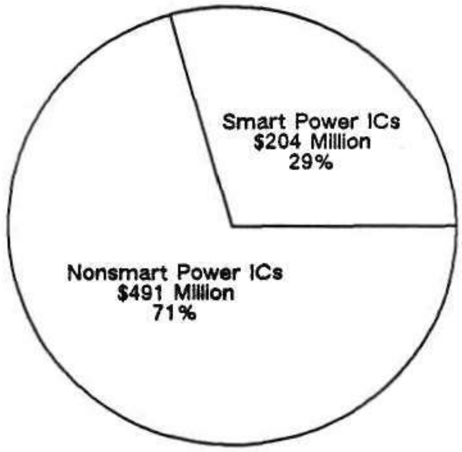
In order to conform with modern power IC segmentation, these products are considered old or new, analog or mixed analog/digital, and nonsmart or smart, based on their logic content, application specificity, and processing technology. Traditional power ICs generally are bipolar devices; are standard products that have a broad application; are inexpensive; and are largely analog in architecture. Newer smart products use a variety of MOS processes, are much more application specific, are somewhat more expensive, and incorporate digital logic. These divisions are listed as follows:

- Analog (nonsmart)
  - Linear regulators
  - Servoamplifiers
  - Audio amplifiers
  - Peripheral drivers
- Mixed (smart)
  - Switching regulators
  - Display drivers
  - Motor controllers
  - Automotive drivers

Based on the analog/mixed or smart/nonsmart partitioning, the market can be broken down into the two major segments shown in Figure 2. Note that the nonsmart segment retains a sizable portion of the market.

Figure 2

Power ICs: Smart versus Nonsmart

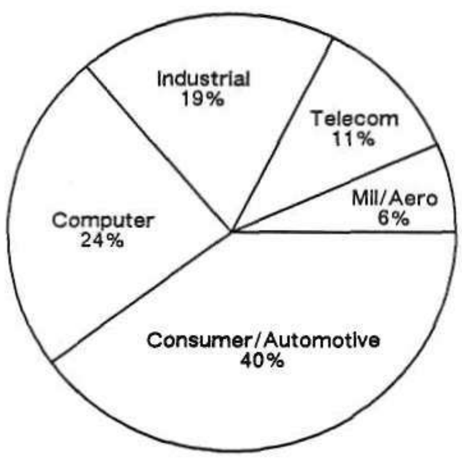


0004447-2 Source: Dataquest July 1989

Power ICs, smart or nonsmart, are consumed in all electronics markets. Smart power products are targeted largely at the emerging automotive market but find applications in all markets. Figure 3 shows some of the application markets for power ICs in 1988.

Figure 3

Power IC Market by Application



0004447-3 Source: Dataquest July 1989

POWER IC SUPPLIERS

The major suppliers of power ICs are listed in Table 1. The top rankings are dominated by traditional voltage regulator and power amplifier suppliers.

Table 1

Market Shares for Power ICs
1988 Revenue

Rank	Company	Market Share (%)	Millions $
1	SGS-Thomson	22.8%	$159
2	National Semiconductor	14.8	103
3	Motorola	12.5	87
4	Texas Instruments	11.3	79
5	Matsushita	7.5	52
6	Sprague	5.6	39
7	Philips	5.4	38
8	Toshiba	4.5	31
9	NEC	2.6	18
10	Hitachi	2.4	17
11	Unitrode	2.1	15
12	Silicon General	1.6	11
13	Linear Technology	1.6	11
14	Cherry Semiconductor	1.3	9
	Other	3.7	26
	Total	100.0%	$695

Note: Columns may not add to totals shown because of rounding.

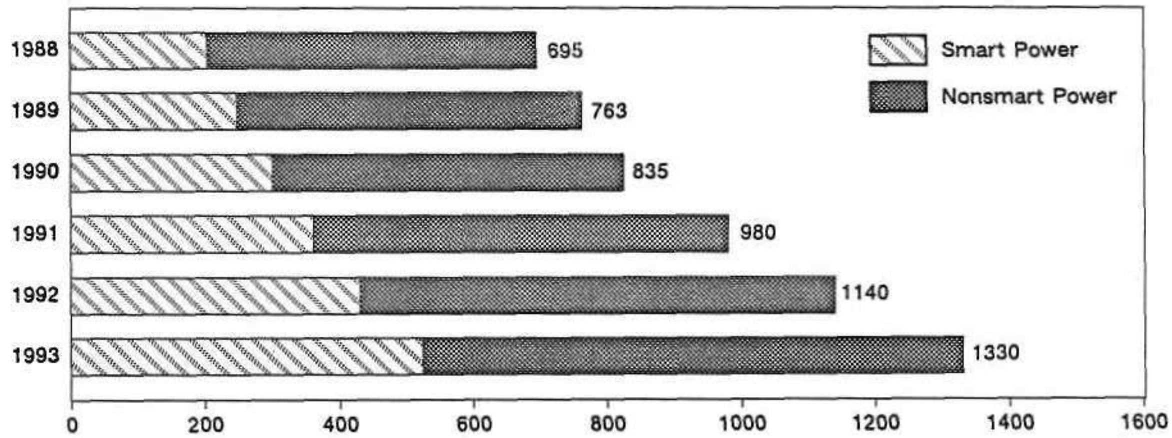
Source: Dataquest
July 1989

POWER IC FORECAST

Although power IC growth will be stunted somewhat by the expected general industry slowdown in 1989 and 1990, we anticipate both the smart and nonsmart segments to continue to grow at substantial rates. Figure 4 shows the anticipated growth in power ICs over the next five-year period. The smart power segment is forecast to show a 20.7 percent compound annual growth rate (CAGR) despite the slowdown, while the more standard products should show approximately a 10.5 percent CAGR. The combined result of these two segments is a 13.9 percent CAGR over the next five years—a growth rate that is strong compared with the lower growth anticipated for other analog segments during this period.

Figure 4

Power ICs Five-Year Forecast



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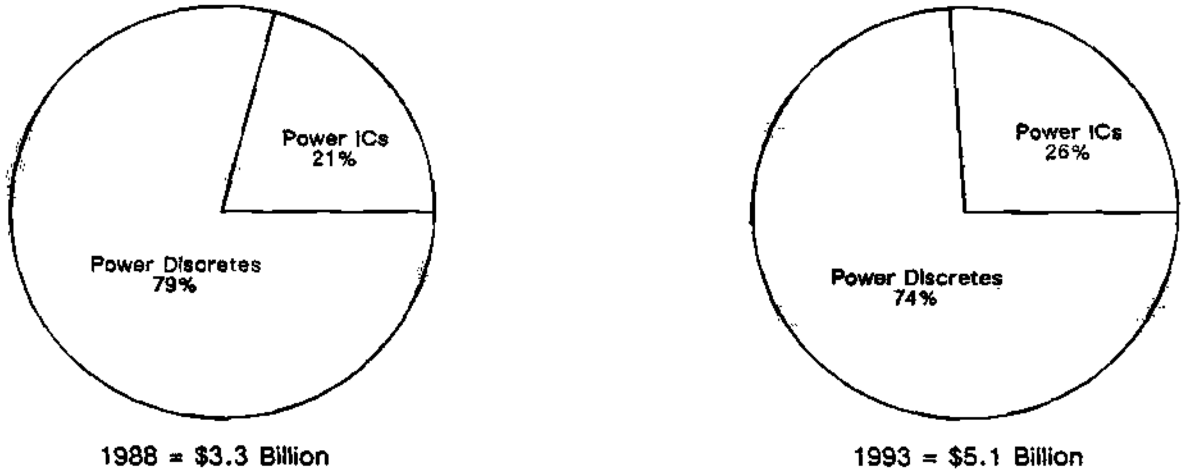
Source: Dataquest July 1989

POWER SEMICONDUCTORS—DISCRETE DEVICES VERSUS POWER ICs

The forecast growth in power ICs comes at some loss of market for discrete power devices. Figure 5 shows that the discrete power transistor market will lose 5 percent of the total power semiconductor market over the next five-year period. This is not so much a loss for discrete solutions as much as it is an emergence of new applications geared to integrated power ICs. Electroluminescent display drivers are but one example of applications that are not really addressable with discrete solutions. However, the cost, availability, and reliability advantages of combining discrete power devices with IC controllers will help the strong discrete presence continue in the market.

Figure 5

Power Semiconductor Market
Discretes versus ICs



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Source: Dataquest
July 1989

DATAQUEST CONCLUSIONS

Power ICs of all types showed strong growth in 1988, paced by switchmode power supply ICs and other smart power devices. Standard linear power regulators made impressive gains as well, showing that these devices are far from a decline. Linear regulator growth was aided by the low dropout (LDO) regulators that offered improved efficiency and lower power dissipation. LDO regulators often are used in conjunction with switching regulators to improve power supply performance.

Dataquest believes that power ICs will continue to be important to growing smart power applications in consumer, computer, automotive, and industrial products, as well as to provide regulated DC power. Smart power ICs provide more custom-oriented or application-specific products that exhibit different requirements in terms of customer relationships, process technology, product life cycle, and price. They are not yet showing the capability of displacing either discrete power devices or the more flexible and less specific nonsmart power ICs. The power semiconductor market needs all three of these alternative solutions.

Gary Grandbois

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Research Newsletter

SMART POWER DEMANDS SMART MARKETING

SUMMARY

Although smart-power ICs may not be particularly smarter than standard power ICs, they *are* different. The many processes, markets, product applications, and user needs present a potential quagmire for suppliers. A slower-than-expected market acceptance and the resulting lowered vendor expectations point out difficulties in defining and marketing smart-power products.

Although it missed the initial predictions of explosive growth, the smart-power segment of the power IC market still is substantial. This segment is estimated to be $204 million, or approximately 29 percent of the total power IC market (see companion power IC newsletter, *Power ICs: Nonsmart Power Still Dominant*, Analog, July 1989). The smart-power segment is expected to grow to $534 million by 1993, a noteworthy 20.7 percent compound annual growth rate (CAGR). Tied to this growth are a number of risk factors, which are the subject of this newsletter.

SMART POWER IS A TECHNOLOGY/METHODOLOGY

Neither fish nor fowl, smart power is neither a market nor an application; rather, it is an IC technology that combines logic circuits with high-current or high-voltage drivers. As with the power discretes they are meant to replace, the markets for smart power ICs fall into every conceivable category. These parts are more than mere arrays of discrete power transistors, however; they definitely are application-specific driver ICs. The logic behind the development of these ICs is the fact that discrete power transistors generally are combined with some IC control circuitry (logic or linear), thus creating the power control function. Integration of the power device and logic was made possible by the development of high-voltage MOS and mixed MOS technologies.

Although they share the electromechanical or electro-optical interface functions of other power ICs, smart-power devices differ from standard power devices in that they are more digital, more application specific, and more expensive. Some of the market segments that smart power addresses include: motor driver/motor control; display drivers; printhead drivers; power supplies; and automotive drivers for instrumentation, engine control, active suspensions, braking systems, and other automobile safety and convenience options.

SMART-POWER RISKS

The risks in developing and marketing smart-power ICs can be greater than for other analog ICs. Risk factors include product definition, technology, packaging, and the nature of the end markets.

Applications and Product Definition

Unlike most other IC products, many smart-power devices are used to interface to an external nonsemiconductor device (e.g., electromechanical, electro-optical, and magnetic). In this way, they are like interface ICs. The electrical and mechanical properties of the external device can determine the electrical and mechanical configuration of the smart-power IC. This is in marked contrast to almost every other semiconductor product offered, (except perhaps for sensors), and it provides a high degree of uncertainty and risk for the semiconductor manufacturer. In addition, much of the emerging smart-power market is tied into developing technologies in the information-display areas such as electroluminescent, PLZT, and plasma. Smart-power product needs can vary immensely as these

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emerging display and other physical interface technologies (such as motors) go through a shakeout period.

Life cycles for application-specific smart-power products will show the shorter life-cycles characteristic of digital products. This shorter life cycle, combined with the lower volumes inherent in most application-specific products, can make learning-curve cost reductions unlikely.

Technology

DMOS, CMOS and DMOS, BiCMOS, BCD, and other technologies are vying in the smart-power market. Which one is the best technology is arguable, as each has advantages for particular applications. The voltage, current, cost, and architecture requirements of the user applications each will drive the technology selection. Although exotic DMOS and CMOS processes can be used at the limits of drive requirements, they would not be cost competitive with standard CMOS and bipolar processes in products that were less state of the art.

Packaging

As previously stated, one aspect of smart-power IC products is that the package may be partially defined by the physical system to be interfaced. Display drivers for flat-panel displays must interconnect with what can be hundreds of thousands of pixels. High pin counts, new addressing and drive schemes, and other concerns in packaging and interconnect work against the standard product concept because each display will require a driver that corresponds to its display drive requirements, pixel demands, and addressing configurations. Smart-power ICs that embody electromechanical drivers may require a package configuration linked to the mechanical and heat-dissipation properties of the motor or module.

Markets

Many diverse applications and markets are united in that they use power or high-voltage devices. Two general market categories are important to the growth of these products. The first is the replacement market for discrete power device implementations in present applications, and the second is the market for new applications.

The power semiconductor market presently is dominated by discrete power devices rather than power ICs. Chasing cost-effective combined discrete/IC solutions with expensive smart-power IC solutions will result in limited penetration. This is because the more specific smart-power ICs each will tend to fragment the market into a myriad of smaller, more specific unit volumes, which in turn will slow advancement down the learning curve.

Smart power is more viable as a technology that is useful to new applications rather than a replacement of discrete power transistors in present applications. Only the automotive, consumer, and computer markets can provide the production volumes that can help make smart-power a cost-competitive alternative. In other emerging applications, pin counts, reliability, and space requirements may make smart power the only reasonable alternative.

Vendor/User Relationship

Although the vendor/user relationship has been more distant in the fragmented standard linear IC market, the application-specific nature of power IC products requires a closer relationship.

In new applications such as drivers for new display technologies, the display and driver IC must be developed in close conjunction. For non-captive suppliers, this requires a close working relationship with the display supplier and/or the end-equipment manufacturer. Without close ties, large potential exists for mistaken product definitions and directions. Strategic alliances are essential. Broad-line semiconductor suppliers have an edge from previously forged connections in end markets. New or specialty smart-power suppliers must align with users or with suppliers/users such as ASEA Brown-Boveri, Delco, Ford, General Electric, Sharp, Siemens, and Telefunken.

Custom, Semicustom, and Standard Products

Because of the close vendor/user relationships and the application-specific nature of smart-power products, the product evolution has moved away from standard products and into custom and semicustom smart-power products. Dataquest believes that the growth of smart power will be more in the custom or semicustom segment of the power IC market rather than from standard products. The semicustom area of power-mixed analog/digital

ASICs is a particularly attractive product for the fast product turnaround required in the automotive and consumer markets.

DATAQUEST CONCLUSIONS

The smart-power market potential is significant, but so are the pitfalls. Dataquest believes that strategic alliances with other smart-power vendors can help share the product risks associated with smart-power ICs. More important, however, are strategic alliances with key customers, a custom product orientation, and a strong technology position, which are vital for ensuring growth in the smart-power market.

Gary Grandbois

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Research *Newsletter*

ANALOG ICs IN THE 1990s: THE FUTURE IS MIXED

INTRODUCTION

The analog IC market has remained at a fairly consistent 20 percent of the total IC market for nearly two decades, yet analog products have been going through significant changes during this period. The pure analog signal processing ICs such as amplifiers, regulators, timers, and other mature product types are losing ground to more advanced products that feature mixtures of analog and digital circuits. Although much has been made of mixed-mode ASIC as a growth area for the next decade, this area represents only a small part of the substantial growth that will be experienced by mixed analog/digital ICs in the coming years. Irrespective of design methodology—ASIC, full-custom, or standard—the market is looking for more complex ICs that simplify design, reduce board space, increase reliability, and lower costs. Mixed signal or mixed-mode ICs provide this solution for the analog/digital interface.

Dataquest estimates that the mixed analog/digital portion of the market is growing 34 percent faster than the analog IC market in general. We expect the mixed-mode products to grow by more than 16 percent compounded over the next five-year period, a period that is expected to see a significant IC sales slowdown in 1989 and 1990. This growth is paced by the 21.4 percent compounded growth anticipated for the mixed ASIC market during the next five years.

MIXED-MODE PRODUCTS AND MARKETS

A mixed-mode or mixed-signal IC combines both analog and digital signal processing functions on the same chip. As Figure 1 shows, the $2.29 billion market for mixed-signal ICs is made up of products from many traditional segments. For this evaluation, we have excluded any mixed-signal portion of the consumer-specific IC market because of the difficulty in quantifying these product types at this time.

Forecast Growth Rates

A comparison of the anticipated compound annual growth rates (CAGRs) for the various analog product categories is given in Figure 2. It is significant that most of the fastest-growing product categories are the categories of mixed products, which are identified by an asterisk (*) on the chart. In addition to the identified mixed-mode categories, the fastest-growing subsegments of largely nonmixed products (such as the switching regulator portion of voltage regulators) also are included in the consolidated mixed-mode products.

The combination of the identified mixed-mode segments and subsegments and their individual forecasts yields the mixed IC forecast listed in Table 1 and depicted graphically in Figure 3.

Figure 3 shows the individual contributing categories to this aggregate five-year growth forecast for mixed-mode ICs.

Analog Market Segments

Partitioning the analog IC market into mixed-mode (or mixed-signal) ICs, pure analog ICs, consumer-specific ICs, and hybrid ICs shows that the mixed-mode ICs will be growing faster than the pure analog products, gaining an additional 5 percent share of the analog market in just five years. Market share will be lost by both hybrid ICs and the traditional analog signal processing ICs to the mixed monolithic ICs. Figure 4 shows the proportional growth of the mixed-mode ICs versus the three other categories. It should be noted that the consumer-specific ICs also will show a rapid

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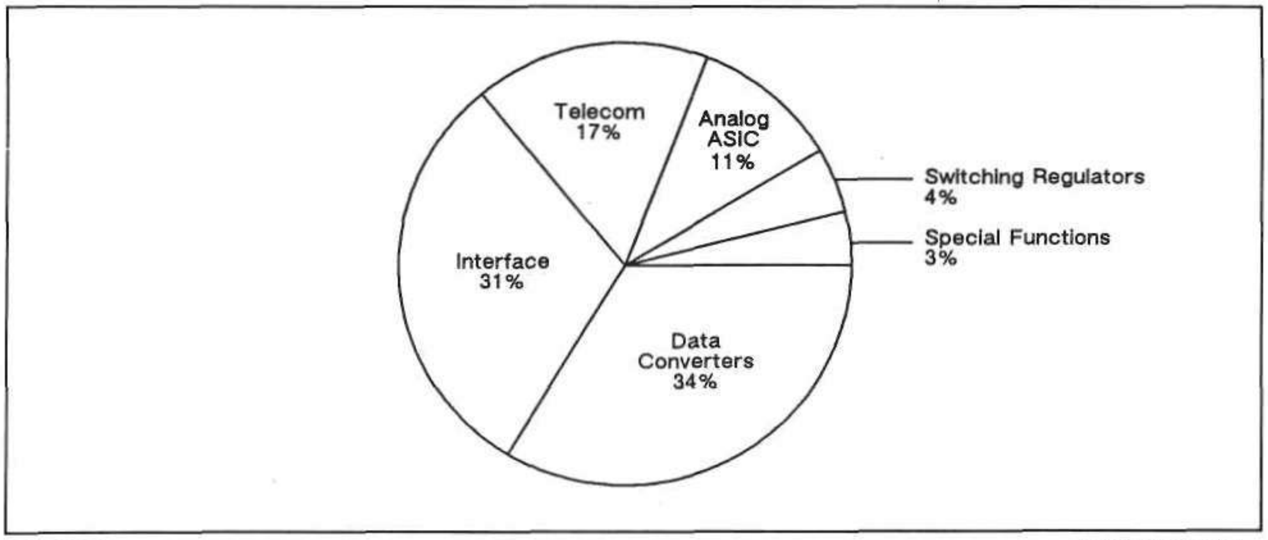
FIGURE 1
Mixed-Mode ICs by Product Category



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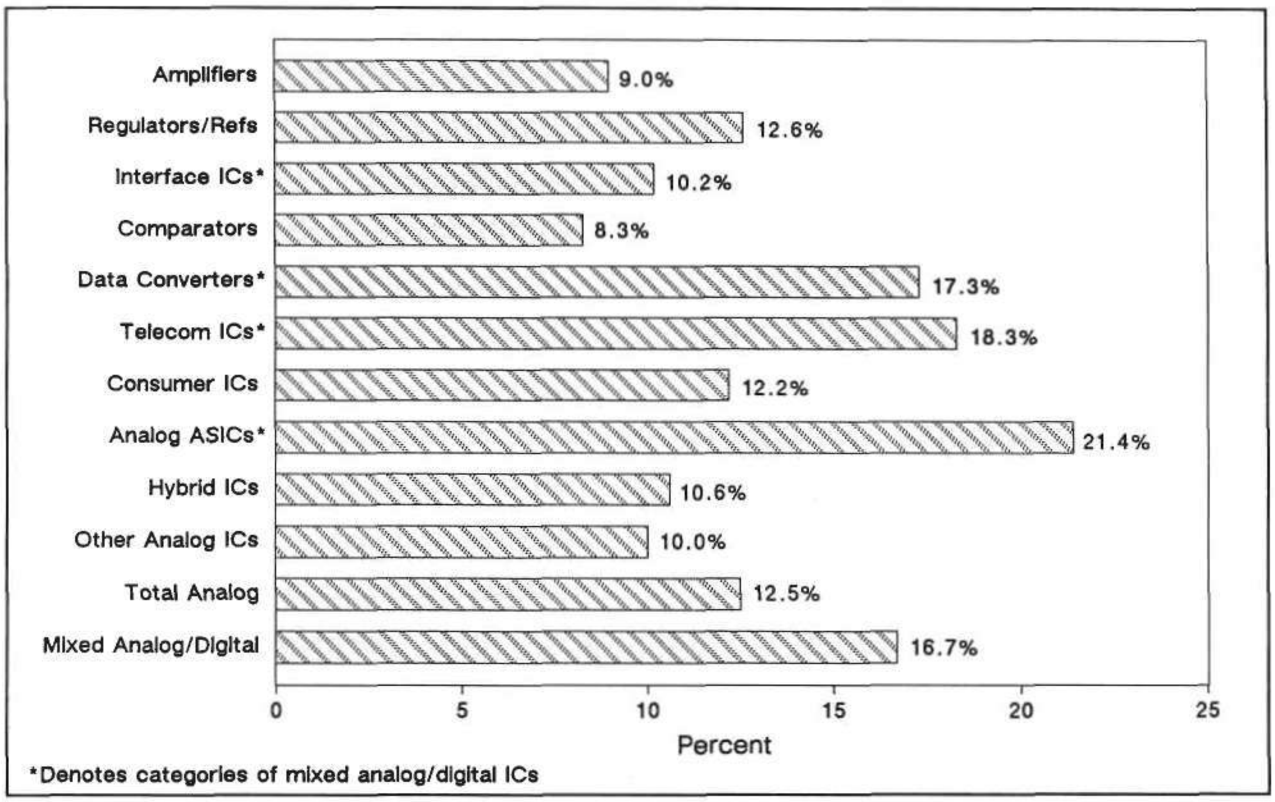
Source: Dataquest
August 1989

FIGURE 2
Forecast CAGRs by Product Category



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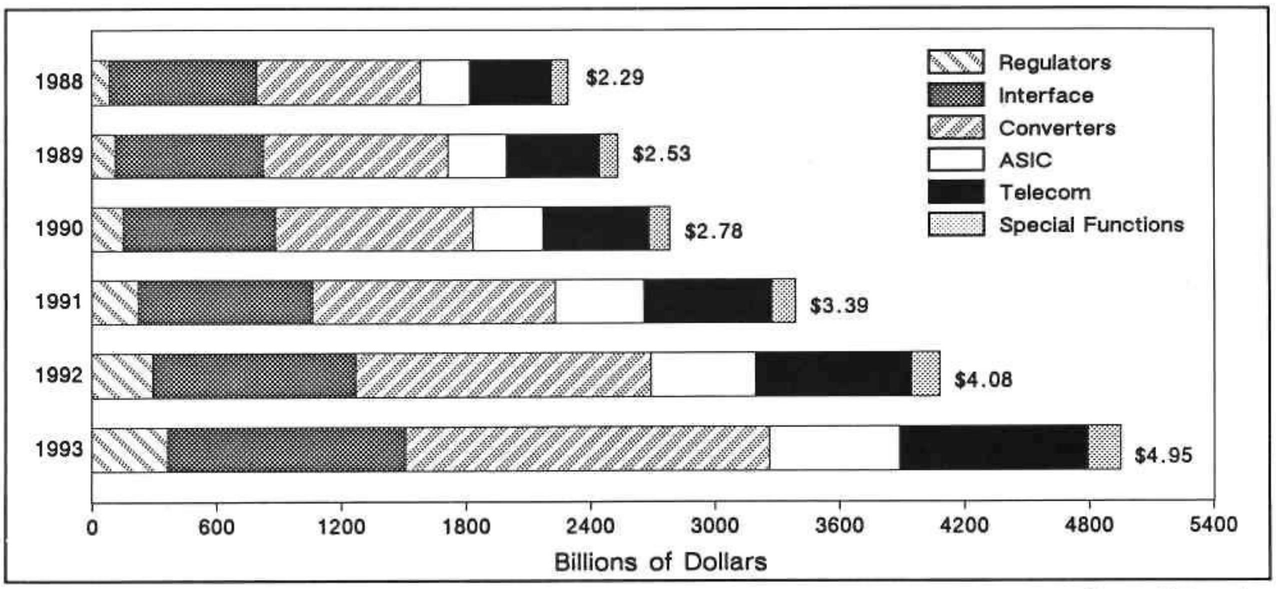
Source: Dataquest
August 1989

TABLE 1
Estimated Mixed Analog/Digital Market (1988-1993)

Segment (Billion $)	1988	1989	1990	1991	1992	1993	CAGR 1988-1993
Total Analog Sales	9.00	9.35	9.80	11.50	13.80	16.30	12.5%
Total Mixed IC Sales	2.29	2.53	2.78	3.39	4.08	4.95	16.7%
Mixed ASIC Sales	0.24	0.29	0.35	0.42	0.50	0.62	21.4%

Source: Dataquest
August 1989

FIGURE 3
Mixed-Mode IC Forecast



0004692-3

Source: Dataquest
August 1989

change to mixed-mode ICs as demand increases from the entertainment (HDTV, digital audio) and automotive markets.

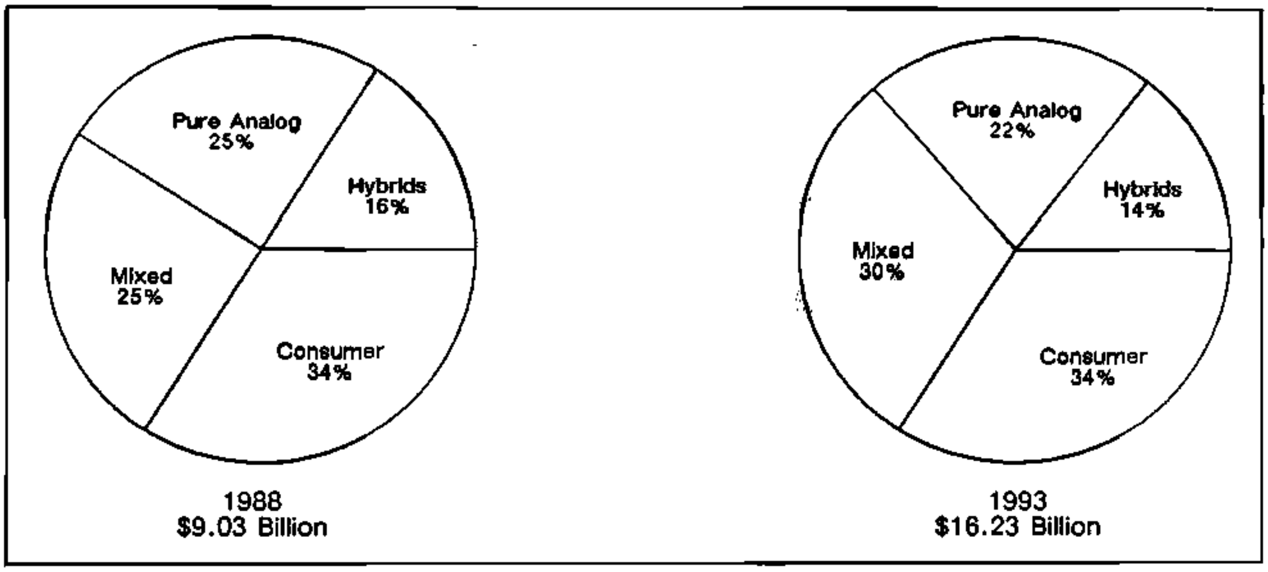
Mixed ASIC and Smart Power

The mixed-mode IC grouping contains ASIC and smart power ICs as well as standard, nonpower ICs. As Figure 5 shows, both ASIC and smart power are relatively minor portions of the mixed-signal grouping. These product types are growing faster than the standard product segments, however, and they present specialized opportunities for growth within the broad mixed-mode product grouping. Mixed ASICs have the potential to replace many of the data converter, interface, and telecom devices now offered as standard mixed-mode products.

Mixed-Mode IC Application Markets

Because the mixed-mode category is a collection of the fastest-growing segments of the analog market, it should not be surprising that these mixed-signal ICs serve the fastest-growing end-application markets. Figure 6 illustrates 1988 mixed-mode IC consumption by application markets. Note that the combination of computer, consumer, and telecom markets consumed 72 percent of the mixed-mode products in 1988.

FIGURE 4
Analog IC Forecast by Special Category



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Source: Dataquest
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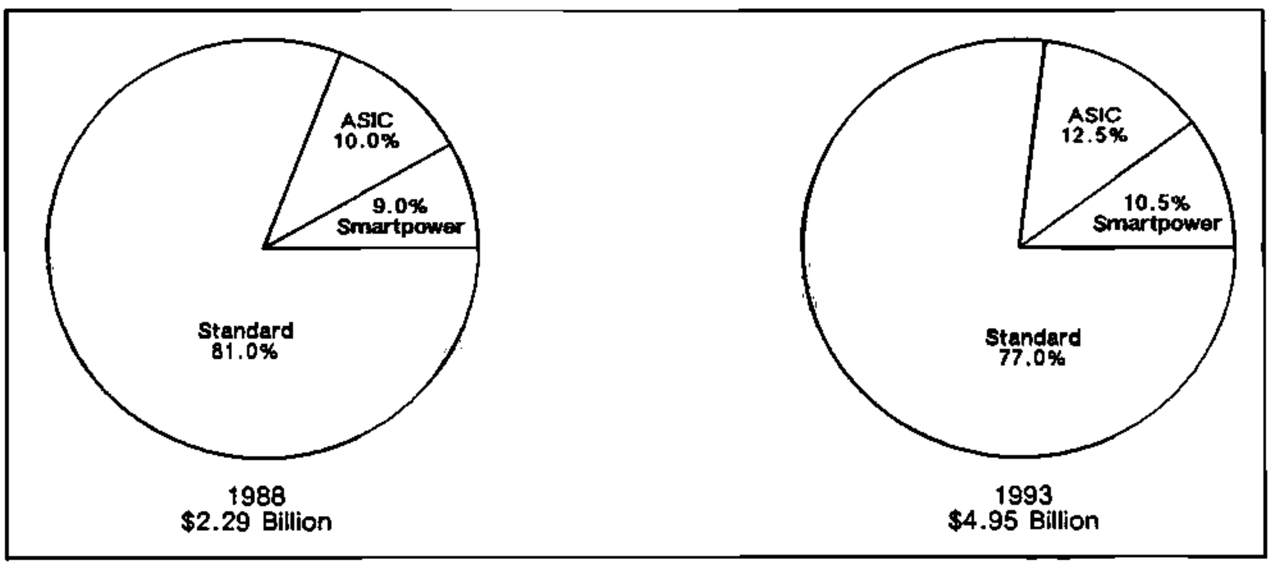
FIGURE 5
Mixed-Mode IC Forecast by Specialty Products



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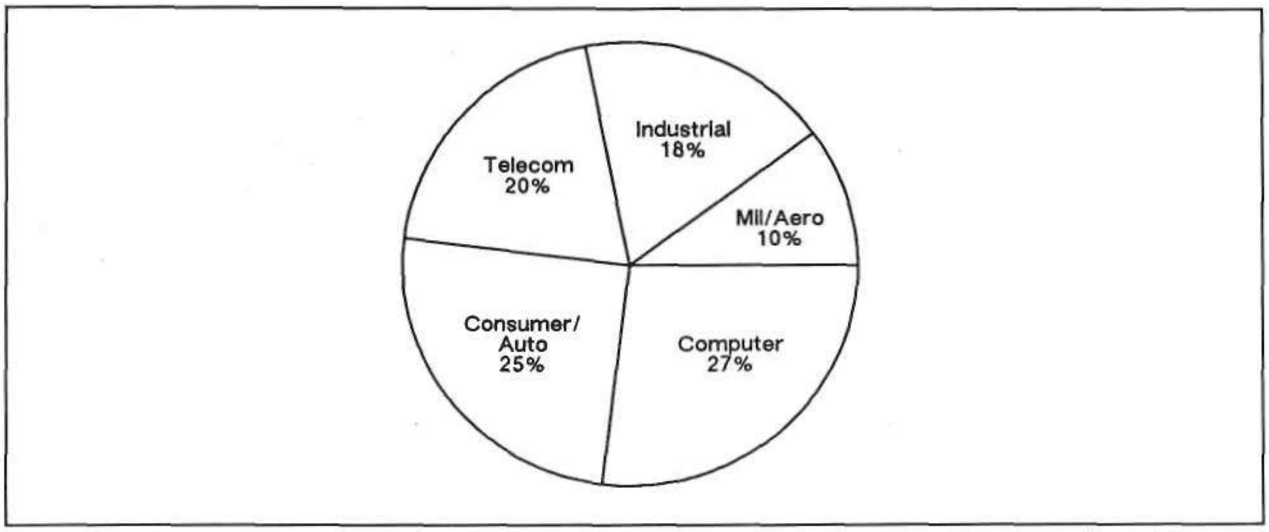
August 1989

Process Technology

Mixed-mode ICs are processed with a wide variety of technologies. Bipolar still dominated in 1988, but we expect it to continue losing ground to CMOS and the various combinations of bipolar, CMOS, and DMOS that we refer to under the BiCMOS designation. BiCMOS is the preferred technology to optimize mixed analog/digital ICs. (See the Dataquest Analog Newsletter entitled, "BiCMOS: A High-Performance Complement to CMOS.") Fewer than 2 percent of analog ICs were

FIGURE 6
Mixed-Mode IC Consumption by Application Markets



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Source: Dataquest
August 1989

processed with this technology in 1988. Dataquest estimates that 7 percent of all IC revenue will come from products utilizing BiCMOS by 1993. The mixed IC forecast by technology is shown in Figure 7.

Suppliers

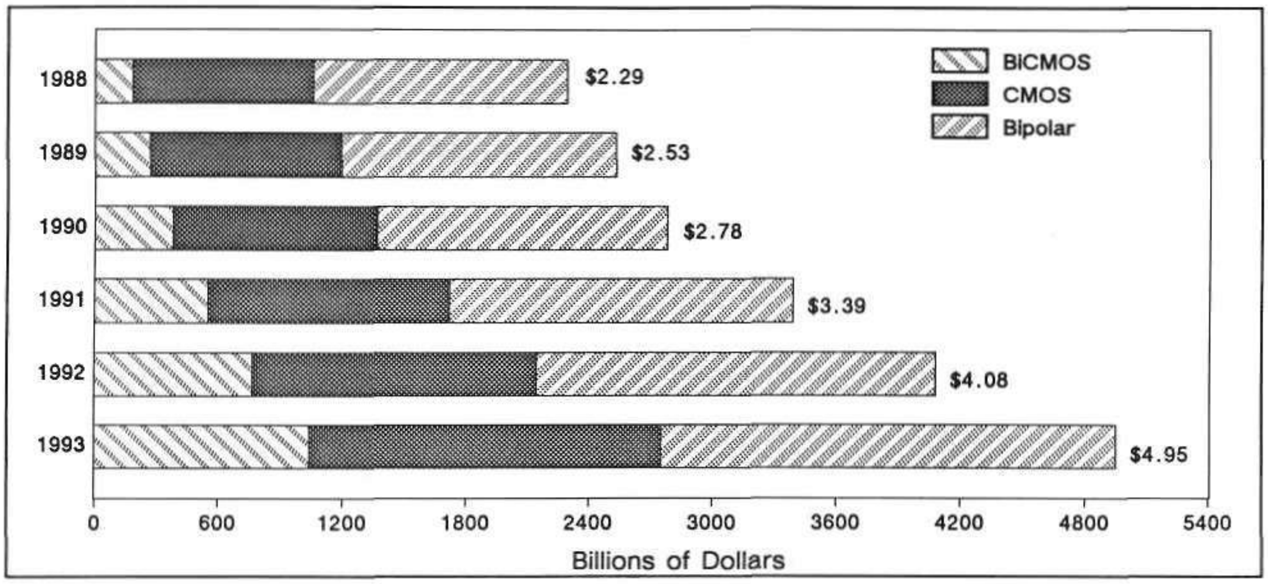
Because mixed-mode analog has long been part of the broad analog IC definition, the majority of analog IC suppliers do offer mixed-mode products. Table 2 lists these suppliers in order of market share. The consumer-specific product segment was not included in this review of mixed-mode products; therefore, the top five suppliers are U.S. manufacturers. A review of this chart shows that the mixed-mode IC market is quite fragmented, with a 3 percent market share sufficient for "top 10" status.

DATAQUEST CONCLUSIONS

Mixed analog/digital ICs are not a new phenomenon; analog suppliers have a long history of supplying mixed-signal ICs to the market. Now, however, the trend toward mixed-signal ICs is accelerating, pressed by the continued incursion of both analog and digital ICs into previously "pure" analog or digital applications and by the success of digital ASICs to integrate digital functions. Mixed-mode is not synonymous with ASIC, but mixed-mode ASIC does represent an explosive growth area for mixed-mode ICs if the standard cells, design tools, and design capability can be brought together. Whether in custom, semicustom, or standard ICs, the future of analog ICs is certainly mixed.

Gary Grandbois

FIGURE 7
Mixed-Mode IC Forecast by Process Technology



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Source: Dataquest
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TABLE 2
1988 Market Share for Mixed-Signal ICs

Rank	Company	Market Share	Millions of Dollars
1	Analog Devices	8.5%	$ 193.0
2	National Semiconductor	8.1	184.0
3	Texas Instruments	6.9	158.0
4	Motorola	5.8	133.0
5	AMD	4.0	92.0
6	SGS-Thomson	3.8	86.0
7	Ericsson	3.5	80.0
8	Philips	3.4	78.0
9	Sprague	3.3	76.0
10	Matsushita	2.7	61.6
11	Silicon Systems	2.7	61.0
12	Burr-Brown	2.3	53.4
13	Inmos	2.1	47.6
14	Brooktree	2.0	45.0
15	Fujitsu	1.9	44.0
16	GE Solid State	1.9	43.0
17	Toshiba	1.8	42.0
18	Siemens	1.8	40.3
19	NEC	1.8	40.0
20	Harris	1.7	38.2
21	Exar	1.7	37.7
22	Hitachi	1.6	36.1
23	Oki Semiconductor	1.4	31.5
24	Rohm	1.1	24.0
25	Precision Monolithics	1.0	23.8
26	Sierra	1.0	23.0
27	Plessey-Interdesign	1.0	23.0
28	NCR Microelectronics	1.0	23.0
29	Mitel	1.0	22.5
30	Sharp	1.0	22.5
31	Sony	0.9	20.0
32	Telefunken Electronics	0.9	20.0
33	Unitrode	0.9	19.7
34	Silicon General	0.9	19.5
35	International Micro Products	0.8	18.9
36	TRW	0.8	18.0
37	Mitsubishi	0.7	17.0
38	Teledyne Semiconductor	0.7	17.0
39	Maxim	0.7	17.0
40	Linear Technology	0.6	12.7
	Other	10.4	247.0
	Total	100.0%	$2,290.0

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1989

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Research Newsletter

HARRIS' ACQUISITION OF GESS: THE IMPACT ON THE ANALOG MARKET

SUMMARY

The acquisition of GE Solid State (GESS) has had a significant impact on Harris' position in both the semiconductor and analog product markets. The merger boosted Harris' overall semiconductor presence; it went from being the 29th largest supplier worldwide to being the 19th and moved from 19th to 15th place among the world's analog product suppliers. Through the acquisition, Harris not only gains added credibility as a world-class supplier but adds operational balance and strength with GESS' world-based facilities and commercial business emphasis.

BACKGROUND

Harris acquired GESS for $206 million in the fall of 1988. With the acquisition, Harris changed its operations mix—from military as the number one revenue generator, to semiconductors. Harris' operations mix prior to the merger included government systems, $792.0 million; information systems, $588.0 million; communications, $383.0 million; and semiconductors, $299.2 million. The before-and-after operations scenarios are presented in Table 1.

THE SEMICONDUCTOR ORGANIZATION

Six divisions were formed to address the new company entity: military and aerospace, power products, commercial products, commercial ASIC, marketing, and manufacturing. The military and aerospace division provides standard, semicustom, and custom products for the military and government markets. The power products, commercial products, and commercial ASIC divisions manufacture power and integrated smart-power devices, general-purpose standard products for the signal-processing and control market, and commercial semicustom and application-specific standard products, including circuit development, for the automotive and telecommunications markets.

TABLE 1
Harris' 1988 Applications Focus—Before and After the Acquisition (Fiscal Year Ending June 20, 1988)

Business/Application Sector	Harris	GESS	Harris/GESS
Communications	$ 383.1	N/A	$ 383.1
Information Systems*	587.8	N/A	587.8
Government Systems	792.5	N/A	792.5
Semiconductors	299.2	$550.0	849.2
Total	$2,062.6	$550.0	$2,612.6

N/A = Not Applicable
*Includes Lanier Division

Source: Harris 1988 Annual Report

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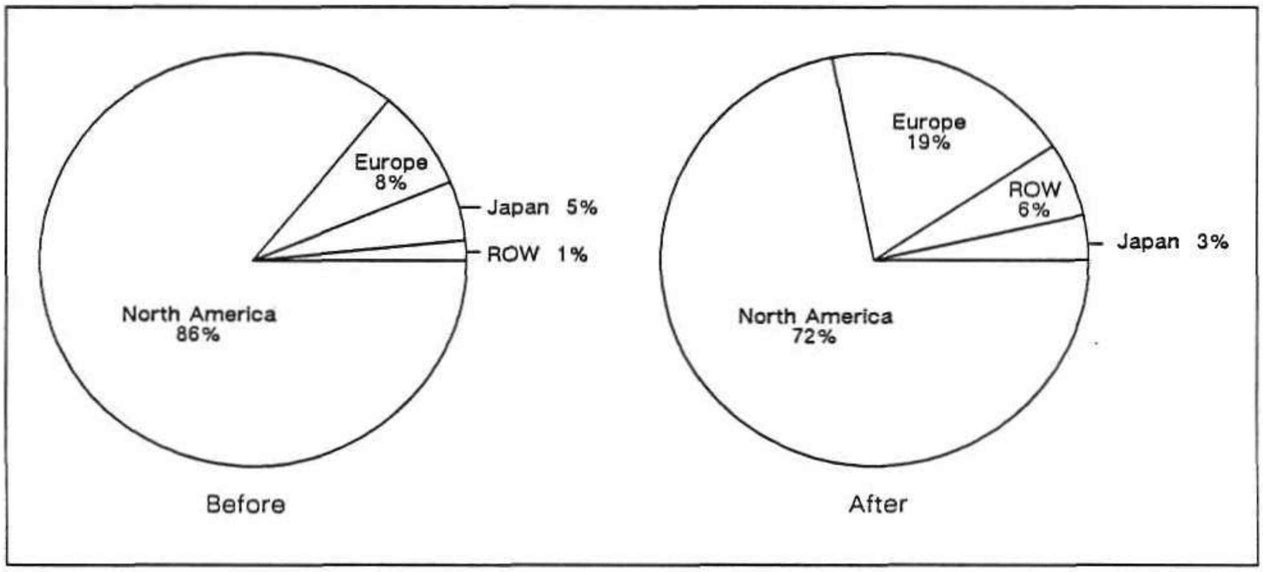
The management center for power, digital ICs, and ASICs is located in Somerville, New Jersey; integrated power is headquartered in Research Triangle Park, North Carolina; and signal processing/analog, military products, and the marketing and manufacturing divisions all are located in Melbourne, Florida.

REGIONAL MARKET IMPACT

The international flavor of the company also changed with the addition of GESS. Sales of semiconductors and analog ICs to European and Asian markets strengthened considerably, as noted in Figures 1 and 2.

FIGURE 1
Harris' 1988 Semiconductor Regional Sales–Before and After the Acquisition



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Source: Dataquest
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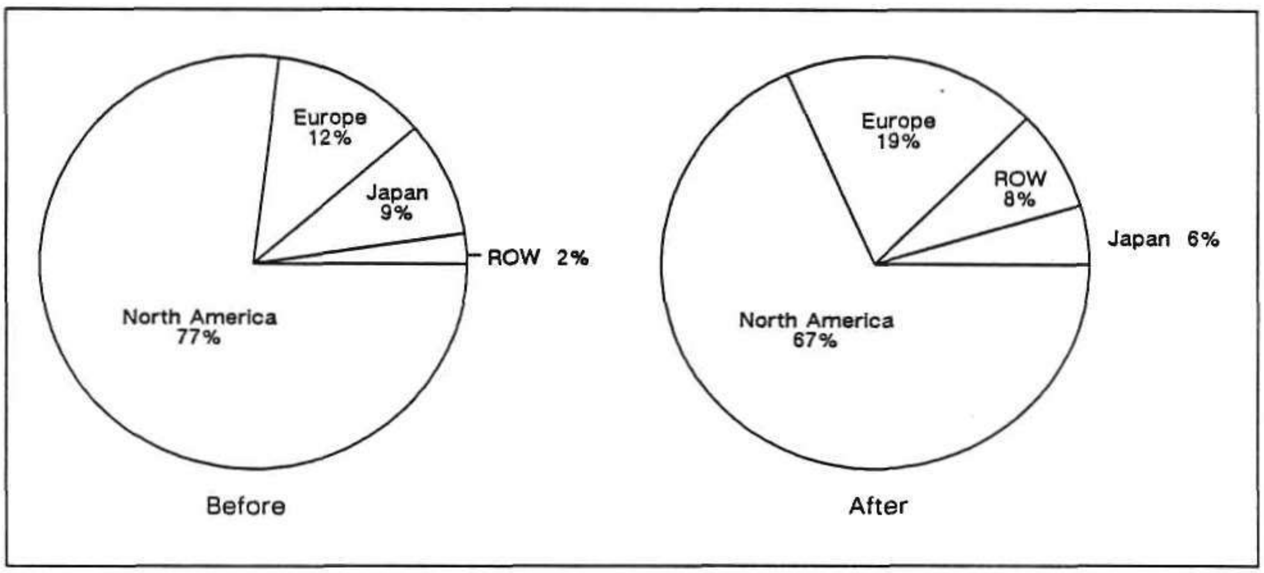
FIGURE 2
Harris' 1988 Analog IC Regional Sales–Before and After the Acquisition



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Source: Dataquest
September 1989

TABLE 2
Harris/GESS—1988 Analog Market Repositioning (Millions of Dollars; Position Rank)

Product Segment	Harris	Rank	Harris/GESS	Rank
Amplifiers	$ 48	7	$ 76	4
Regulators/References	2	33	8	15
Comparators	0	19	6	7
Interface ICs	3	25	15	12
Data Converters	48	4	78	2
Other Analog ICs	21	11	28	8
Telecom ICs	13	15	19	11
Consumer ICs	1	29	20	21
Hybrids	0	-	0	-
Total Analog ICs	$138	19	$250	15

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest September 1989

ANALOG MARKET IMPACT

Focusing more specifically on the product segments of analog, Dataquest notes upward positioning in certain markets. The most notable changes are to data converters and amplifiers. As shown in Table 2, Harris/GESS moved from fourth to second place in data converters and from seventh to fourth place in amplifiers. Positive rank changes are seen across the board in all product areas.

DATAQUEST CONCLUSIONS

The unification of the companies was from the first a challenge, considering the very different entities of Harris, GE, RCA, and Intersil. Yet the successful union undoubtedly can create a much stronger company that banks on the strengths of both companies, Harris' military expertise, and GE/RCA's commercial strength. The diversification of operations can offer strength by balancing the two application markets and opening up new opportunities.

Barbara Van

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Research Newsletter

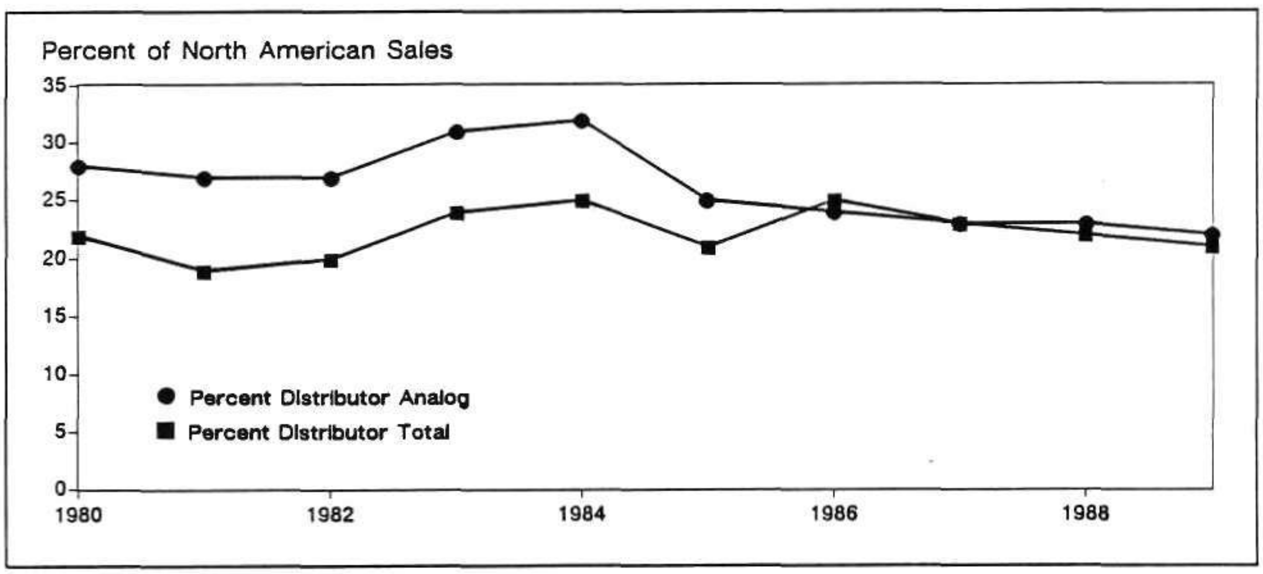
DISTRIBUTORS AND COMMODITY LINEAR: THE BASTIONS ARE CRUMBLING

Distributors have long provided a significant channel for analog IC sales. Traditionally, the rule of thumb for many analog suppliers has been that the distributor channel should account for approximately 27 percent of total North American sales. Higher percentages were expected for companies highly involved in commodity linear ICs (e.g., National Semiconductor) and lower percentages for suppliers of high-performance specialty products (e.g., Analog Devices). The pattern of the last five years shows that the distributors' percentage of analog IC sales in North America has declined about 5 percent, as shown in Figure 1.

Although the North American share of the analog market has declined significantly in the past decade, analog IC consumption in this region grew 41 percent between 1985 and 1988. A notable problem, however, is that the growth of analog revenue through distribution grew only 31 percent during the same period. This lagging sales growth has reduced the percentage of analog sales through distributors to 22 percent, bringing analog in line with the percentage of all ICs sold through distribution to the North American market.

One school of thought views this decline in the analog distributor/OEM ratio as a distortion

FIGURE 1
Analog Distribution versus Total Distribution, 1980-1989



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Source: WSTS
Dataquest
September 1989

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brought about by Japanese suppliers reporting all North American sales as OEM sales. The problem with this argument is that this reporting anomaly, if true, should distort the total IC ratio as much as that of analog ICs. That this does not appear to be the case is shown in Figure 1, where it can be seen that the total North American distributor IC sales average about 22 percent during the last decade and have shown little change after 1984 (the year Japanese reporting to World Semiconductor Trade Statistics (WSTS) started).

COMMODITY LINEARS FUEL THE DECLINE

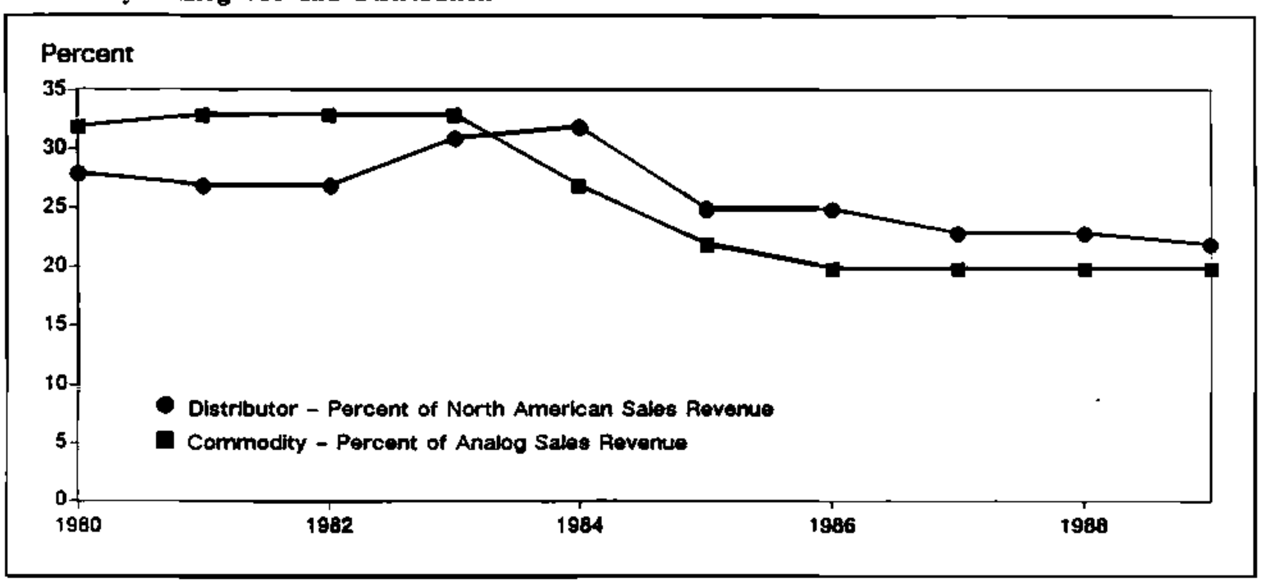
One of the mainstays of the analog market is the commodity linear IC. This product is a standard, simple linear building block such as an amplifier, timer, comparator, or voltage regulator, commonly sold through distributors. Because commodity linear products and distributors have been strongly intertwined, the decline in distributors' importance in the North American market can be attributed to the decline in the sales growth of commodity linear ICs.

The main factors in this decline are as follows:

- Rapidly eroding average selling prices (ASPs) in commodity linear ICs
- Decline in the growth of commodity linear IC units
- Decline in the U.S. share of the linear market
- The emergence of specialty, application-specific products including custom, semicustom, and mixed-mode products
- Higher levels of integration, which incorporate the standard linear blocks, thereby decreasing the market for commodity linear functions
- Digital signal processing decreasing the use of linear signal processing products
- Closer supplier-customer relationship needed for effective application of application-specific products

Figure 2 shows the changing mix of analog as the combined sales revenue of the two major categories of commodity linears, amplifiers and regulators, are plotted along with the change in the percentage of distribution revenue. Although the

FIGURE 2
Commodity Analog ICs and Distribution



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Source: WSTS
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WSTS data prior to 1984 may be suspect (due to the need to estimate Japanese sales), the trend since 1984 is quite definite. Together, commodity linear ICs and distribution are declining in importance in the analog IC sales mix.

DATAQUEST CONCLUSIONS AND RECOMMENDATIONS

The role provided by distributors will continue to be important to analog IC suppliers and users. Nonetheless, it should be realized that the weakening of distributor sales to 22 percent of total North American analog sales is not a temporary phenomenon, but a significant readjustment to the changing nature of analog ICs and their consumption. Sales channels and strategies for analog ICs are not independent of the changing nature of the product, application, or purchaser. As commodity linear ICs decline in importance, the analog IC market more closely resembles the broad IC marketplace.

Gary Grandbois

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Research Newsletter

OEM MONTHLY–SEPTEMBER 1989 COLOR MONITORS DISPLAY SALES GROWTH AND DESIGN INNOVATION

OEM Monthly provides insight into application markets so that clients can make better strategic and technical marketing decisions.

MONITOR SHIPMENTS

Rapidly growing sales of color monitors have caught the attention of semiconductor suppliers, and some of these companies are ending up with a big piece of the action. The results are application-specific standard products (ASSPs) that improve performance and reduce costs.

Dataquest's worldwide forecast of color monitors is presented in Table 1. Low- and high-resolution monitors have five-year compound annual growth rates (CAGRs) of 10 and 65 percent, respectively.

Monochrome displays are losing market share. We estimate that 58 percent of the PCs and workstations sold in 1988 had color monitors, and that this ratio will increase to 65 percent by 1993.

TABLE 1
Forecast of Worldwide Color Monitor Shipments (Millions of Units)

Year	Low Resolution	High Resolution
1988	11.2	0.19
1989	12.7	0.41
1990	13.2	0.93
1991	14.6	1.91
1992	15.2	3.50
1993	16.6	4.80

Source: Dataquest
September 1989

MONITOR INNOVATIONS

A color system includes a monitor connected to a PC or workstation (see Figure 1).

The video DAC in the PC/workstation changes the information to be displayed from digital data to red, green, and blue (RGB) analog signals. After amplification by the video circuits in the monitor, these signals appear on the cathode-ray tube (CRT) as either text or graphics.

High-resolution displays present greater challenges to engineers because wideband analog circuits are more difficult to design and build. Low- and high-resolution graphics require monitor bandwidths in the 5- to 50- and 50- to 200-MHz ranges, respectively (see Table 2 for a listing of screen and bandwidth requirements).

Integrated Wideband Analog Circuits

Until recently, the video amplifiers in high-resolution color monitors have been built with discretes. (The 1-volt signals from the video DAC must be boosted to 60 volts for the CRT.) Today, companies such as National Semiconductor and TRW/Motorola have introduced monolithic and hybrid amplifier circuits designed specifically for use in these monitors.

A major benefit of this integration is a 50 percent reduction in the number of adjustments needed to align the RGB channels in the monitor. Another benefit is the need for fewer parts, which also reduces assembly time and cost.

DATAQUEST CONCLUSIONS

There is still room for further innovations in color monitors. For example, the monitor channels

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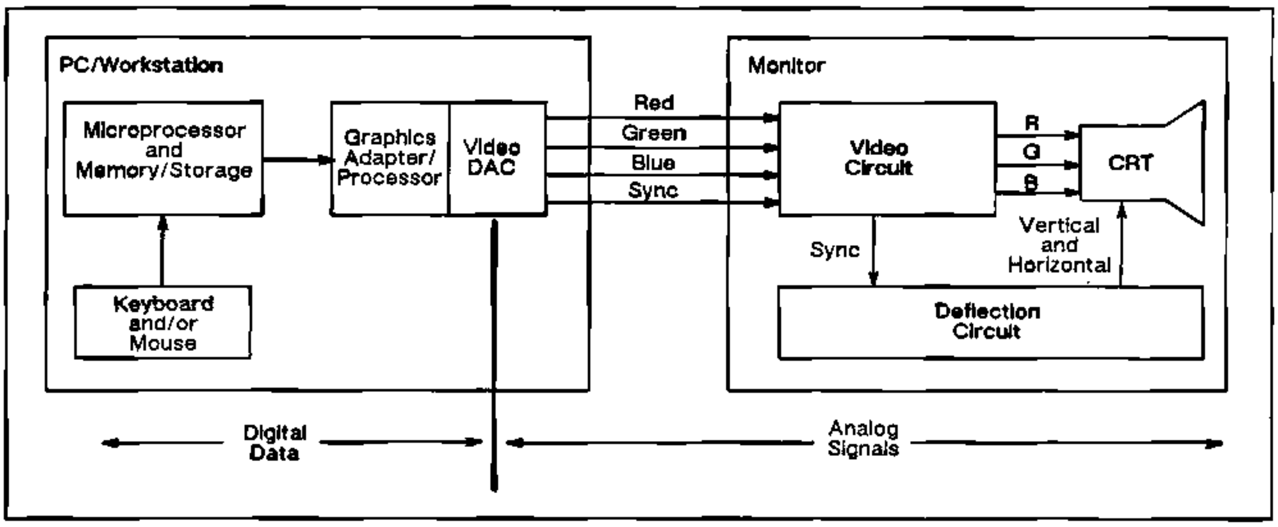
FIGURE 1
Block Diagram of a Color Display System



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Source: Dataquest
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TABLE 2
Graphics Display Requirements for Color Monitors

Segment	Standard	Screen	Bandwidth (MHz)
Low-Resolution Graphics	CGA	640 x 200	10
	EGA	640 x 350	20
	VGA	640 x 480	25
	VESA	800 x 600	35
High-Resolution Graphics	8514/A, TIGA	1,024 x 768	60
	Workstation	1,152 x 900	80
	Workstation	1,280 x 1,024	100
	Workstation	1,664 x 1,248	160

Source: Dataquest
September 1989

still must be aligned so that the correct colors will appear on the screen. These adjustments now are done manually and take approximately five minutes to complete.

This adjustment time could be reduced to less than five seconds using electronic methods. Digitally controlled monitor circuits, for example, could be aligned initially at the factory. The settings might then be updated regularly by a microcontroller in the monitor to compensate for the wear that causes the display to look fuzzy (e.g., CRT aging).

The result would be a high-resolution display that always looks sharp. Dataquest believes that these "smart monitors" are being developed now for market introduction by 1991.

Dataquest realizes that only a few semiconductor companies will have the high-frequency transistor and hybrid component capabilities needed to develop integrated monitor circuits. We featured color monitors in this issue of *OEM Monthly* to illustrate how entrepreneurial thinking can lead to the discovery of hidden needs and create proprietary solutions.

Gary Grandbois
Roger Steciak

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Research Bulletin

THE TOP 30 ANALOG IC SUPPLIERS 1988: THE WORLD MARKET SYNOPSIS

SUMMARY

The top 30 analog IC suppliers account for 86.5 percent of the total worldwide analog IC market and also comprise the majority of Dataquest's product categories. Within the ranks of the top 30, we see the supplier stars in our product categories of amplifiers, regulators, data converters, interface ICs, other analog ICs, telecom ICs, consumer ICs, and hybrids. This bulletin highlights the characteristics of some of these analog stars and their positioning in the various markets.

OVERVIEW

National Semiconductor plays a dominant role in the world supply of analog products. Although it is not the largest supplier of analog products (including hybrids), it is the largest supplier of monolithic analog circuits and a leader in five out of eight product segments identified in Table 1. Texas Instruments and Motorola also are very strong U.S. suppliers that hold leadership positions in various product segments (see Table 1).

TABLE 1
Top 5 Worldwide Suppliers by Select Analog Product Category

Rank	Amplifiers	Regulators	Interface	Data Converters
1	National	National	TI	Analog Devices
2	NEC	Motorola	National	Burr-Brown
3	TI	Matsushita	Motorola	Siliconix
4	Mitsubishi	SGS-Thomson	SGS-Thomson	Harris
5	Analog Devices	TI	Matsushita	Inmos

Rank	Other Analog	Telecom	Consumer	Hybrids
1	Hitachi	SGS-Thomson	Toshiba	Sanken
2	Silicon Syst.	AMD	Sony	Sanyo
3	Sprague	Ericsson*	Philips	NEC
4	National	National	Sanyo	Rohm
5	TI	Motorola	Matsushita	Hitachi

*Ericsson is primarily a captive manufacturer.

Source: Dataquest
October 1989

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TABLE 2
Top 30 Worldwide Analog IC Suppliers by Revenue (Millions of Dollars)

Rank	Company	Revenue
1	Toshiba	$ 569.0
2	National	540.0
3	Sanyo	471.0
4	NEC	469.0
5	Philips	456.0
6	Motorola	425.0
7	Matsushita	423.1
8	Texas Instruments	422.0
9	Sony	420.0
10	Hitachi	415.0
11	Mitsubishi	400.0
12	SGS-Thomson	352.0
13	Analog Devices	340.0
14	Rohm	271.0
15	Fujitsu	180.0
16	Siemens	165.0
17	Sanken	157.0
18	Burr-Brown	143.8
19	Harris	137.7
20	New Japan Radio	119.0
21	GE Solid State	114.0
22	Silicon Systems	112.0
23	Sprague	111.0
24	AMD	107.0
25	Ericsson	100.0
26	Sharp	95.2
27	PMI	86.2
28	Telefunken Electronic	82.0
29	Linear Technology	66.5
30	Siliconix	63.0
	Total Top 30	$7,812.5
	Percentage of Total	86.5%
	Total Analog Market	$9,034.0

Source: Dataquest
October 1989

Among the Japanese companies, prominent analog positions are held by Hitachi, Matsushita, NEC, and Toshiba. Although Japanese companies normally are associated with consumer ICs, they also compete effectively in the product areas of amplifiers, regulators, and interface. European companies are well represented by SGS-Thomson—a leader in telecom, regulators, and interface—and Philips—a strong contender in the consumer IC market.

The data converter, other analog IC, telecom, and consumer product segments show a very different mix of suppliers from those that are active in supplying building block parts. Specialization has occurred in these product areas. And, interestingly, these product areas are mostly dominated by one particular regional market. For instance, data converters and other analog ICs are dominated by U.S. suppliers, telecom ICs are dominated by U.S. and European suppliers (see Table 1), and consumer ICs are dominated by Japanese suppliers.

Table 2 lists the top 30 suppliers across all analog product categories, arranged in rank order by cumulative analog revenue.

Barbara Van

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Research *Newsletter*

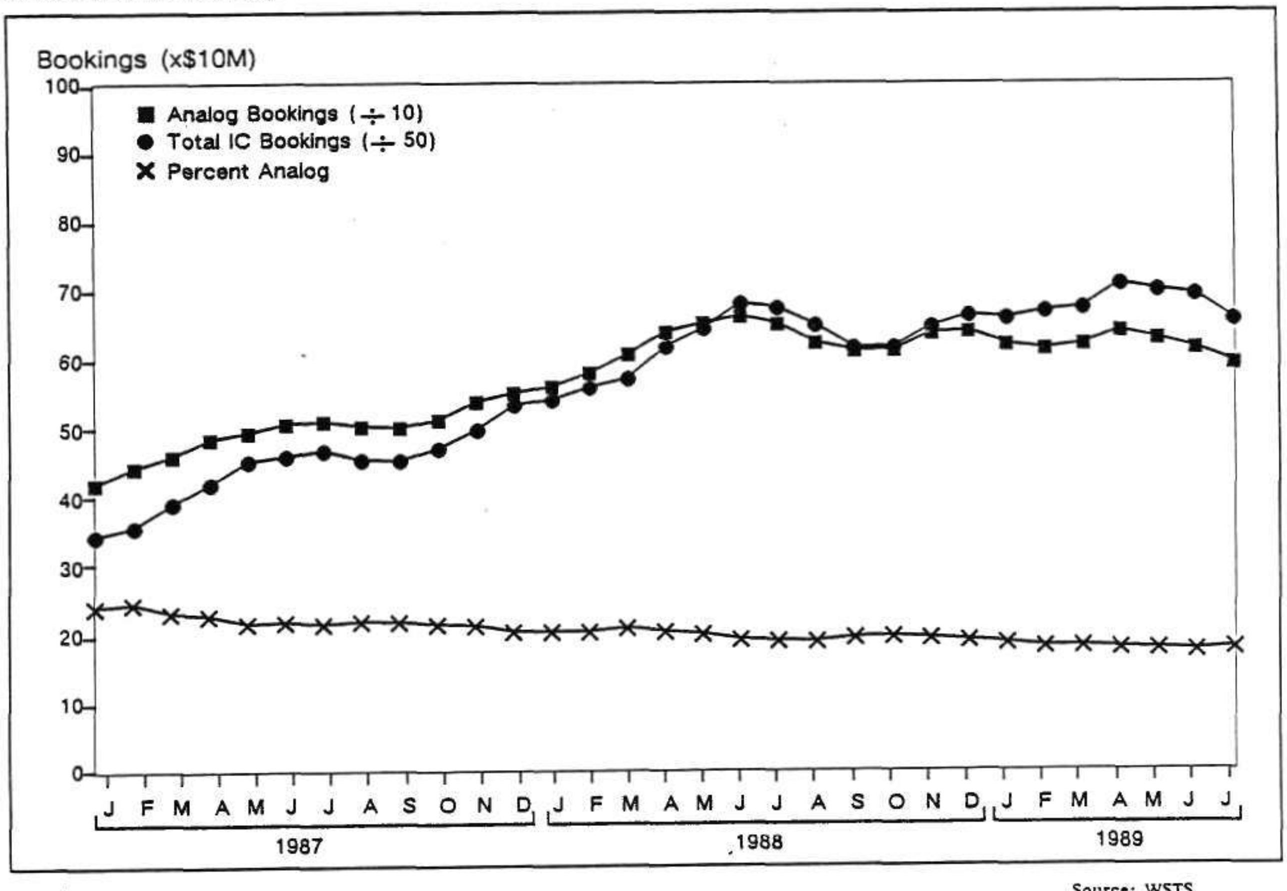
ANALOG ICS: DECLINING ASPs LEAD "SLOWDOWN"

SUMMARY

The summer of 1988 marked the start of a no-growth period for the analog IC market that has persisted during the past year. Although unit shipments stalled in late 1988, they returned to a growth mode during the first half of 1989, while average selling prices (ASPs) eroded rapidly in most analog IC categories, especially in the traditional or "commodity" linear ICs.

Figure 1 shows the three-month rolling average for bookings during the past two and a half

FIGURE 1
Analog and Total Bookings 1987-1989
(Three-Month Average)



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Source: WSTS
Dataquest
October 1989

SIS Newsletters 1989 Analog

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years. This figure shows the analog IC and total bookings divided by 10 and 50, respectively, to place them in close conjunction on the graph. Note that by mid-1988, analog IC bookings were flattening out; they then remained essentially flat during the past year. This contrasts somewhat with total IC bookings, which showed some growth during this same period.

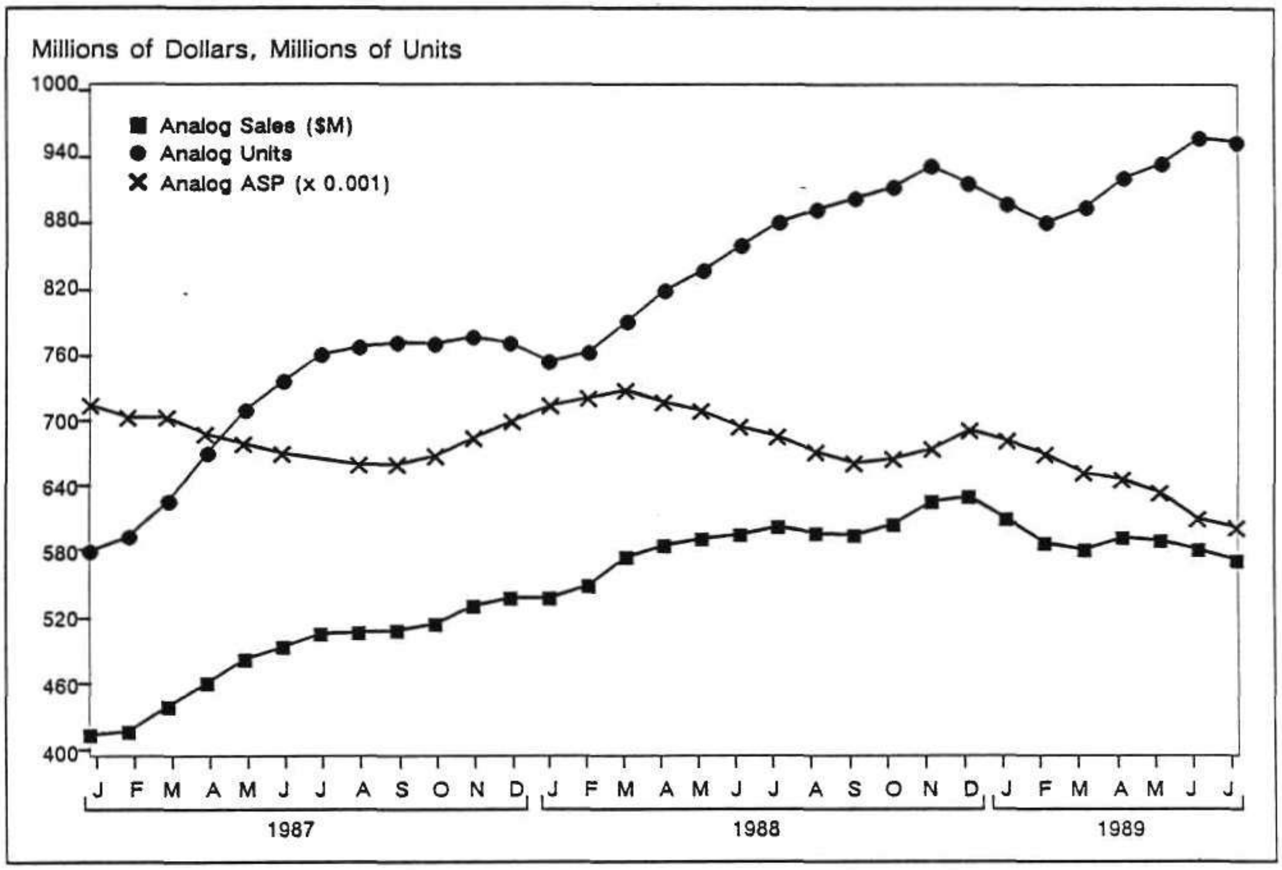
LEADING INDICATOR

In previous newsletters, Dataquest showed that analog IC sales stayed consistently in the 20 percent range of total IC sales during the past 18 years. There is nothing magic about 20 percent. It is merely an arbitrary number that is close to the mean of the analog percentage variations over time. Because of this fact, the crossing of the 20 percent boundary generally has indicated that a change in market conditions, usually a growth or slowdown period, is occurring. The year 1988 was no exception to this observation. Note in Figure 1 that analog IC bookings went flat, coinciding with the crossing of the 20 percent boundary.

AVERAGE SELLING PRICES (ASPs)

In terms of units, analog IC shipments are continuing at a strong rate after some weakness in late 1988. Figure 2 shows the three-month rolling averages for units, revenue, and ASPs during a two-and-a-half-year period that started in 1987. Although the recent slowdown in revenue originated in a downturn in unit shipments, it continued into 1989 as a rapid decline in ASPs. Unit growth in voltage regulators has remained particularly strong, while their ASPs have dropped 20 percent during the past year to maintain a flat revenue

FIGURE 2
Analog IC Unit, Revenue, and ASP History



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Source: WSTS
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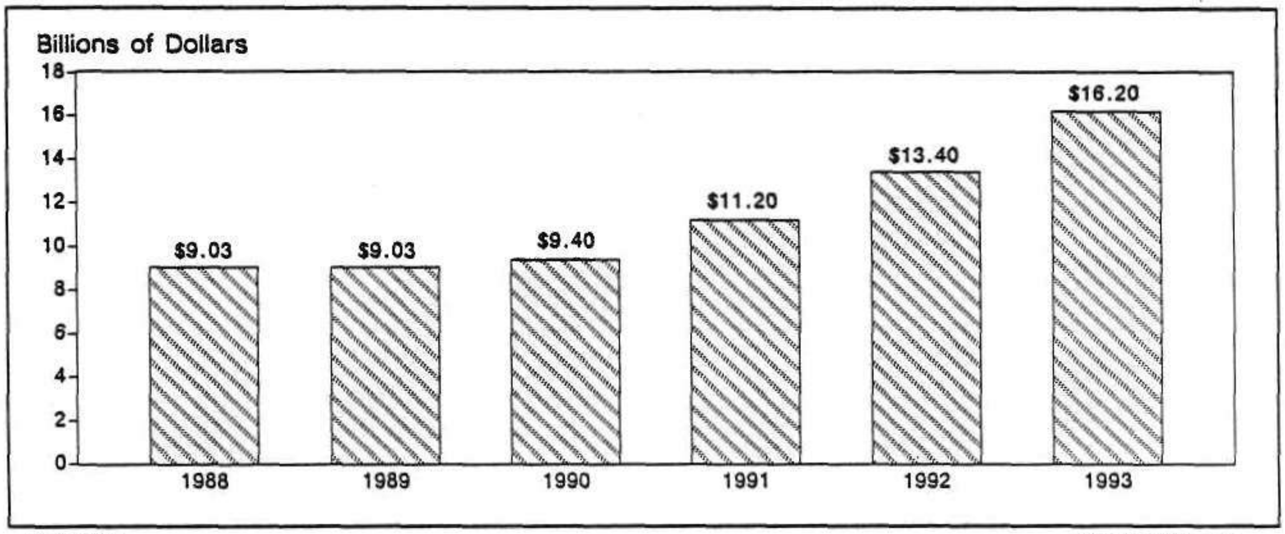
October 1989

FIGURE 3
Analog IC Forecast
1989-1993



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Source: Dataquest
October 1989

profile. During the first half of 1989, data converter ASPs rose but unit shipments were weak. The net effect is that analog revenue essentially has been flat since the summer of 1988.

The present no-growth trend is expected to continue until September 1990. The result is that 1989 will have no analog IC growth over 1988 and that 1990 will have only 4 percent growth over 1989. Analog IC growth will exceed 17 percent annual growth in the 1991 through 1993 period. The forecast is presented graphically in Figure 3. The impact of the two very flat years is a low compound annual growth rate (CAGR) of 12.4 percent from 1988 to 1993.

CONCLUSIONS

The slowdown occurred faster than anticipated for analog ICs. The good news is that unit demand continues, albeit at a slower pace; the bad news is that ASPs are eroding, especially on commodity linears. Nonetheless, price erosion on analog ICs during the past year can hardly compare with the memory chip erosion that Dataquest expects to occur in the coming year. For most analog IC suppliers, we predict that this period will continue to be a slowdown rather than a recession.

Gary Grandbois

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Research Newsletter

ANALOG IC FORECAST: THE IMPACT OF THE MARKET SLOWDOWN

SUMMARY

The semiconductor market slowed considerably during the past year, and this change is affecting the market for analog ICs. First quarter 1989 signaled the start of a shaky year that will apparently continue into 1990. This newsletter examines some of the history and expectations with respect to analog worldwide, regional, and product markets.

OVERVIEW

The strongest change to date in worldwide quarterly analog trends was the surprising negative 8.0 percent growth registered in first quarter 1989. Quarterly shipments weakened in all regions and are expected to remain relatively flat to slightly up during the next four quarters. Figure 1 looks at the immediate worldwide analog IC past and forecasts the future in quarterly growth rates.

REGIONAL TRENDS

All regional markets are slowing down, but North America and Japan, in particular, are weak. At year-end 1989, Dataquest expects North America and Japan to register the weakest performance at negative 3.4 percent and negative 2.5 percent, respectively. In the long term, we anticipate that Asia/ROW will become a much larger consumer of analog circuits, as illustrated by Figure 2. We expect other regions to decline slightly in their overall percentage consumption of analog circuits.

Issues influencing Dataquest's regional forecast include GNP expectations for the various regions and the shifts in regional manufacturing/consumption. These factors are identified in the following subsections.

Regional GNP

Highlights of regional GNP expectations include the following:

- In the U.S. market, GNP is expected to drop from 4.4 percent in 1988 to 2.6 percent in 1989 and 1990. Although this decline may create a general slowdown, it is not expected to trigger a recession.
- GNP levels in the major European markets are expected to be on a par with or slightly above U.S. levels in 1989 and 1990.
- Forecast GNP for Japan is expected to be 4.0 percent and 3.0 percent in 1989 and 1990, respectively. These figures are slightly above both the United States and European countries, but significantly below the newly industrialized economies (NIEs) of Asia (i.e., South Korea, Taiwan, and Hong Kong).
- GNP growth for NIE countries in Asia is expected to range between 6.2 percent and 9.7 percent in 1989 and 1990.

Manufacturing/Consumption Shifts

Some highlights of manufacturing and consumption pattern changes are described below.

- The 1992 phenomenon, which will open European trade barriers and offer advantage to goods manufactured in Europe, is drawing plants to Europe. As a result, European semiconductor consumption should rise in the near future.
- Japanese companies are moving much of their electronic equipment manufacturing to the United States and Europe to take advantage of the strong consumer markets.

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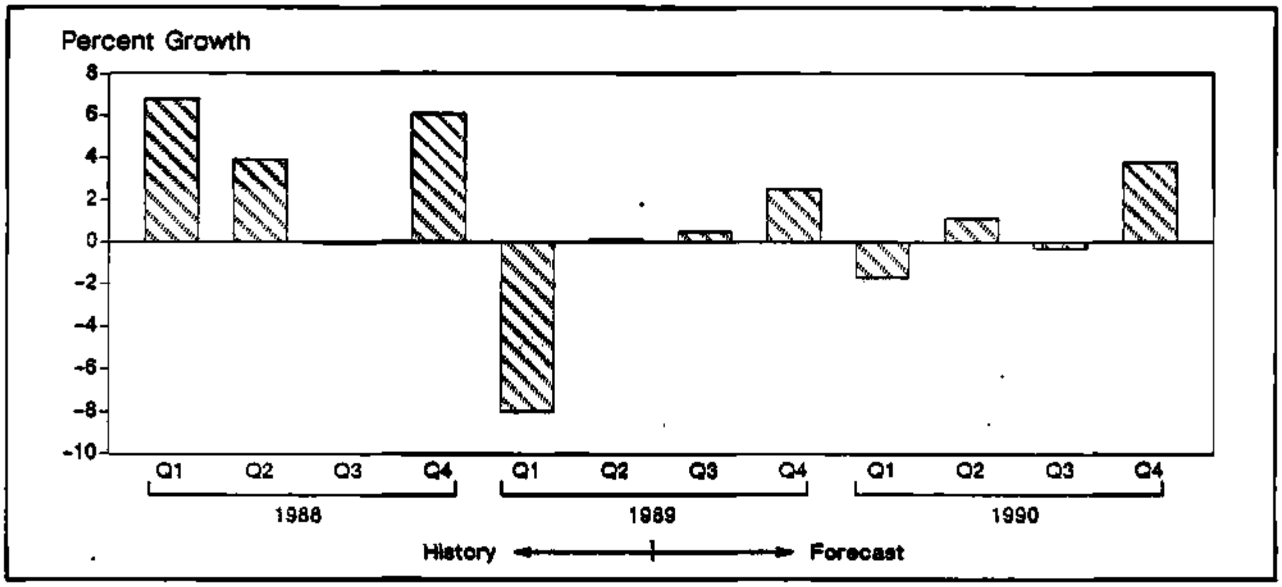
FIGURE 1
Quarterly Worldwide Analog IC Growth—History and Forecast
(In Percent)



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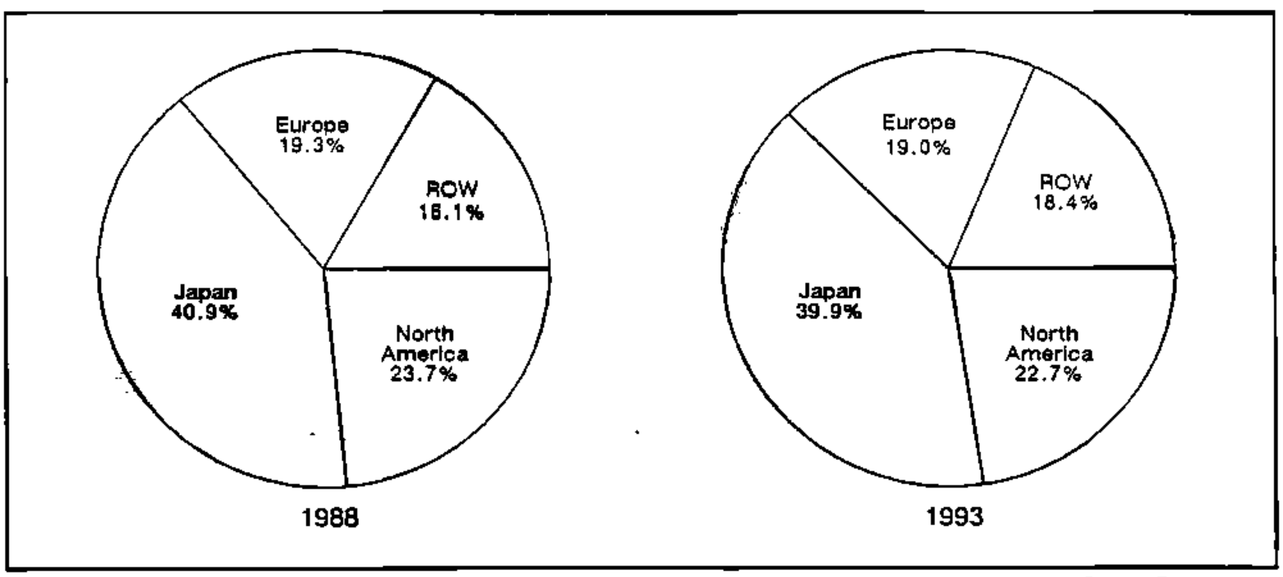
Source: WSTS
Dataquest
October 1989

FIGURE 2
Worldwide Regional Markets—1988 and 1993
(In Percent)



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Source: Dataquest
October 1989

TABLE 1
Analog IC Forecast by Product Segment, 1989-1993 (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	CAGR 1988-1993
Amplifiers	$ 935	$ 935	$ 945	$ 1,080	$ 1,240	$ 1,440	9.0%
Regulators	552	530	577	697	827	1,000	12.6%
Interface ICs	709	690	715	830	970	1,150	10.2%
Comparators	171	170	175	200	228	255	8.3%
Data Converters	790	790	850	1,057	1,370	1,755	17.3%
Other Analog ICs	612	600	620	720	840	985	10.0%
Telecom ICs	614	634	700	840	1,040	1,300	16.2%
Consumer ICs	3,057	3,060	3,100	3,700	4,475	5,500	12.5%
Analog ASIC	235	270	335	420	510	620	21.4%
Hybrids	1,358	1,350	1,400	1,620	1,890	2,200	10.1%
Total Analog ICs	$9,033	$9,029	$9,417	$11,164	$13,390	$16,205	12.4%

Source: Dataquest
October 1989

Product Trends and Forecast

Dataquest believes that analog ASICs and telecom IC products will be the only areas that will show growth in 1989. Most of the traditional analog product areas either will be flat or negative in growth from 1988 to 1989. In the long range, (i.e., 1988 through 1993), Dataquest anticipates strong growth in the areas of analog ASICs, data converters, and telecom ICs. Traditional analog products are expected to grow at less than the total market rate of 12.4 percent.

Dataquest expects analog ASIC growth to be strong over the next five years. This growth is driven by an interest in integration and the proven benefits known to exist with digital ASICs. Although this growth is strong, it comes from a small revenue base. Telecom and graphics systems also will continue to demand higher-end chips with higher prices and increased units, leading to high growth rates for both data converters and telecom ICs. The analog IC forecast by product is shown in Table 1.

Barbara Van

 0005232

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Research Newsletter

ANALOG IC FORECAST: MAJOR MARKETS PROVIDE MAJOR OPPORTUNITIES

SUMMARY

In addition to forecasting the general business climate, the 1989 through 1993 analog IC product forecast is predicated on the following three broad product trends:

- The product growth trends based on recent sales history
- The application market changes resulting from product evolution
- The consumption growth trends tied to the growth of the end-application markets

This newsletter relates the IC sales forecast to end-market use and growth.

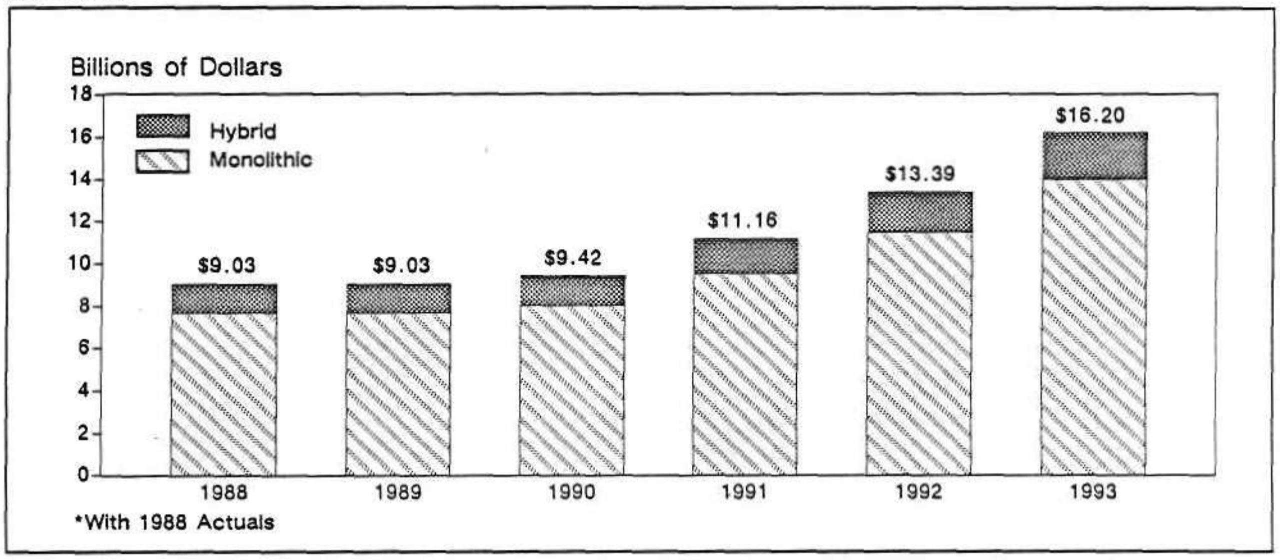
THE FORECAST

Dataquest expects analog ICs to grow by 12.4 percent from 1988 through 1993. Analog sales by year for the sum of monolithic and hybrid production by IC suppliers are shown in Figure 1.

Table 1 presents Dataquest's analog IC forecast segmented by product category.

This product forecast, based on historical trends and anticipated market needs, also takes into account the changing nature of the products themselves (e.g., linear versus mixed-signal, standard versus ASIC) as well as the changing nature of the end markets. Figure 2 shows the historical and forecast compound annual growth rates (CAGRs) by product category. Most product categories are forecast to show declines in CAGR as a result of the anticipated flat period from 1989 through 1990.

FIGURE 1
Analog IC Forecast*
1989-1993



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Source: Dataquest
October 1989

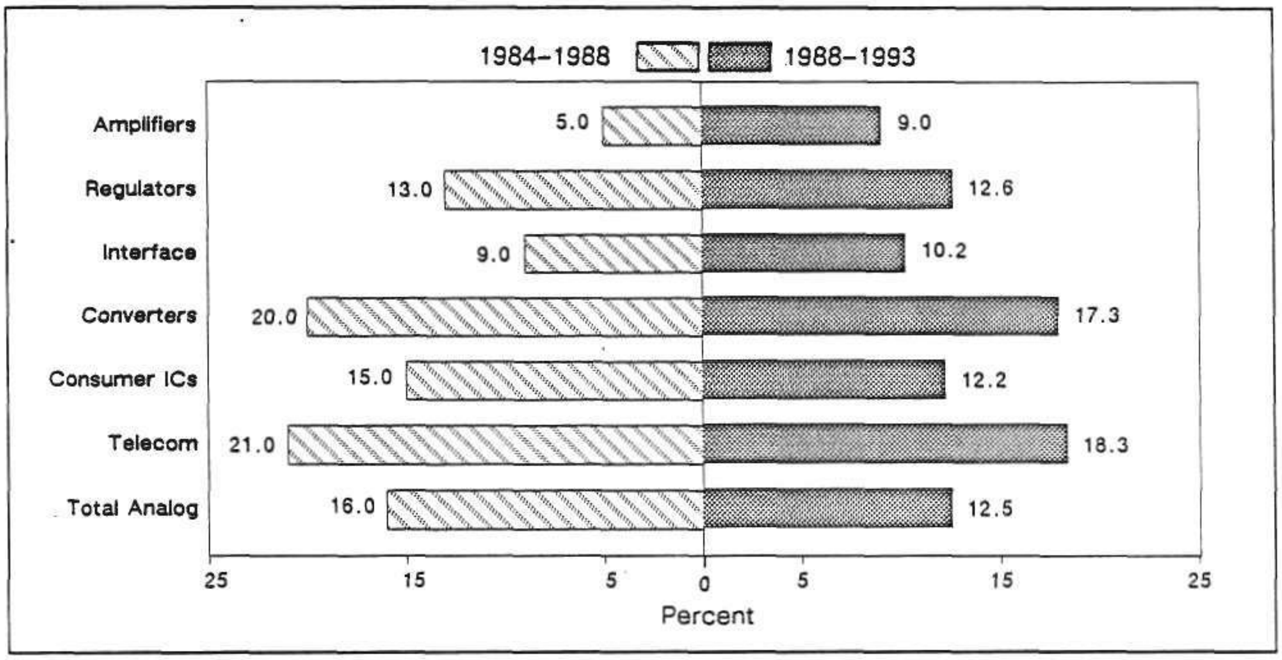
TABLE 1
Analog IC Forecast by Product Category*
1988-1993

Product	1988	1989	1990	1991	1992	1993	CAGR 1988-1993
Amplifiers	935	935	945	1,080	1,240	1,440	9.0%
Comparators	171	170	175	200	228	255	8.3%
Voltage Regulators	552	530	577	697	827	1,000	12.6%
Data Converters	790	790	850	1,057	1,370	1,755	17.3%
Interface	709	690	715	830	970	1,150	10.2%
Special Functions	612	600	620	720	840	985	10.0%
ASIC	235	270	335	420	510	620	21.4%
Telecom Specific	614	634	700	840	1,040	1,300	16.2%
Consumer Specific	3,057	3,060	3,100	3,700	4,475	5,500	12.5%
Monolithic Total	7,675	7,679	8,017	9,544	11,500	14,005	12.8%
Hybrids	1,358	1,350	1,400	1,620	1,890	2,200	10.1%
Analog Total	9,033	9,029	9,417	11,164	13,390	16,205	12.4%

*With 1988 actuals

Source: Dataquest
October 1989

FIGURE 2
Product Growth History/Forecast
(1984-1993)



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Source: Dataquest
October 1989

Market Breakdown and Review

Figure 3 shows 1988 monolithic analog IC consumption by the six major market categories, further segmented by product type. These major markets are data processing, communications, industrial, military, consumer, and transportation/automotive.

Data Processing

Although the data processing market is largely digital, it does represent a strong and growing market for analog ICs. Interface ICs find substantial use in data transmission and display as well as in power control. Power supply requirements fuel the need for regulators. Data converter consumption derives from many different conversion needs but largely from the video DACs for color graphics. Peripheral products such as printers show a strong use for all types of analog ICs.

The market for data processing products—computers and peripherals—is expected to grow at a CAGR of 11.4 percent. Although the products for this market have a high IC content, the projected analog IC growth of 15.8 percent shows that greater growth is expected for analog support components. As computers gain features to assist in human interface (such as high-resolution graphics, video frame grabbers, speech-to-text, and sensors) and data transmission, they necessarily will increase their analog IC content.

Communications

This market is a strong user of both custom and application-specific standard ICs. A moderate 8.8 percent CAGR is forecast for end-market growth in communications. We anticipate analog IC growth in this market to continue strongly through the 1990s with a 13.6 percent CAGR.

Industrial

The industrial market uses a wide range of product types. Analog technology is well entrenched because of the need for signal acquisition, processing, and control interface. Instruments use analog ICs in substantial quantities. Sensor and motor controller products represent some portion of the "special function" category used in the industrial market.

The industrial sector is not growing greatly (6.8 percent CAGR), nor is the analog IC market penetration anticipated to increase significantly. Dataquest forecasts a 7.8 percent analog IC growth rate through 1993.

Military

A broad-spectrum user of analog ICs, the military market represents the slowest growth area for these devices. Declining military programs in the United States will be instrumental in slowing growth in this market sector to approximately 3.7 percent compounded.

Consumer

Like the communications market, this market is a substantial user of custom and application-specific standard ICs. Analog ICs dominate in consumer electronics, especially in entertainment products. We anticipate that analog IC revenue will grow even faster than the consumer market (12.6 percent versus 5.3 percent, respectively) as more feature-laden products are introduced. Digital audio and video enhancements to entertainment products as well as "smart" appliances will lead this growth.

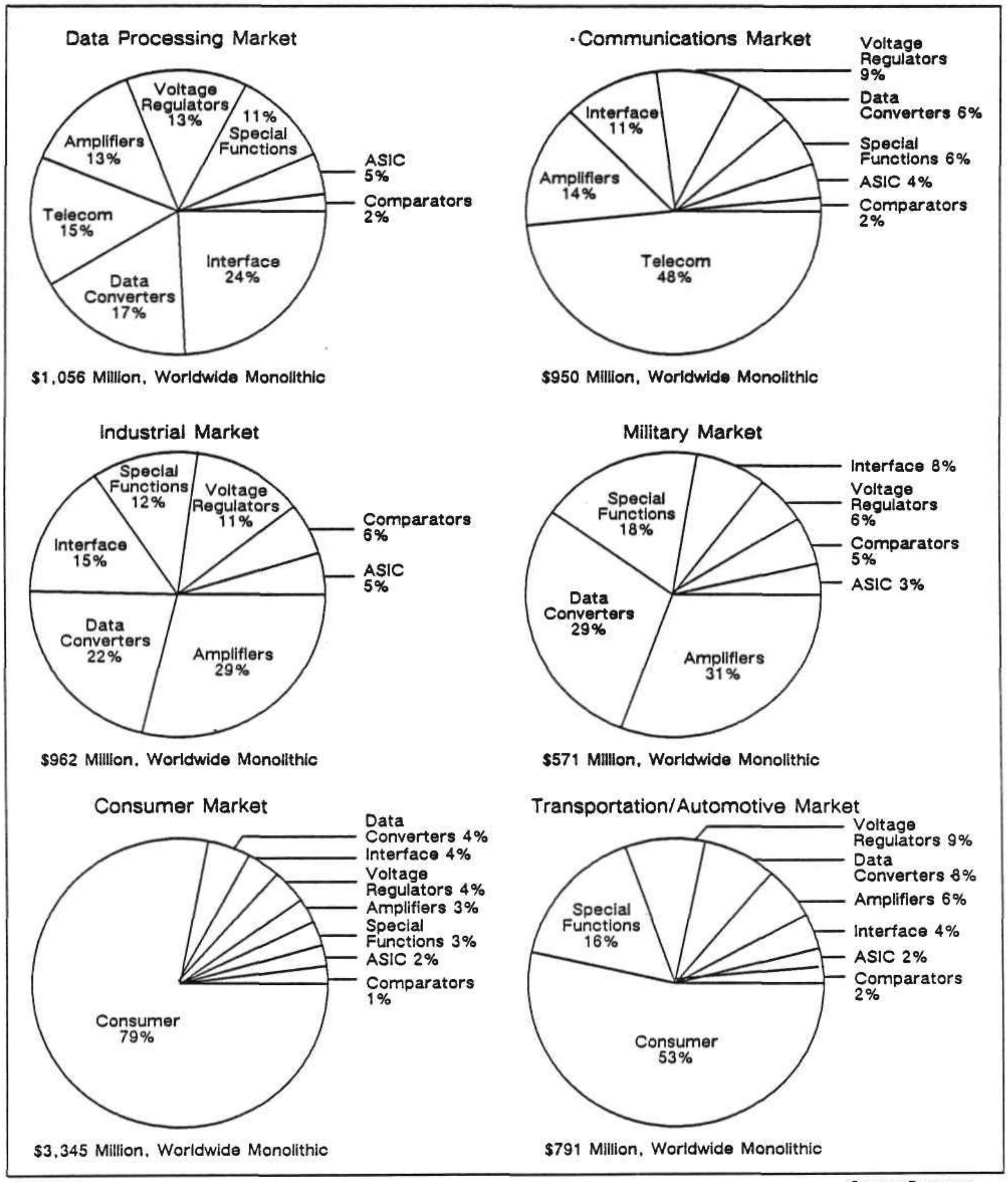
Transportation/Automotive

Essentially a consumer market, the automotive portion of the transportation market also uses custom and application-specific ICs. Dataquest expects all analog IC segments to experience rapidly increasing revenue in this market. Analog ICs are crucial to the sensing, conversion, interface, and power control functions so prevalent in automotive electronics. We expect strong CAGR of 18.8 percent, despite a setback in auto sales in the coming few years and the lower 8.0 percent CAGR anticipated for the automotive electronics market.

Forecast Growth by Market

Table 2 summarizes the forecast growth for analog ICs in the six major markets, listed in order of forecast growth rate.

FIGURE 3
Analog IC Consumption by Market and Product



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Source: Dataquest
October 1989

Total Monolithic Analog IC Market

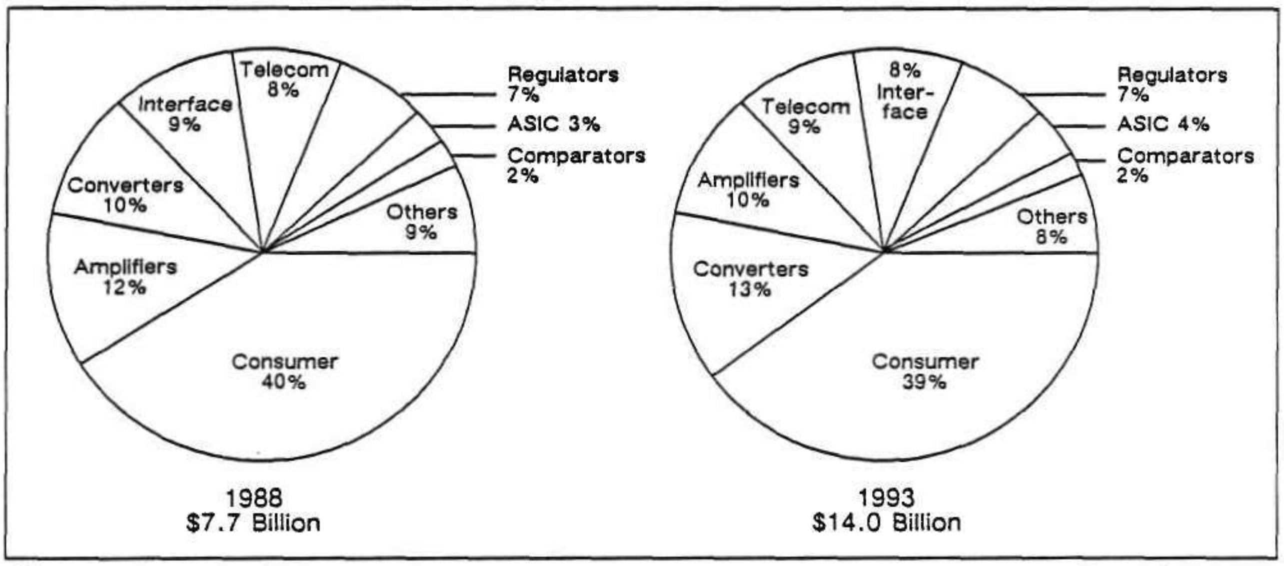
The summation of these markets gives a 12.8 percent compound growth rate for monolithic analog ICs. A somewhat slower growth for hybrid ICs reduces the total analog IC growth to 12.4 percent. Figure 4 shows the monolithic revenue for 1988 by product categories, as well as the 1993 forecast. Changes are most notable in the converter, amplifier, and ASIC products. Figure 5 shows the present and forecast market segmentation for monolithic analog ICs.

TABLE 2
Analog IC Growth Forecast by Market

Market	1988	1989	1990	1991	1992	1993	Analog IC CAGR 1988-1993	Market CAGR 1988-1993
Transportation	791	810	900	1,134	1,450	1,870	18.8%	8.0%
Data Processing	1,056	1,056	1,100	1,370	1,710	2,200	15.8%	11.4%
Communications	950	950	990	1,190	1,465	1,800	13.6%	8.8%
Consumer	3,345	3,330	3,452	4,125	5,000	6,050	12.6%	5.3%
Industrial	962	962	990	1,115	1,235	1,400	7.8%	6.8%
Military	571	571	585	610	640	685	3.7%	3.0%
Total Analog	7,675	7,679	8,017	9,544	11,500	14,005	12.8%	

Source: Dataquest
October 1989

FIGURE 4
Analog IC Revenue by Product Category



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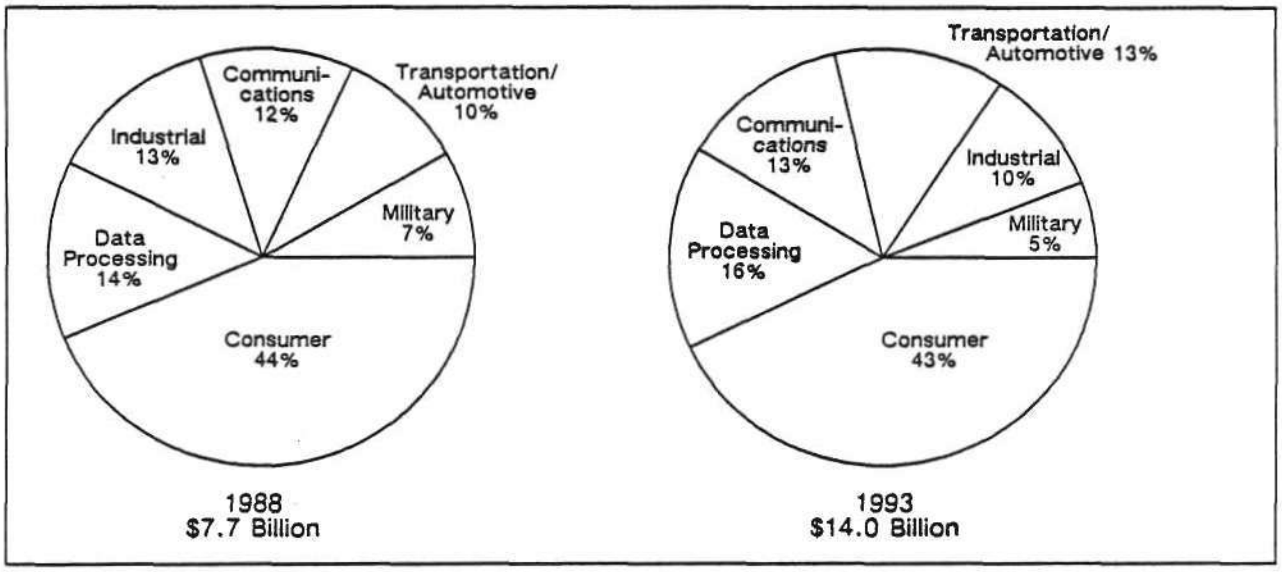
Source: Dataquest
October 1989

FIGURE 5
Analog IC Revenue by Market



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Source: Dataquest
October 1989

DATAQUEST CONCLUSIONS

It is an axiom that the maximum growth will occur with the fastest-growing products in the fastest-growing markets. Mixed-mode ICs in the Data Processing, Consumer, Transportation/ Automotive, and Communications markets represent the fast track of analog IC growth. Dataquest estimates that these markets provide growth opportunities for analog ICs that are 50 to 100 percent faster than the end-market growth itself.

Gary Grandbois

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Research Bulletin

ANALOG INTEGRATION: THE PRESSURE GROWS

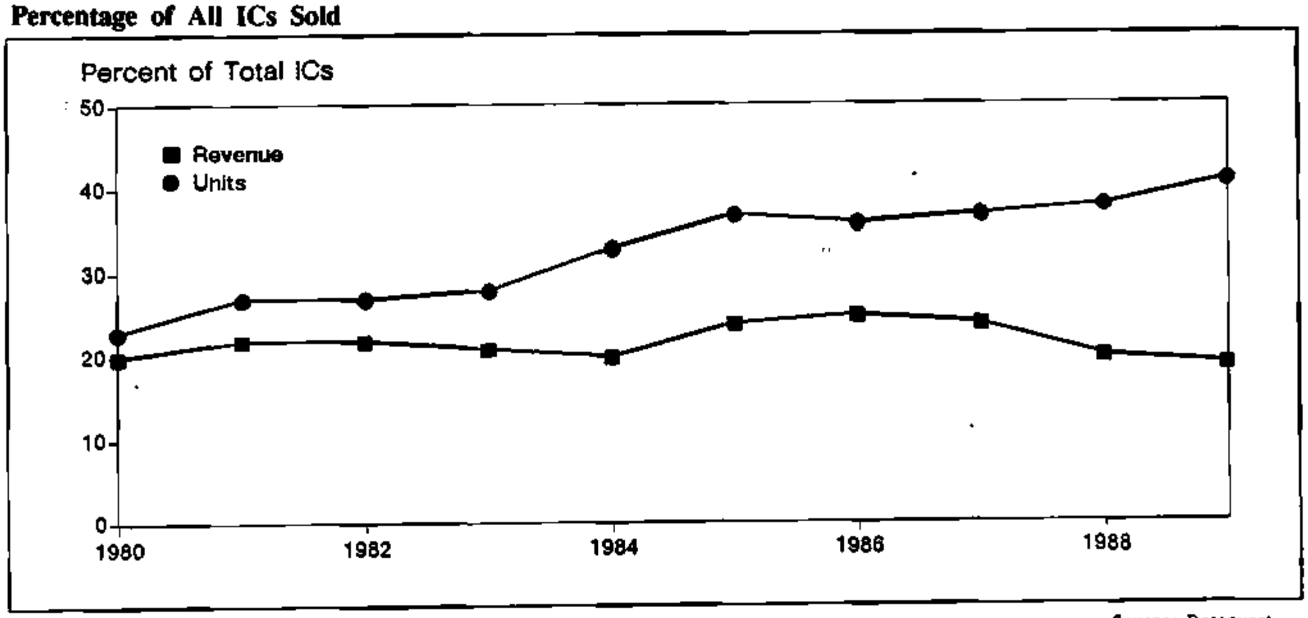
Many of the "hot" analog issues of the 1990s revolve around a single concern—meaningful integration. The lack of significant gains in the level of analog integration creates continuing erosion of selling prices and substantial pressure toward alternative solutions. Some of the solutions to the integration problem include the following:

- Mixed analog/digital ICs
- Mixed-mode ASICs
- Application-specific standard products (ASSPs)
- Digital signal processing (DSP) to minimize analog content
- BiCMOS processing technology

THE PATH OF INTEGRATION

Integration of digital functions has progressed at a furious rate during the past two decades. Advances in process technology and ASIC methodology have assisted the consolidation of complex digital functions. As Figure 1 shows, at the start of the 1980s, analog ICs composed about 20 percent of both total IC revenue and total units. For a variety of reasons, both technical and market oriented, analog ICs have not benefited from the same functional consolidation as digital ICs. The result is that monolithic analog ICs are expected to make up more than 40 percent of the total IC units shipped in 1989 but to account for the same 20 percent of the IC revenue that they have aver-

FIGURE 1
Analog ICs
Percentage of All ICs Sold



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Source: Dataquest
October 1989

Dataquest Incorporated, 1290 Ridder Park Drive, San Jose, CA 95131-2398 / (408) 437-8000 / Telex 171973 / Fax (408) 437-0292

aged for almost 20 years. The average PC board is now reaching the state where equivalent numbers of digital and analog ICs are used.

DATAQUEST CONCLUSIONS

Despite a lack of analog integration, the need for analog ICs continues to grow. Integration gains will be made in all analog IC types in the coming decade, but especially in the mixed-mode and ASSP areas. Computers, automobiles, and home appliances need analog ICs to interact with the physical world directly to become "smart." Analog ICs will be key to growth in high-resolution graphics and high-definition TV (HDTV) as well as expansion of DSP in both audio and video applications. A resurgence of analog techniques in neural networks and "fuzzy" logic will drive the leading edges of analog technologies and integration. Is analog dull? Not in the coming decade.

Gary Grandbois

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Research Newsletter

ANALOG HYBRID ICs: THE WHAT, WHY, WHEN, WHO, AND WHERE?

SUMMARY

Hybrid ICs often are at the forefront of performance, offering otherwise unavailable speeds and functions. Although these capabilities tend to be transferred into monolithic circuits over time, the need for high performance undoubtedly will continue to foster this high-end portion of the market. Significant in size and growth expectations, hybrid ICs are recognized to be an important dimension of the analog world.

Note that Dataquest does not track the entire hybrid IC market. With the analog segment, however, we do track hybrid ICs that are an alternative form of packaging for companies that make the analog devices used in the circuits. This newsletter looks at the market segments included within our analog database; future newsletters will examine new and demanding applications for hybrid ICs.

WHAT?—THE SIZING OF THE ANALOG HYBRID IC MARKET

Dataquest's analog hybrid IC database addresses a worldwide market of approximately $1.4 billion, which is 15 percent of our total analog database. Although this is sizable, we believe that the total hybrid IC market, which includes captive manufacturers and merchant manufacturers of various sizes, is many times larger. The total market for hybrid devices may be as much as 6 to 10 times the figure reported here.

WHY?—WHY USE HYBRID ICs OVER MONOLITHICS?

Why does a company chose a hybrid circuit design over a monolithic chip? There are numerous reasons why a hybrid IC may be a more attractive option. First, there is the issue of high-end performance. Hybrid circuits frequently are at the cutting edge of performance, offering faster speeds or unique function combinations. These combined circuit packages can be optimized in varied technologies without the performance degradation that may occur in a monolithic design or because of excessive signal path length when using multiple packages. Power dissipation problems also can be improved in a hybrid IC because of power and signal partitioning. From a cost standpoint, development costs for a hybrid IC design are considerably lower than for a monolithic design. Finally, there are many more hybrid IC suppliers from which to choose.

WHEN?—THE ANALOG HYBRID IC FORECAST

Dataquest expects the portion of the hybrid IC market that it tracks to grow at a rate of 10.1 percent annually over the next five years. Currently valued at $1.4 billion, this market is expected to reach $2.3 billion in 1993. Dataquest's hybrid IC forecast is presented in Figure 1.

WHO?—THE SUPPLIERS

Many types of hybrid IC manufacturers exist. Hybrid IC suppliers include large captive houses that manufacture solely for internal purposes, large semiconductor houses that are primarily in the monolithic circuit business, small hybrid IC houses that purchase monolithic circuits for hybrid assembly, and some foreign contractors. Although most companies that supply hybrid ICs are very small, the highest cumulative revenue is believed to come

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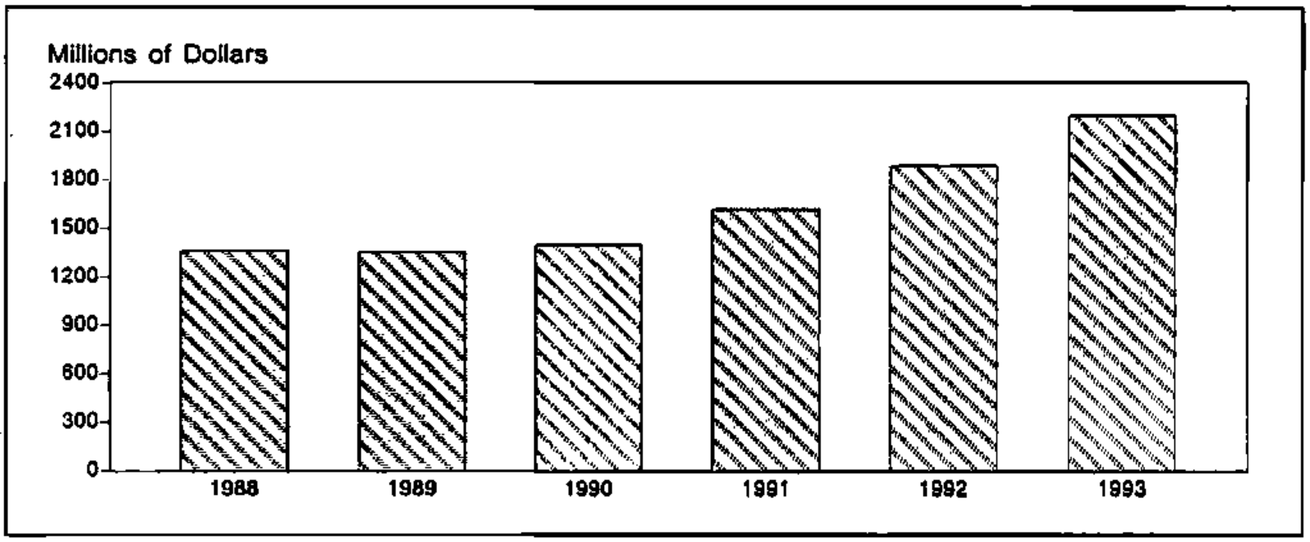
from captive manufacturers as a whole. Dataquest, however, measures only the business associated with analog circuit manufacturers that sell hybrid ICs in the merchant market. Analog hybrid IC suppliers that we track and their revenue are listed in Table 1.

Figure 1
Worldwide Analog Hybrid IC Forecast
(Millions of Dollars)



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Source: Dataquest
December 1989

Table 1
1988 Worldwide Market Share of Analog Hybrid ICs
(Millions of Dollars)

Rank	Company	Percent Share	Sales
1	Sanken	11.6%	$ 157.0
2	Sanyo	10.6	143.5
3	NEC	9.9	134.0
4	Rohm	7.8	106.0
5	Hitachi	7.4	101.0
6	Mitsubishi	6.5	88.0
7	Toshiba	6.3	85.0
8	Fujitsu	4.8	65.0
9	Analog Devices	4.6	63.2
10	Burr-Brown	4.4	59.4
11	Sony	3.7	50.0
12	Motorola	3.1	42.0
13	National Semiconductor	2.9	39.0
14	Sharp	1.9	26.0

(Continued)

TABLE 1 (Continued)
1988 Worldwide Market Share of Analog Hybrid ICs (Millions of Dollars)

Rank	Company	Percent Share	Sales
15	Unitrode	1.7	23.0
16	Goldstar	1.5	21.0
17	Ericsson	1.5	20.0
18	Sipex	1.4	19.0
19	Philips	1.3	18.0
20	Mitel	1.2	16.3
21	Elantec	0.4	4.8
22	Silicon General	0.2	3.3
23	Oki Semiconductor	0.2	3.0
24	Fuji Electric	0.2	2.9
25	Maxim	0.1	2.0
26	New Japan Radio	0.1	1.0
	Other Companies	4.7	64.6
	Total	100.0%	$1,358.0

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
December 1989

WHERE?—WHERE THE MARKETS ARE

Regionally speaking, our analog hybrid IC database identifies a much larger user market in Japan. The Japanese market consumes more than $800 million in hybrid ICs. The next largest market is North America, with analog hybrid IC consumption of slightly more than $200 million. We believe that the North American market is characterized by many small companies that purchase chips from large semiconductor manufacturers; we do not track these companies because counting them would misrepresent analog circuit sales. The Asia/Pacific region ranks third at $187 million, and Europe's market is $138 million.

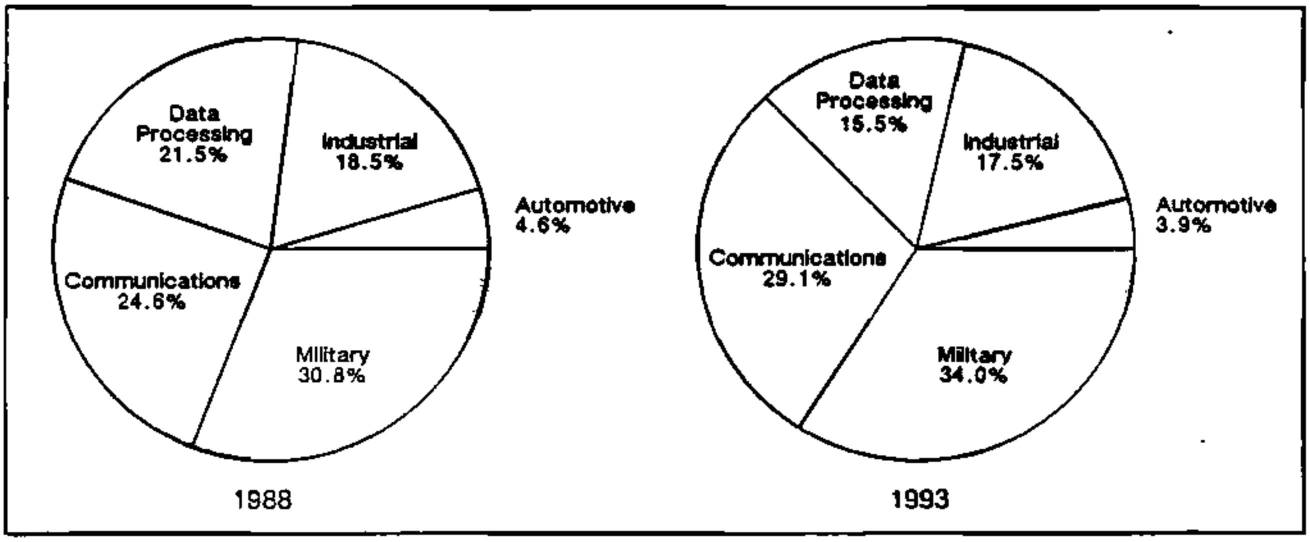
From an applications standpoint, although all markets use hybrid ICs, those that are emerging especially strong are the military and communications markets. Focusing on the U.S. market, we expect both of these application segments to grow as a percentage of the total market, which is in excess of our forecast total market value of 10.1 percent. The changing configuration of the U.S. applications market is shown in Figure 2. The military market, which was the dominant U.S. market in 1988 at 30.8 percent, is expected to grow to 34.0 percent by 1993. The communications segment of the U.S. hybrid IC market is expected to go from 24.6 percent to 29.1 percent between 1988 and 1993.

DATAQUEST CONCLUSIONS

The analog hybrid IC market continues to be strong, with heightened demand from new application markets such as power ICs and ASICs. Although the market is not expected to grow as fast as the total analog IC market even with these driving applications, it should hold its own with 10.1 percent growth forecast over the next five years. Companies that participate in the hybrid IC market and companies that push the performance limits on monolithic circuits should find that hybrid IC developments bear watching.

Barbara Van

FIGURE 2
U.S. Hybrid ICs by Application Market—1988 and 1993



0005689-2

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December 1989

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Research Newsletter

SIS Code: Newsletters 1989
ASIC/PMT
0003736

"OUR TIME, OUR CHOICE, OUR ANGUISH, OUR DECISION"

SUMMARY

When Stephen Vincent Benet wrote those words, he could have been referring to the ASIC segment of the semiconductor industry. He was writing about destiny and opportunity, and that is just what the ASIC industry will face in the 1990s. Dataquest believes that ASICs are entering a time of choice, and the entire infrastructure of the supplier base will face some tough decisions. We believe that ASICs are going to experience the following four fundamental megatrends that will alter the course of the industry:

- A growing demand for regionalism
- A slower growth rate for consumption
- An accelerating capital investment in technology
- A break in the DRAM-ASIC "food chain"

Together, these trends will test the mettle of every supplier and user; out of this shakeup will come an industry with fewer but stronger suppliers.

ASIC REGIONALISM

Dataquest believes that there is an unrelenting trend toward regionalism with ASICs just as there is with all semiconductors. Customers around the world want their ASICs locally. This growing demand is driven by many factors, all of which hinge on the desire for more local content. From Bangkok to Bruxelles, we see customers under increasing pressure to design and manufacture with ever-faster turnaround time. The end-product life cycles have become shorter and shorter, which in turn is placing demands on ASIC suppliers to compress development cycles. But it does not stop there; now ASIC users are giving preferential treatment to suppliers who manufacture locally, too. This situation is driven partially by the local content laws and partially by the nature of the products manufactured. For example, in the Pacific Rim, we see heavy concentration of consumer electronics; in Europe, we see telecom applications; and in North America, we see computers.

It is easy to personally experience this megatrend; a brief trip to a local electronics store tells it all. One can see a dazzling array of electronic gadgetry that seems to change in feature content almost monthly. What was a simple four-function calculator a few years ago is today a calculator for the accountant, or the engineer, or the financial analyst. Clock radios now come with phones, answering machines, or cassette recorders. Products have become more specialized, and the rate of change in features is increasing. This trend is not confined to just consumer electronics. We see the same pattern repeated across the telecom, computer, and industrial sectors as well.

All this suggests challenges and opportunities for the ASIC supplier of the 1990s. Serving the regional markets of the next decade means making key changes in the infrastructure of the ASIC industry. It means that the ASIC supplier must locate design and manufacturing close to the user. Historically, regional design centers have been a part of the scene for a long time; but looking to the future, that will not be enough. It means that production in each region will become a critical success factor, too. The challenge here is to build small, quick-turn factories that are tailored to the markets of the region. It is conceivable that even manufacturing processes would be tailored to suit the region. For example, in the Pacific Rim, where consumer electronics is dominant, an ASIC supplier may offer a low-voltage CMOS process, or in Europe, a double-poly process to support telecom applications.

This regionalization has some interesting implications for ASIC suppliers. First, it will severely tax the financial resources of the cadre of companies that have been marginally profitable for some time. Second, it will accelerate mergers and alliances in order to gain access to certain markets. Third, it means that suppliers not wishing to be world-class suppliers must specialize. Fourth, it could spell the departure of some of the weaker suppliers.

Regardless of which scenario occurs, the implication is quite clear. The survivors will require deep pockets and worldwide perspective or they will have to find a specialty market that is not well served and become the dominant supplier for that market.

ASIC GROWTH TAKES A PAUSE

Historically, the ASIC segment has grown for the past five years at a compound annual growth rate (CAGR) of 20 to 30 percent. However, the next five years will be different. Dataquest believes that over the next five-year horizon, ASICs will experience a CAGR of 15 percent, which is considerably slower. This slowdown can be traced to two primary forces. First, ASIC is now a major component in the total IC industry; thus, it is subject to forces that affect the entire industry. The second force is also related to ICs; namely, the entire industry is expected to experience a slowdown in the third and fourth quarters of 1989 and the first two quarters of 1990. Our current forecast shows ASIC growth for 1989 at 15.7 percent and growth for 1990 at a mere 5.6 percent. This forecast is substantially below the historical rates of the past five years, leading us to believe that suppliers will experience considerable profit pressure in an industry that is already only marginally profitable.

ASIC TECHNOLOGY AND DEEP POCKETS

Figure 1 shows the ASIC technology road map for the past six years. This figure illustrates when each new CMOS process technology was, or will be, introduced in a production environment. What is interesting to note is that for the last six years, a new process has been introduced each year, and along with each new process has come an increase in gate count. For example, with the introduction of 2-micron CMOS in 1985, we saw gate arrays in the 20K gate range for the first time. Moving forward two years to 1987, we see 100K gate arrays in a 1.25-micron technology. This process evolution largely results from scaling of successive generations of the CMOS process. Dataquest believes that this pattern will continue, but as development work moves closer to 0.5-micron technology, the cost of process development will rise substantially. It is widely believed that current stepper technology will not work at the 0.5-micron level. Furthermore, the entire CMOS process must be redesigned to achieve geometry in the 0.5-micron range. Most observers expect that major investments will be required to achieve gate counts in the 500K range, so once again, ASIC suppliers will be required to make heavy investments in order to stay competitive.

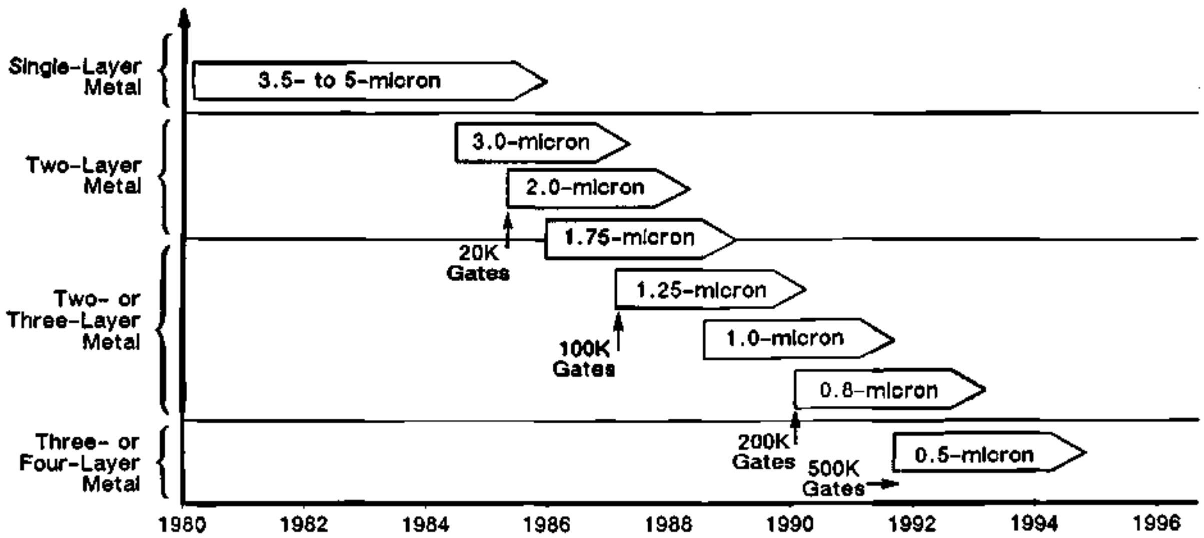
DRAM-ASIC FOOD CHAIN

Another factor spells heavy investments for ASIC suppliers; it relates to the DRAM-ASIC food chain. Historically, ASIC suppliers have followed DRAM process development. That is to say, much of the process development effort used today in ASICs is derived from work done earlier for DRAMs. Conventional thinking would suggest that this trend would continue as both industries move to 0.5-micron technology. The DRAM suppliers would first develop the basic process, and about a year later the ASIC suppliers would use the same technology to make ASICs; but a closer look shows a very different picture.

ASICs and DRAMs follow very different paths. Figure 2 shows a parting of ways. The food chain still exists, but the next phase for each product line will require separate development. This parting of ways is driven by the nature of the products themselves. ASIC suppliers are obsessed with the challenge of interconnect. They must develop ways to connect complex cells or macros, and they are preoccupied with how to connect logic blocks without sacrificing chip area. It only seems natural that ASIC companies would be interested in developing processes that make interconnect easier, or to say it another way, in making the surface of the chip planar so that more complex interconnect can be achieved. There are other factors that differentiate ASICs from DRAMs. ASIC suppliers are not interested in large production volumes. Most ASICs are sold in very low quantities when compared with DRAMS. ASIC suppliers must ship the product on very quick turnaround and must make yield improvements over limited production runs. ASIC suppliers also must pioneer investment in high lead count packaging technology.

Figure 1

Technology Road Map (CMOS and ASIC)



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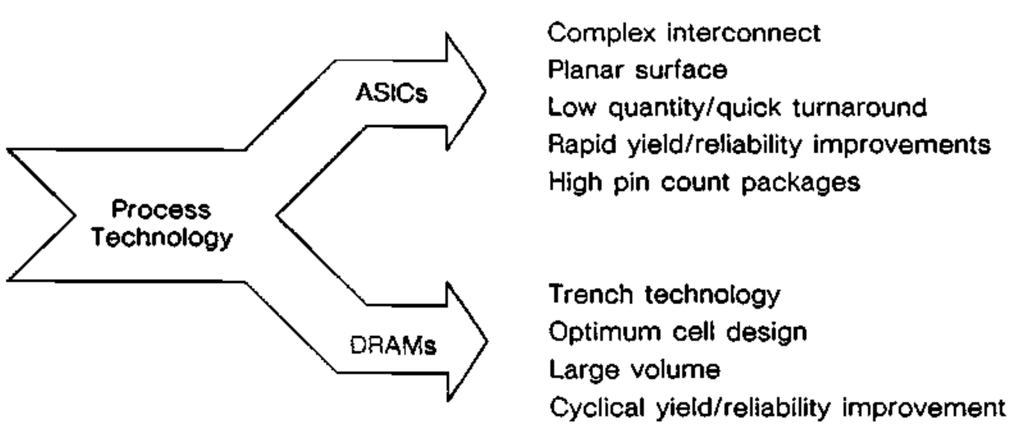
Source: Dataquest May 1989

Figure 2

ASICs and DRAMs: A Parting of the Ways!



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Source: Dataquest May 1989

DRAM suppliers have a very different agenda. The success of the next generation of DRAMs will depend on developing trench process technology, which has nothing to do with complex interconnect required in ASIC applications. DRAM developers are obsessed with RAM cells. The ultimate cost of a DRAM chip is directly related to the size of the memory cell. Therefore, it stands to reason that DRAM suppliers will devote major portions of their resources to optimizing the memory cell. DRAMs are made in very large production quantities. Yield improvements tend to be cyclical rather than one-time efforts, as with ASICs.

This leads us to believe that the ASIC and DRAM process developments are about to part ways. While much of the base technology is similar, and will continue to be so in the core process, a major portion of future development will be funded separately. For the ASIC supplier, this means that one more major expenditure must be added to the already-strained development budget. The ASIC company of the 1990s must divide the research funds three ways: CAD tools, ASIC manufacturing equipment, and now ASIC process development. Therefore, ASIC companies must have very deep pockets indeed—deeper than some can afford—leading us to conclude that it is fallout time for ASICs.

A CONVERGENCE OF FORCES

When we stand back and look at the prevailing forces expected to be at work during the next five years, we can reach only one conclusion. The ASIC industry is going to experience a pruning of suppliers. As the four factors previously outlined converge, we can expect major changes in the infrastructure. As demand grows for regional production centers, as ASIC consumption slows, as process development requires heavier investment, and as ASIC departs from the DRAM food chain, Dataquest expects a major consolidation to occur.

IMPLICATIONS

We do not expect the consolidation to fall equally across all ASIC product areas. For the swift and strong, and for certain product categories, the impact will vary, as follows:

- Gate Arrays—We see the gate-array market destined for a severe pruning of suppliers. With 57 suppliers in a very mature and very price-sensitive market, it seems inevitable that fallout will occur. Pressure to cut turnaround time, spiraling process development costs, and massive regional investment will force as many as one-third of the suppliers to exit the market.

- Cell-Based ICs (CBICs)—Dataquest believes that CBICs are less vulnerable for several reasons that are unique to this segment. First, the regional markets are less mature. From a regional point of view, CBIC is largely a North American and European market, and less developed in Japan and the Pacific Rim. Second, users appear to be willing to tolerate longer turnaround times, largely because of the extra time required in manufacturing. A third reason is that the cell libraries are so diverse and often proprietary, direct competition is less prevalent. Once users become familiar with certain suppliers' libraries and how to apply them to their needs, there is a strong reluctance to switch. Last, production volumes tend to be much higher with CBICs than with gate arrays, which in turn means that the customer must invest a larger NRE during the design phase; thus, the user is less willing to abandon a project once the funds are committed.

- Programmable Logic Devices (PLDs)—We see this segment as the least vulnerable segment, and this is especially true for the CMOS segment. Regional presence is easier to achieve, because distribution of this product is similar to a standard product. In a PLD, the customization occurs at the user's site. From the user's perspective, PLDs offer the quickest turnaround time of any ASIC product. One should also remember that of all the ASIC markets, the CMOS PLD market is the least mature. It is about one-seventh the size of the gate array market and about one-fourth the size of the CBIC market. The food chain also is different. PLDs are by-products of EPROM, EEPROM, or SRAM technology, and the technology gap is expected to narrow over the next few years. Finally, this segment is largely populated by small companies with very innovative products; thus, direct competition on a product basis is limited.

DATAQUEST CONCLUSIONS AND RECOMMENDATIONS

We believe that our clients should look at the following ASIC megatrends from two perspectives—as both suppliers and as users of ASICs:

- Suppliers—Dataquest believes that any supplier who plans to be a world-class ASIC company must establish regional design and production centers <u>now</u>. ASIC process development is going its own way, and to be competitive in the 1990s will mean funding process development aimed specifically at ASIC applications. We recommend that our clients seek out another company to share process development for the suppliers who do not wish to go it alone.

  - We strongly urge the smaller suppliers to reexamine their product lines to ensure that they are really protected from mainstream competition and to seek out those niches that make them the dominant supplier.

- Users—Dataquest recommends that its clients pick a gate array supplier with great care.

  - Choose a CBIC supplier on functional performance. If the supplier has cells that suit your applications, then continue to foster the relationship.

  - With respect to PLD suppliers, we recommend a higher level of risk. The current products emerging from these companies are quite innovative and may give a competitive edge.

Andy Prophet

Dataquest

Conference Schedule

1989

Semiconductor User/ Semiconductor Application Markets	February 27-28	Le Meridien Hotel San Francisco, California
Japanese Components	April 20-21	Tokyo Bay Hilton International Tokyo, Japan
Computer Storage	April 26-28	The Doubletree Hotel Santa Clara, California
Document Processing	May 16-18	Monterey Sheraton Hotel Monterey, California
Copiers	May 16-17	
Printers	May 16-17	
Electronic Publishing	May 18	
Imaging Supplies	May 18	
Color	May 18	
SEMICON/West Seminar	May 24	The Dunfey Hotel San Mateo, California
Telecommunications	June 5-7	Silverado Country Club Napa, California
European Components	June 7-9	Park Hilton Munich, West Germany
Asian Semiconductor and Electronics Technology Seminar	June 28	Radisson Hotel San Jose, California
Financial Services	August 22-23	The Doubletree Hotel Santa Clara, California
Technical Computing and Applications	September 11-13	The Doubletree Hotel Santa Clara, California
European Copying and Duplicating	September 18-19	Majestic Hotel Cannes, France
Western European Printer	September 20-22	Majestic Hotel Cannes, France
Taiwan Conference	September 25-26	Grand Hotel Taipei, Taiwan
Distributed Processing	September 26-28	The Doubletree Hotel Santa Clara, California
SIA/Dataquest Joint Conference	September 27	Santa Clara Marriott Santa Clara, California
Information Systems	October 2-6	Tokyo American Club Tokyo, Japan
Semiconductor	October 16-18	Monterey Sheraton Hotel Monterey, California
Asian Semiconductor and Electronics Technology	November 2-3	Kunlun Hotel Beijing, China
European Telecommunications	November 8-10	Grand Hotel Paris, France
European Personal Computer	December 6-8	Athens, Greece

Dataquest

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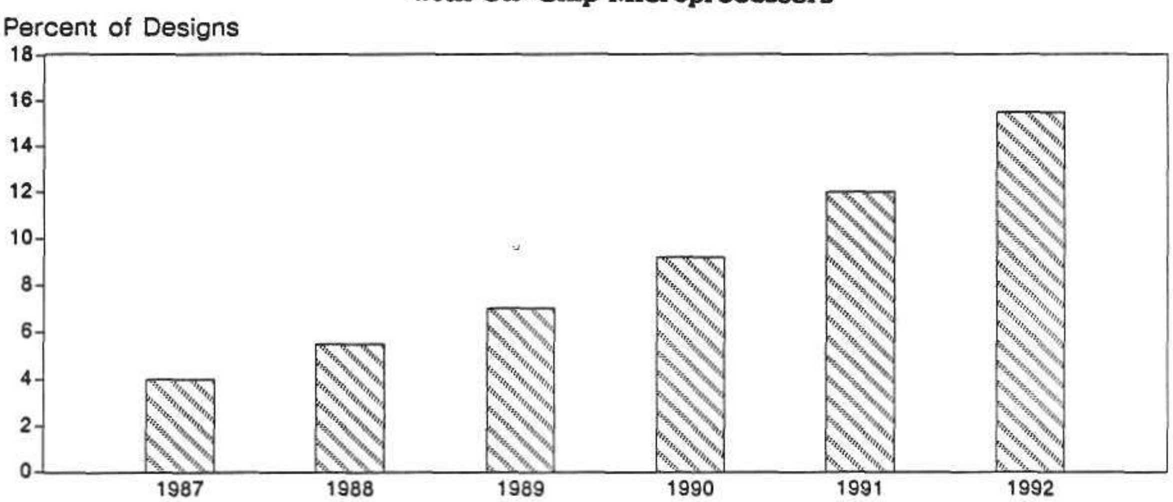
CELL-BASED ICs—THE BRIDGE TO SINGLE-CHIP SYSTEMS

Integrated circuits (ICs) have evolved from simple gates and flip-flops containing less than 10 transistors to chips containing more than 1 million transistors. Consider this: Technology now enables an entire computer system to be placed on a single chip. With this capability, application-specific integrated circuits (ASICs), specifically cell-based ICs (CBICs) and gate arrays, become the bridge to single-chip systems. With ASICs, the microprocessor, memory, and logic can be incorporated on a single chip, thus reducing the size and cost of a system while improving the performance and reliability. In 25 years, IC technology has gone from conception to a reality that far exceeds the wildest dreams of the inventors.

Microprocessor core cells are critical to single-chip systems. As Figure 1 shows, only 83 designs (4 percent of 1987 North American CBIC designs) used microprocessor core cells. However, Dataquest believes that by 1992 this percentage will exceed 15 percent, primarily as a result of submicron CMOS technologies, increases in CAD efficiency, and high demand for alterable RISC microprocessors.

Figure 1

Estimated North American CBIC Design Starts with On-Chip Microprocessors



0003759-1

Source: Dataquest May 1989

Dataquest Incorporated, 1290 Ridder Park Drive, San Jose, CA 95131-2398 / (408) 437-8000 / Telex 171973 / Fax (408) 437-0292

As suppliers strive to offer single-chip system solutions, large megacells and compilable cells rise in importance. Ultimately, the end users will determine the functions required for cell libraries. Most CBIC suppliers are analyzing the needs of each application market and have found that microprocessor, memory, and analog cells are in high demand.

While single-chip CBIC systems are just starting to emerge, the CBIC market has already become quite large. During 1988, Dataquest estimated worldwide CBIC consumption to be $1.3 billion, up 33.4 percent over 1987. AT&T Technologies was the top 1988 CBIC supplier, followed by two very aggressive suppliers, Texas Instruments (TI) and Toshiba.

Key areas addressed in this newsletter include the following:

- 1988 supplier market share
- Design starts
- Cell library trends
- 1989 and beyond

1988 SUPPLIER MARKET SHARE

As shown in Figure 2, AT&T Technologies had a significant lead over its competitors in 1988; however, AT&T received a large portion of its revenue from sales to internal divisions (intracompany revenue). Texas Instruments and Toshiba both had great years with growth in excess of 60 percent, which gave them the momentum to surpass both NCR and VLSI Technology.

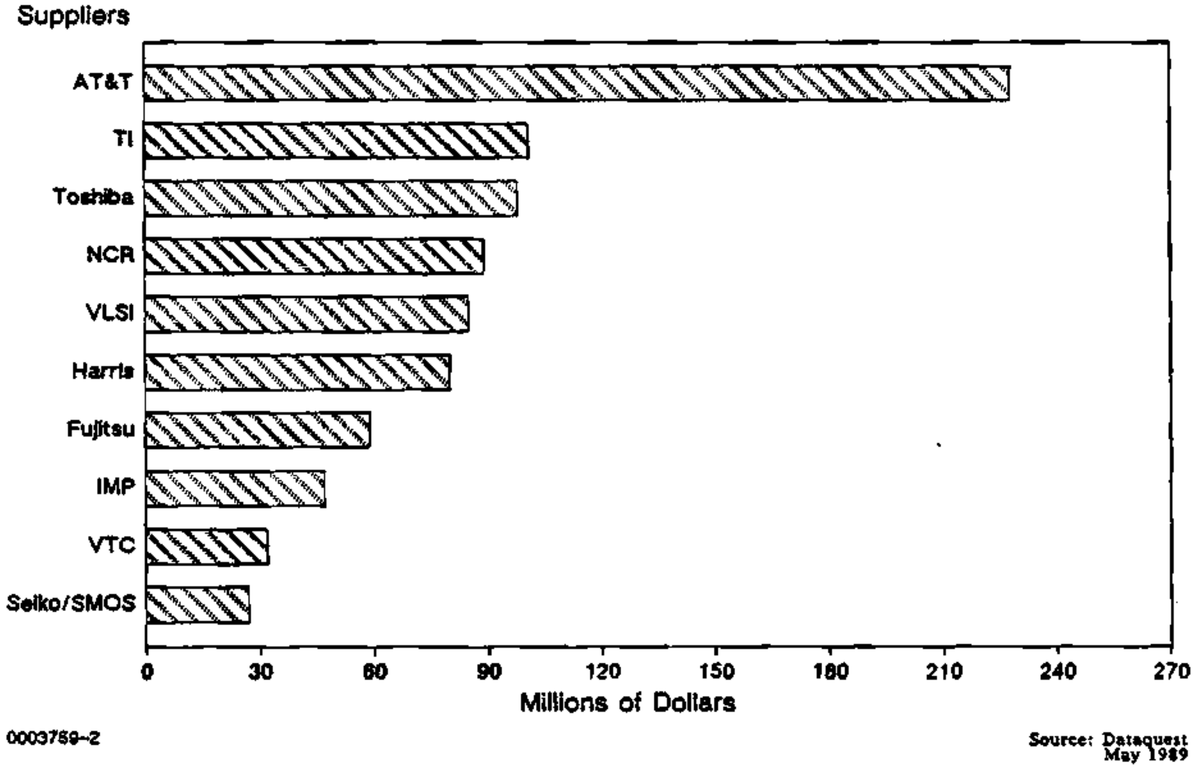
While Toshiba has made major headway in the CBIC market, we believe that a large portion of Toshiba's 1988 sales were derived from what we call optimized gate arrays. Toshiba modified some of its gate arrays that were running in high volume by removing the unused gates and routing channels; the company retooled the devices using a full set of masks. This fits the CBIC definition because they were customized using a full set of masks, yet they were not traditional CBICs. Furthermore, we believe that other Japanese companies such as Fujitsu and Seiko/SMOS generated a portion of their CBIC revenue in the same manner.

Dataquest believes that the Japanese companies will continue to focus on gate arrays, optimized gate arrays, and structured arrays (megacells embedded in gate array base wafers), and that traditional CBICs will be of secondary importance to them.

Three of the leading suppliers—NCR, VTC, and IMP—made the top-ten ranking by focusing on mixed analog/digital CBICs. Mixed analog/digital ASICs have been exclusively targeted by North American suppliers until early this year, when NEC announced its "stepped array" (structured array), which included analog cells. We believe that other Japanese companies will soon follow suit with mixed analog digital ASICs.

Figure 2

Estimated Worldwide CBIC 1988 Shipments



DESIGN STARTS

Design starts are a leading indicator of future product trends. Dataquest analysis indicates that there were 3,520 worldwide CBIC design starts during 1988, with 94.4 percent MOS and 5.6 percent bipolar.

Bipolar design starts consist of two types: analog and digital emitter-coupled logic (ECL). During 1988, more than 80 percent of the bipolar design starts were analog. By the early 1990s, we believe that the vast majority of bipolar design starts will be digital ECL, and that BiCMOS will emerge as the premier solution for mixed analog/digital CBICs. Texas Instruments is the first supplier to capture analog BiCMOS CBIC designs, while National and Fujitsu were the first to capture ECL CBIC designs. Table 1 shows estimated worldwide CBIC design starts from 1987 through 1992, broken down by MOS, bipolar, and BiCMOS.

Table 1

Estimated Worldwide CBIC Design Starts by Technology

Technology	Number of Design Starts					
	1987	1988	1989	1990	1991	1992
Total	2,930	3,531	4,266	4,914	6,107	7,662
MOS	2,785	3,333	3,992	4,556	5,578	6,892
Bipolar	145	187	236	269	325	395
BiCMOS	0	11	38	89	204	375

Source: Dataquest
May 1989

CELL LIBRARY TRENDS

Microprocessors

As mentioned earlier, microprocessor core cells are a critical element in single-chip systems. The following three microprocessor strategies currently are being implemented by ASIC suppliers:

- Bit-slice processors (2901 family)
- General-purpose CISC processors
- RISC processors

The first type of processor to be included in CBIC libraries was a version of Advanced Micro Devices' 2901 bit-slice processor. The 2901 was popular because of its flexible architecture, small cell size, and fast speed. The 2901 is 4 bits wide and can be stacked to achieve 16- and 32-bit processor cores. Currently, the percentage of CBIC designs using this approach is in decline because of the emergence of general-purpose and RISC microprocessors.

General-purpose microprocessor cells such as 6502, 80C49, 80C51, and Z80 emerged in cell libraries two to three years after the first bit-slice processors. Most general-purpose microprocessor cores that have been designed in thus far have been 8 bits wide because 16-bit and 32-bit microprocessor cores have been too large and uneconomical for 2-micron and 1.5-micron CMOS libraries. As sub-1.3-micron CMOS libraries emerge, some suppliers will offer 16-bit and 32-bit microprocessor cells. Dataquest believes that the demand for these processors may not be as large as many suppliers believe, because using off-chip standard product microprocessors may be more cost-effective in many applications. The demand for general-purpose microprocessors is declining also because of the high demand for RISC microprocessor cores.

Dataquest predicts that CBIC designs with RISC microprocessor core cells will experience rapid growth in the next five years. The demand for RISC microprocessors as standard products, as well as the number of suppliers, has increased dramatically in the last two years. Many of these RISC-standard product suppliers are also CBIC suppliers. Users want to tailor the memory and logic in combination with the RISC processor in a single chip for their application. LSI Logic has already announced RISC microprocessor CBIC cells, and we believe that others will soon follow suit.

Memory

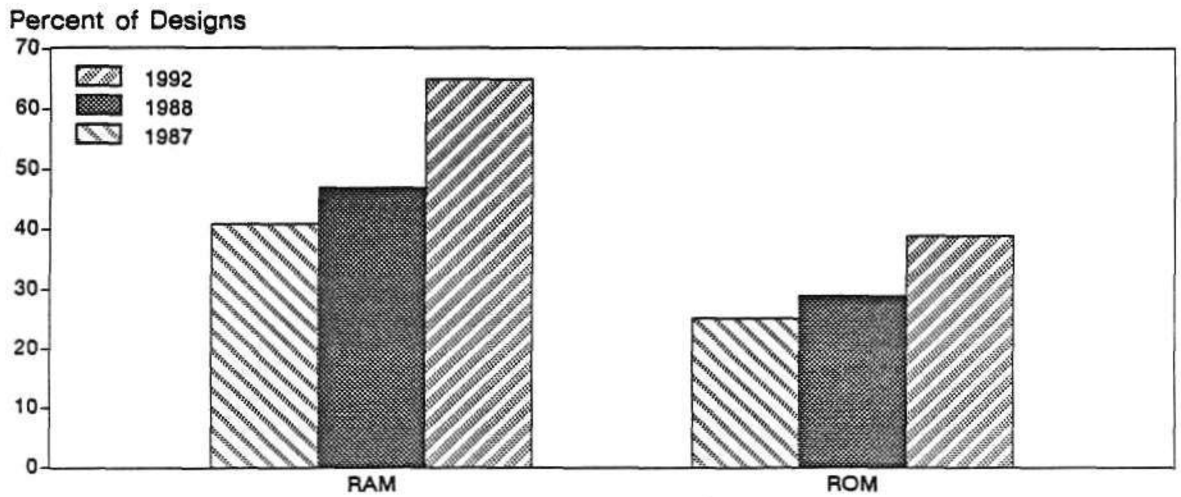
Memory cells are also important when designing single-chip systems. Almost all CBIC suppliers offer RAM and ROM in a variety of configurations. Dataquest believes that the percentage of CBIC designs that incorporate memory will increase because on-chip memory increases the system performance by reducing the number of times the processor must go on- and off-chip. This is not to say that all system memories will go on-chip, but some on-chip memory is necessary to reduce access times.

Dataquest believes that compiled cache memory will be the trend for the 1990s. End users will configure the exact amount of on-chip memory required for their unique applications. Many suppliers already offer configurable memory. Furthermore, we believe that as process geometries shrink toward the 0.5-micron level and maximum gate counts increase beyond 100,000 gates, larger cache memories will go on-chip to further reduce access times.

Figure 3 illustrates the percentage of North American CBIC designs that incorporate on-chip RAM and ROM for 1987, 1988, and 1992.

Figure 3

Estimated North American CBIC Design Starts with On-Chip Memory



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Source: Dataquest May 1989

1989 AND BEYOND

During the first quarter of 1989, many of the CBIC suppliers started to experience a slowdown in their bookings and billings. Personal computer business (including disk drives) was reported to be soft. This especially affects suppliers who are focusing on the mixed analog/digital CBICs. We believe that this is an indication that the worldwide CBIC market is decelerating, as Dataquest had predicted, and that growth rates will decline from the 33.4 percent in 1988 to 22.5 percent and 13.0 percent in 1989 and 1990, respectively.

Table 2 shows the estimated worldwide CBIC consumption forecast by technology from 1987 through 1994. Dataquest forecasts and supplier shipment revenue include nonrecurring engineering (NRE) revenue, device revenue, CAD software, and intracompany revenue (internal sales). Please note that our forecasts do not include captive manufacturing of companies that do not sell to the merchant market, such as Digital Equipment, IBM, and Northern Telecom.

Table 2

Estimated Worldwide CBIC Consumption by Technology (Millions of Dollars)

	1987	1988	1989	1990	1991	1992	1993	1994
Total	949.5	1,266.2	1,551.0	1,753.1	2,298.9	3,094.4	3,994.3	4,731.7
MOS	912.9	1,214.4	1,481.5	1,659.4	2,153.9	2,843.1	3,553.8	4,015.8
Bipolar	36.6	50.8	64.5	74.7	94.0	126.3	159.2	181.5
BiCMOS	0	1.0	5.0	19.0	51.0	125.0	281.3	534.4

Source: Dataquest
May 1989

Single-chip systems are the wave of the future. Cell-based ICs and gate arrays are in a race, with the finish line being the ultimate single-chip system solution. Dataquest believes that gate arrays and CBICs ultimately will look very similar. We believe that during the next three years, structured arrays (megacells embedded in gate array base wafers) will emerge that combine the best of both worlds. RISC microprocessor cores and memory will be embedded in the base wafer, and random logic will be routed with the final layers of interconnect. This offers the efficiency and increased speeds of cell-based ICs, along with the flexibility, shorter time to market, reduced design cost associated with gate arrays, and security from cloning.

By the 1990s, it will be very difficult to tell a CBIC product from a gate-array product. Perhaps the way that these products emerged will be only of historical interest. One thing that is certain, however, is that their impact on system design is transforming the IC industry.

Bryan Lewis

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Research Newsletter

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0004229

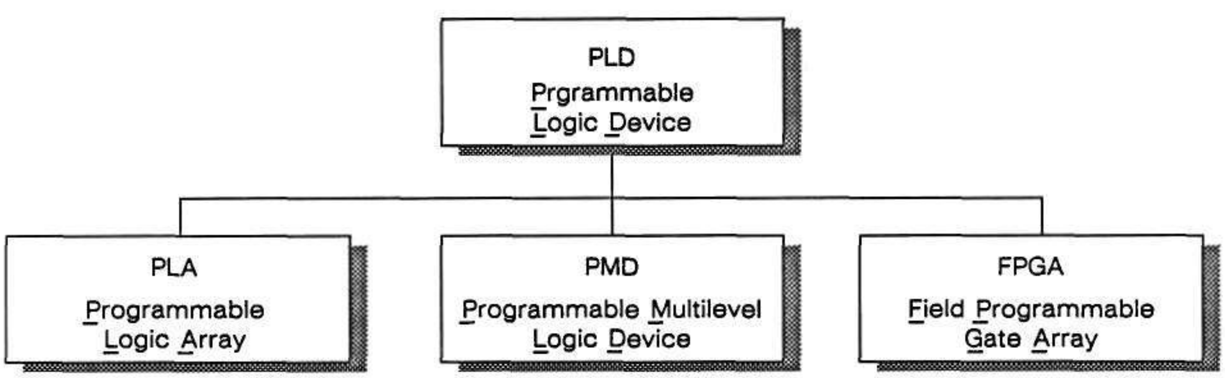
THE PLD EVOLUTION

SUMMARY

PLDs are going through a rapid evolutionary cycle. Fueled by high-density, high-performance process technologies, PLDs have evolved from low-density, low-functionality devices to products capable of implementing up to 9,000 equivalent gates. PLDs have grown from one to three basic architectures. The first is the traditional programmable logic array (PLA), which incorporates up to two levels of logic; the second is the programmable multilevel logic device (PMD), which evolved from the PLA but is capable of implementing multiple levels of logic; and the third, field programmable gate array (FPGA), traces its roots back to conventional gate arrays (see Figure 1). The latter two are capable of implementing very complex logic functions while still maintaining the inherent benefits of a PLD—low risk, low development cost, and quick time to market.

Figure 1

PLD Family Tree



0004229-1

Source: Dataquest
June 1989

Although the traditional PLA still provides more than 95 percent of the 1988 PLD sales revenue, Dataquest believes that it is time to define the other PLD categories and to track and forecast them separately from the PLA. Starting this process now will provide more meaningful analysis and forecasts to our clients, while resulting in only a modest modification to historical data.

SIMPLE QUESTIONS

Simple questions deserve simple answers. The answer to the question, "What is a PLD?" is, of course, "A PLD is a programmable logic device. Next question?" However, much confusion surrounds that "simple" question today. Dataquest's definition of a PLD is quite generic. Put simply, a PLD is any device containing logic elements, which, in its packaged form, can be programmed to implement an application-specific function.

This definition covers logic devices of all complexities. A device may contain dedicated I/O with fixed internal interconnects, or it may be able to configure any pin as an input, output, or I/O with complete flexibility in interconnecting the various elements within the device. It may contain a single logic array, or it may provide a nearly infinite number of internal logical levels.

The term PLD is meant to be as generic a descriptor as possible while still referring only to logic devices. Any use of broader terminology invariably would include other programmable devices such as PROMs, EPROMs, and EEPROMs. Inclusion of the word "logic" in the general descriptor specifically excludes these nonlogic products.

Another question is: "What are the various subgroups within the PLD category?" Dataquest has observed three, which are as follows:

- PLAs—These devices have fixed or preconnected architectures capable of providing up to two levels of logic without using additional input, output, or I/O cells or pins (e.g., PAL, GAL, PEEL, and 22V10-type devices). (PAL is a registered trademark of Advanced Micro Devices; GAL is a registered trademark of Lattice Semiconductor; PEEL is a registered trademark of Integrated CMOS Technology.)

- PMDs—These are devices with primarily fixed or preconnected architectures that can implement multiple levels of logic (more than two) without using additional input, output, or I/O cells or pins (e.g., PML, PEEL-Array, and MAX-type devices). (MAX is a registered trademark of Altera Corporation; PML is a trademark of Signetics.)

- FPGAs—These devices are based on programmable interconnect technology. Typically, they are capable of implementing multiple levels of logic, as is a PMD; however, they contain no preconnected routing channels (e.g., LCA- and ACT-type devices).

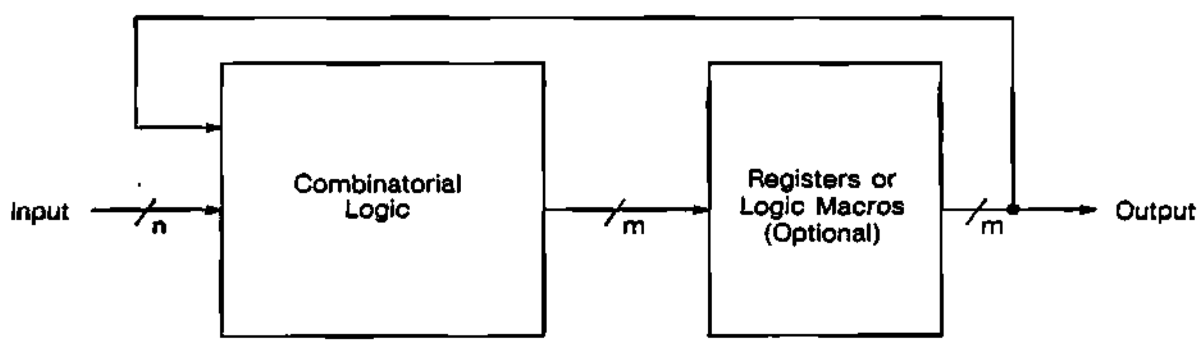
PLDs DEFINED

Programmable Logic Array (PLA)

PLA devices incorporate a one– or two–level programmable logic array with fixed interconnect paths (see Figure 2). This is the basic architecture of the original PLD product offerings, and it still is the primary contributor to the 1989 PLD sales revenue forecast of $898 million.

Figure 2

Typical PLA Block Diagram



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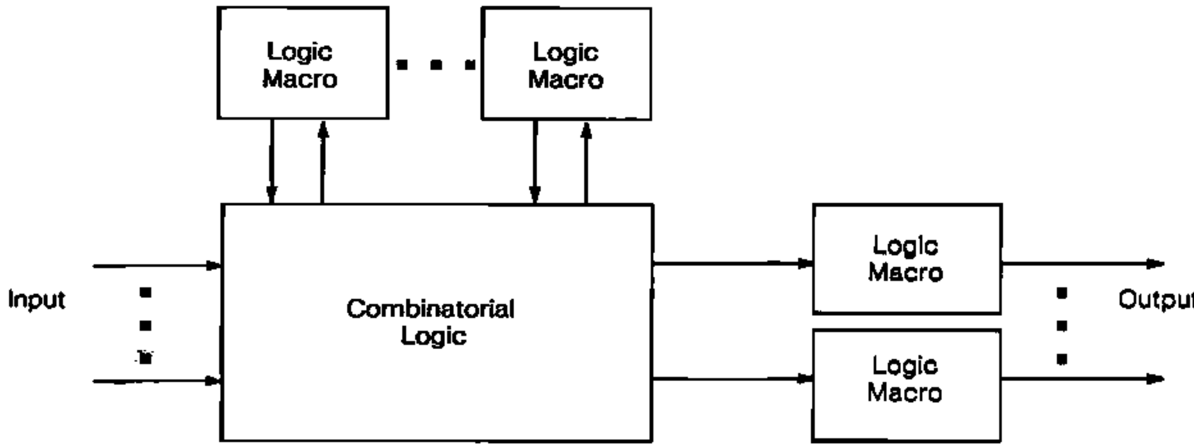
Source: Dataquest June 1989

Programmable Multilevel Logic Device (PMD)

PMDs evolved from the basic PLA (see Figure 3). However, PMDs incorporate architectures to efficiently implement complex logic functions that cannot be addressed by the basic PLA. Typically, they are preconnected, as in a PLA; however, their architecture is not limited to an and–or array feeding a register bank. PMDs can implement multiple levels of logic (more than two) without sacrificing input, output, or I/O cells or pins. Simultaneously, these devices enjoy the benefits of a basic PLA in that they are easy to understand, development tools are available, and timing is predictable.

Figure 3

Typical PMD Block Diagram



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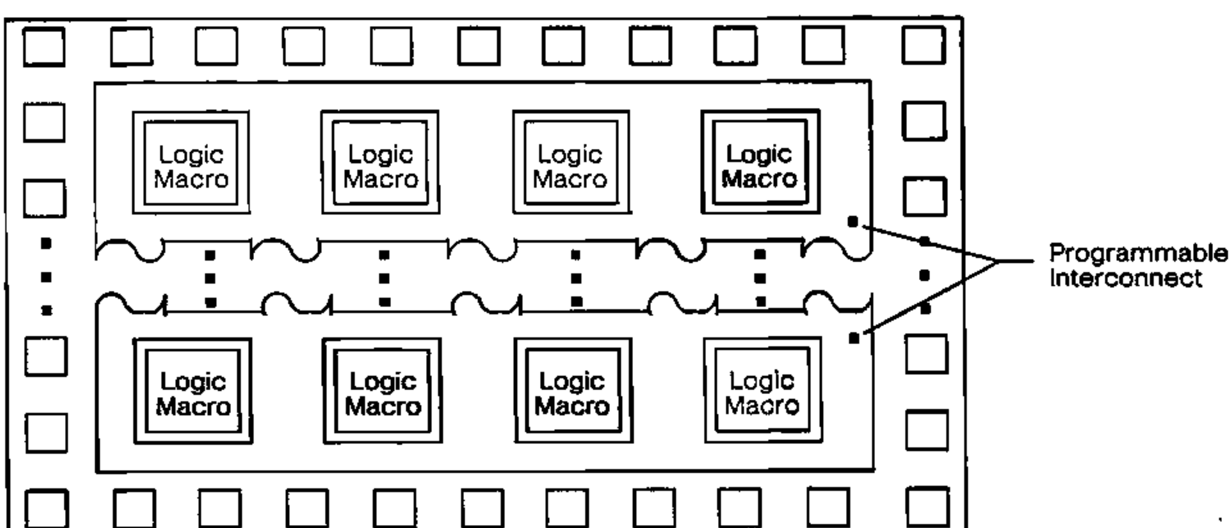
Source: Dataquest
June 1989

Field Programmable Gate Array (FPGA)

FPGAs incorporate an array of programmable logic elements that are not preconnected. Interconnections between the various elements are user programmable (see Figure 4).

Figure 4

Typical FPGA Block Diagram



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Source: Dataquest
June 1989

The programmable interconnect consists of predetermined levels of interconnect that can be connected to, or disconnected from, other interconnect lines as defined by the user. The device is analogous to a gate array in that it requires the use of the programmable interconnect in order to operate. The gate array analogy continues in that the performance of the device is a function of the fixed delays of the logic elements, as well as the variable delays of the interconnect paths. The interconnect delays in an FPGA can be quite substantial, as they consist of not only the resistance of the metal or polysilicon trace but also the resistance, capacitance, and propagation delay of the programmable switch used to connect one trace to another.

The development tools for FPGAs are somewhat more complex than those required for PMDs in that they must perform some form of AC timing analysis and require auto place and route software.

DATAQUEST CONCLUSIONS

The rapid transition of PLDs from low-density two-level logic replacements to devices that can implement multilevel logic functions of up to 9,000 equivalent gates demands that the PLD category be broken into finer resolution. The term "programmable logic device" (PLD) remains the generic descriptor, as any broader term does not exclude nonlogic devices. To reiterate, the PLD category easily breaks down into three distinct subcategories, as follows:

- Programmable logic array (PLA)
- Programmable multilevel logic device (PMD)
- Field programmable gate array (FPGA)

All future forecasting and product analysis will be based on these PLD definitions. Dataquest believes that this is the most comprehensive and meaningful way to analyze and forecast the PLD market.

Jerry Banks

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Research Newsletter

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THE ASIC PACKAGE PROLIFERATION

SUMMARY

Surface-mount technology is now mainstream. Dataquest believes that surface-mount devices (SMDs) will continue to grow at a pace that exceeds traditional packaging and assembly techniques. As ASICs continue to grow in usage, many new surface-mount package families will be developed. This will cause multiple package choices for the same IC, resulting in difficulties for design engineers, assembly engineers, and purchasing agents (i.e., nonstandard packages for second-sourcing). It could make it more costly for semiconductor manufacturers to compete.

This newsletter will discuss the packages currently being used or under development for ASICs. It will also review the issues and choices pertaining to standards involved in ASIC packaging.

INDUSTRY ANALYSIS

Dataquest expects the worldwide integrated circuit package market to grow at a 10 percent compound annual growth rate (CAGR) from 1987 to 1992. We expect surface-mount devices to continue to show the greatest gain. They are expected to grow from the current level of 20 percent (year-end 1988) to almost one-half of all IC packages (48.4 percent) by 1992. These statistics are shown in Tables 1a and 1b.

The forecast shows the fastest growth area to be the quad flat package (76.3 percent CAGR). This is directly related to the worldwide increase in ASIC production.

Table 1a

Estimated Worldwide Shipments by Package Type
(Millions of Units)

Package	1987	1988	1989	1990	1991	1992	CAGR 1987-1992
Plastic DIP	23,194	26,282	25,292	21,741	21,103	20,625	(2.4%)
CERDIP	3,346	3,738	3,274	2,778	2,783	2,727	(4.2%)
Ceramic DIP	270	277	250	231	225	203	(5.9%)
Quad/Ceramic and Plastic	284	805	1,357	1,640	2,785	4,833	76.3%
Ceramic Chip Carrier	207	315	374	383	430	562	22.1%
Plastic Chip Carrier	508	1,024	1,412	1,513	1,987	2,792	40.6%
SO	3,092	4,954	6,202	7,167	9,396	12,881	33.0%
PGA/Ceramic and Plastic	234	614	983	1,118	1,583	2,339	58.5%
Other (TAB/COB/ FCHIP)	470	860	1,224	1,480	2,249	3,817	52.0%
Others	479	657	684	596	612	608	4.9%
Total	32,084	39,526	41,051	38,647	43,153	51,386	9.9%
Total of SMT	4,561	7,958	10,569	12,183	16,847	24,885	40.4%
Percent of SMT	14.2%	20.1%	25.7%	31.5%	39.0%	48.4%	

Table 1b

Estimated Worldwide Shipments by Package Type
(Percent)

Package	1987	1988	1989	1990	1991	1992
Plastic DIP	72.3%	66.5%	61.6%	56.3%	48.9%	40.1%
CERDIP	10.4	9.5	8.0	7.2	6.5	5.3
Ceramic DIP	0.8	0.7	0.6	0.6	0.5	0.4
Quad/Ceramic and Plastic	0.8	2.0	3.3	4.2	6.5	9.4
Ceramic Chip Carrier	0.7	0.8	0.9	1.0	1.0	1.1
Plastic Chip Carrier	1.6	2.6	3.4	3.9	4.6	5.4
SO	9.6	12.5	15.1	18.6	21.8	25.1
PGA/Ceramic and Plastic	0.7	1.6	2.4	2.9	3.7	4.6
Other (TAB/COB/ FCHIP)	1.4	2.2	3.0	3.8	5.2	7.4
Others	1.4	1.6	1.7	1.5	1.4	1.2
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Note: Percentages may not add to 100.0% because of rounding.

Source: Dataquest
June 1989

PACKAGE TYPES

Quad Flat Packs—Old and New

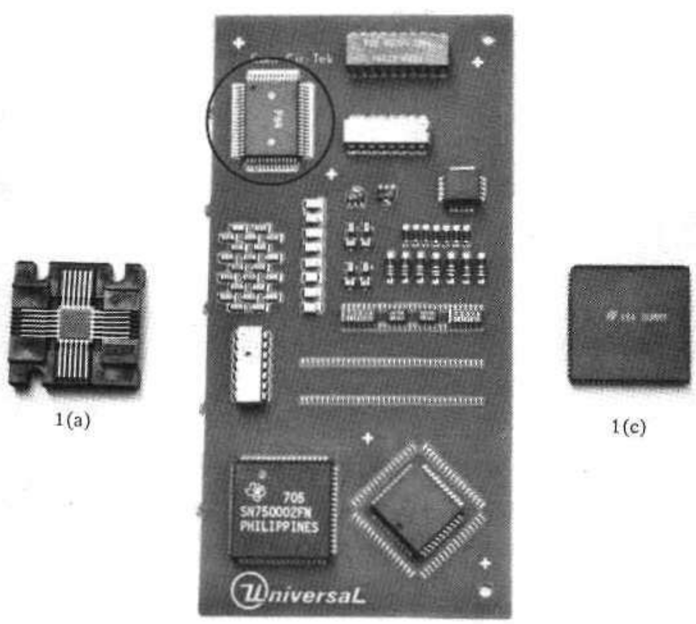
The true, original flat package is not new. Based on 50-mil lead spacing and ceramic technology, it has been and still is used primarily in military applications. The quads are mostly flat, retangular packages with bodies constructed of alumina or beryllia, with glass-to-metal seals. The long leads are splayed out away from the package body on all sides, in a gull-wing-style lead form. Lead counts generally range from 12 to 28 leads. Figure 1(a) shows a photograph of a ceramic quad flat package.

As commercial development of surface mount became prevalent in the early 1980s, the Electronic Industries Association of Japan (EIAJ) began to develop its own plastic versions of the quad flat package. These packages were based on the premise of keeping package body sizes the same and varying the lead pitch, thus increasing lead count density. Pitches of 1.0mm (39.4 mils), 0.8mm (31.5 mils), and 0.65mm (25.6 mils) form standards that define packages from 20 to 240 leads, depending upon body size. This package is also called the quad flat pack (QFP), as seen in Figure 1(b).

Expanding on this, the U.S. manufacturers agreed that placing leads on all four sides of a package was beneficial. But bending the leads underneath the package would increase density even further, and it also could be compatible with the ceramic leadless chip carrier board footprint. Thus the J-bend plastic leaded chip carrier (PLCC) was developed, with lead counts ranging from 18 to 100 leads on 50-mil center lead spacing (see Figure 1(c)).

Figure 1

Ceramic Quad Flat Package



1(a) 1(c)

1(b)

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Source: Dataquest
June 1989

However, the PLCC on 50-mil spacing did not address the increasing demand of ASIC products for higher lead counts (more than 100 pins). So, the United States through the Joint Electronics Device Engineering Council (JEDEC) developed the plastic quad flat package (PQFP) for this requirement. It uses the same plastic body sizes as the PLCC, but has leads on 25-mil centers and a molded "bumper" protruding from each corner for lead protection during handling. Lead counts for this package family range from 44 to 244 leads, and the gull wing is the preferred lead form (see Figure 2).

Figure 2

Plastic Quad Flat Package

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Source: Dataquest
June 1989

Finer Pitch Packages

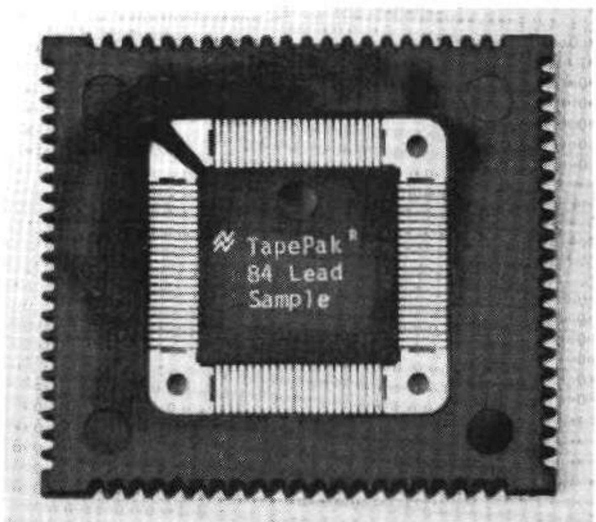
With the consumer market driving for smaller, less costly electronic gadgets and the ASIC market needing higher lead count packages, the Japanese have developed yet another package family: The shrink quad flat package (sometimes called the very small quad flat package (VQFP)). In some ways, this family is an extension of the EIAJ quad flat package (QFP). It also uses standard body sizes, but the package is one-half the thickness, and the lead pitches are reduced to 0.5mm (19.7 mils), 0.4mm (15.7 mils), and 0.3mm (11.8 mils). Lead counts range from 32 to 520 leads.

Besides those mentioned, two more surface-mount package families have recently been introduced into the market for ASIC packaging. One is TapePak developed by National Semiconductor; the other is the TQFP, a TAB quad flat pack developed by LSI Logic.

TapePak uses TAB (tape automated bonding) tape as the lead frame that is attached directly to the die. No wire bonding is used. This die-on-tape combination is then molded in plastic so that an outside ring is formed apart from the inside encapsulated die. This outside ring provides for lead protection and test capabilities. The package body is excised from the carrier ring by the pick-and-place machine and is subsequently attached to the printed circuit board. Like the Japanese quad flat pack, the TapePak family uses standard body sizes with lead counts from 40 to more than 460 leads on 20-, 15-, and 10-mil pitch. This package is shown in Figure 3.

Figure 3

TapePak



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Source: Dataquest
June 1989

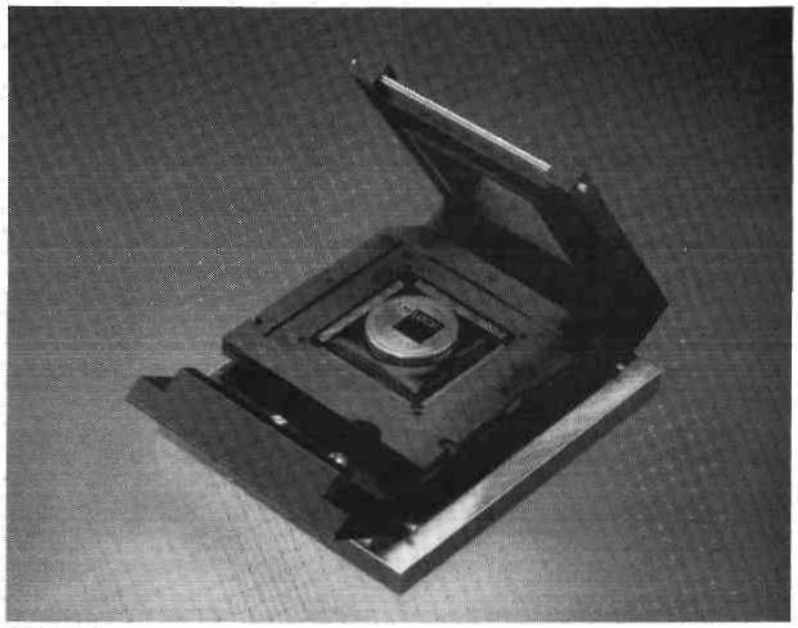
The TQFP is similar to TapePak, except for the following:

- It uses wire bonding for lead counts up to 300 and TAB from 300 to 524 leads.
- The die is encapsulated, using a liquid epoxy "blob."
- A two-piece plastic disposable slide carrier is used for lead protection and test.
- Pin counts range from 164 to 524 leads.

A picture of the TQFP is shown in Figure 4.

Figure 4

TAB Quad Flat Pack



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Higher Lead Counts and the No-Package Package

Another packaging solution to ASICs is the pin grid array. Although not assembled to the board using surface-mount technology, it does provide high-density capability to 1,000 leads and beyond. Rows of pins on 100-mil spacing (and more recently 50 mil) are arranged in a grid format to form the PGA (see Figure 5). It is available in both ceramic and plastic and is capable of dissipating more heat than most surface-mount packages.

There is one more approach to ASIC packaging that does not really use a package in the traditional sense. Chip-on-board (COB) technology enables the bare die to be attached directly to the printed circuit board. The die is attached to the board via an adhesive (usually epoxy) and wire-bonded directly to the pads or traces on the PCB. After bonding, the die is usually coated with a blob of plastic material to provide for mechanical and environmental protection.

Variations of the COB approach include TAB-on-board (TOB). Component leads are etched on single-layer or multilayer copper/copper-polyimide tape. The tape is etched to form patterns that correspond to the die pad layout. These patterned leads then make the connection between the die and the printed circuit board. Whereas wire-bonded COB is done on a chip-by-chip basis, TOB can be done via an automated, reel-to-reel process. The die-on-tape can then be attached to the board and encapsulated, as in the COB process. An example of TOB is Siemens' Micropak. A basic flow of the TOB process is shown in Figure 6.

Figure 5

Rows of Pins Forming the PGA

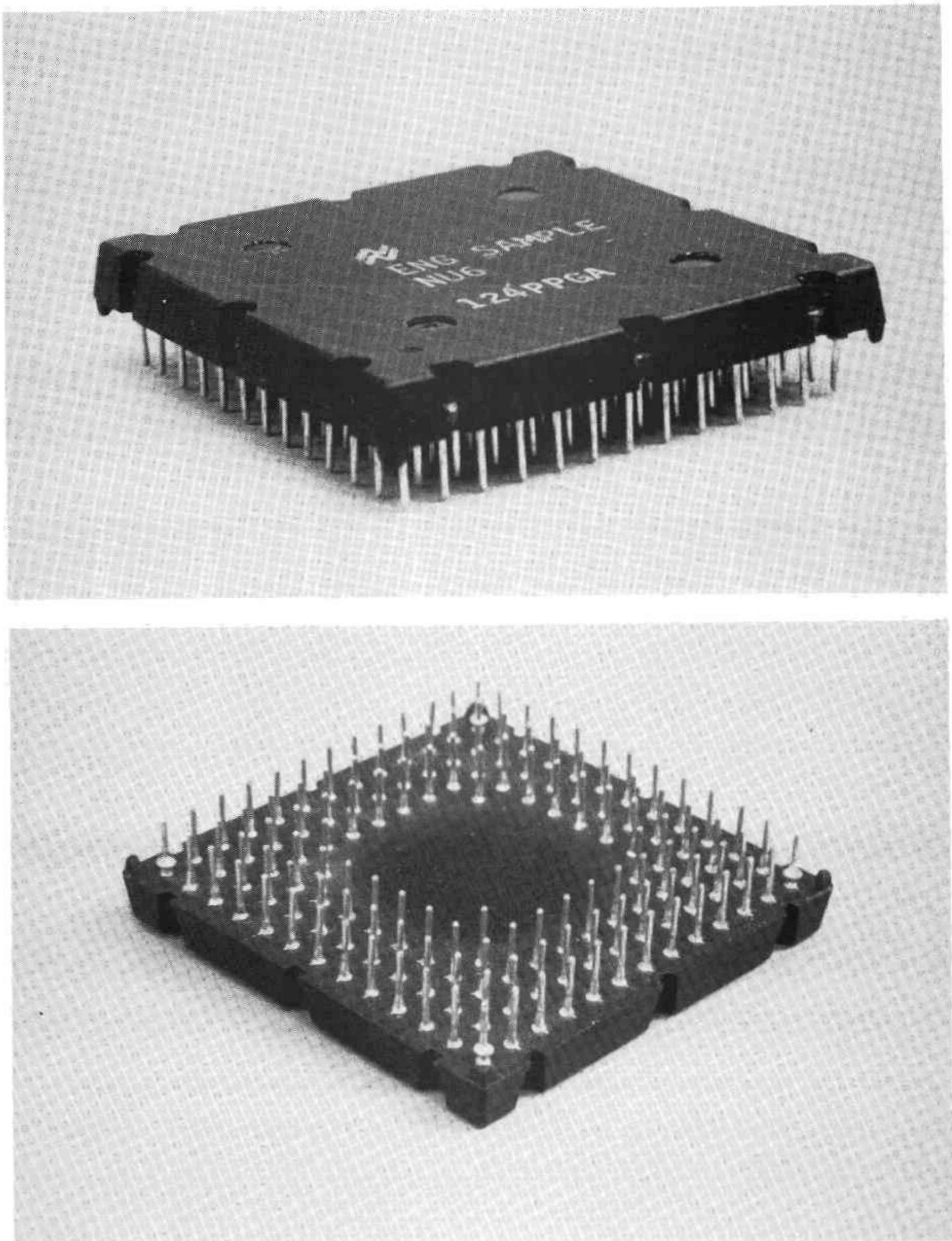

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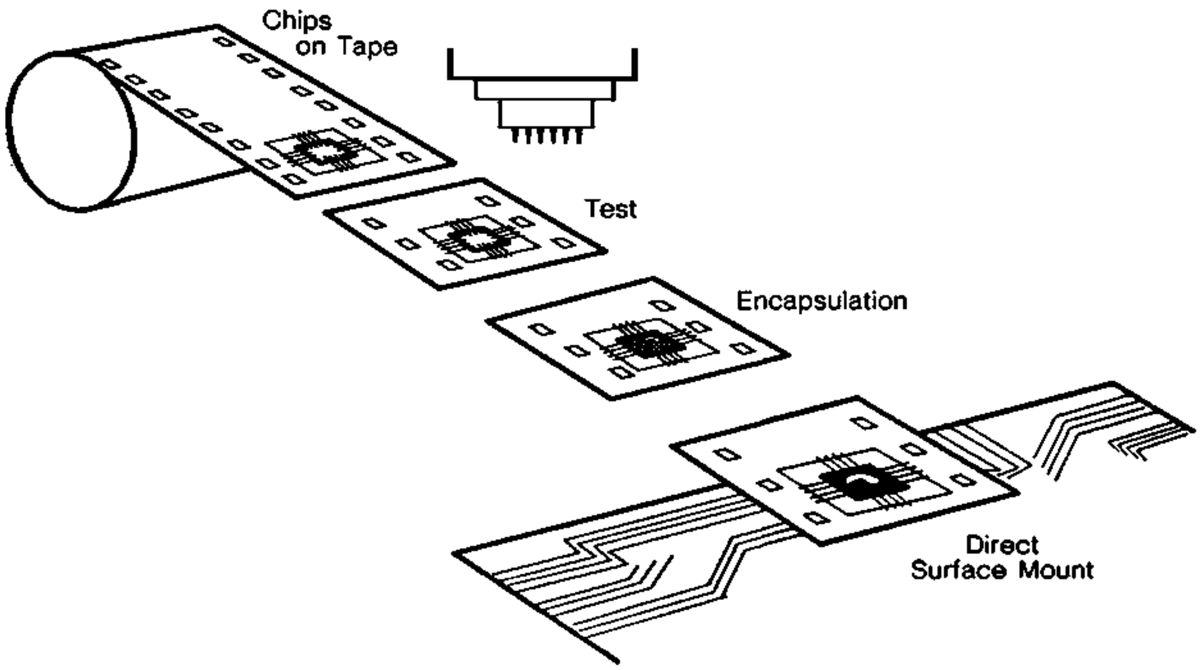
Figure 6

TOB Process (Basic Flow)



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Source: MESA Technology

Finally, flip chip is one other assembly process that can be used in ASIC packaging. This process was developed by IBM in the late 1960s and is known as C-4, for controlled-collapse chip connection. It is basically a process in which the chip is designed for facedown reflow soldering. The bond pads are bumped with solder while in wafer form. Passivation (silicon nitride) is added, and the wafer is tested via the solder bumps. After testing, the dice are placed facedown, or flipped, on the ceramic substrate, and the assembly is heated in a furnace to reflow the solder. The surface tension of the solder aligns the dice properly to the substrate. This is the maximum use of interconnect density, as no lead frame, wires, or tape are used.

A DESIGNER'S NIGHTMARE

What package should an ASIC design engineer choose? Assuming that it is an ASIC requiring 68 leads, the following choices can be made if a plastic package is desired:

- 68–lead PLCC (JEDEC)
- 68–lead PQFP (JEDEC)
- 68–lead QFP (EIAJ)
- 68–lead VQFP (EIAJ)
- 68–lead TapePak (JEDEC)
- 68–lead PPGA (JEDEC)
- 68–lead COB (No standard)
- 68–lead TOB (EIA/IPC/ASTM)
- 68–lead Micropak (Europe/DIN)

The following section discusses the above listing in more detail. Table 2 lists some common specifications for each package.

Table 2

68–Lead Package Options*

	Lead Pitch	Lead Width	Package Size	Package Height
PLCC	0.050"	0.028"	0.950" sq.	0.180"
PQFP	0.025"	0.012"	0.550" sq.	0.102"
QFP	0.0256"	0.0118"	0.394" x 0.551"	0.100"
VQFP	0.0118"	0.004"	0.197" x 0.276"	0.050"
TapePak	0.020"	0.010"	0.505" sq.	0.072"
PPGA	0.100"	0.018"	1.14" sq.	0.180"
COB	0.008"	0.0014"	0.378" sq.	0.032"
TOB	0.020"	0.010"	0.378" sq.	0.032"
Micropak	0.0197"	0.009"	0.386" sq.	0.025"

*See Appendix A attached to this newsletter.

Source: Dataquest
June 1989

One can readily see that little, if any, compatibility exists among the various packaging styles, except possibly COB versus TOB. This means that designing with an ASIC from supplier A in PQFP (JEDEC) may not be compatible with the ASIC from supplier B in QFP (EIAJ), even if the silicon function is the same. The possible result is a sole-source supplier based primarily on package offering, not silicon.

STANDARDS ACTIVITY

There has been criticism of industry organizations for their lack of leadership in setting surface-mount standards. Some is justified, as it is difficult to get everyone to agree on one of anything, whether it be process, part, or package. There are major differences between the U.S. and Japanese styles of packages. Work needs to continue to bring commonality to this area.

Package standardization is proceeding within the United States at a faster rate as surface mount becomes a proven technology. To address industry awareness and the need for areas of standardization in surface-mount technology, representatives from EIA, IPC, JEDEC, and ASTM have joined together to form the Surface Mount Council. In January 1989, they issued a document entitled "Survey Report: Surface-Mount Standards, Requirements, and Issues."

This report surveyed responses regarding the awareness and usage of 14 typical standards currently available to the industry. In the case of integrated circuit components, the survey found that only 61 percent of the respondents used all or part of the EIA JEP-95 specification (JEDEC Registered and Standard Outlines for Semiconductor Devices). Eighteen percent were aware of this standard but did not choose to use it, and 16 percent were not aware of the standard. Highlights from this report related to component standards are shown in Table 3.

Table 3

Surface-Mount Component Standards

	Use Standard	Use Part of Standard	Do Not Use	Unaware of Standard
EIA RS 481A--Taping of SM Components for Automatic Placement	30.6%	18.8%	17.6%	20.0%
EIA PDP 100--Mechanical Outline for Registered and Standard Electronic Parts	14.1%	29.4%	16.5%	27.1%
EIA JEP 95-JEDEC--Registered and Standard Outlines for Semiconductor Devices	24.7%	36.5%	17.6%	16.5%
EIA JESD 11--Chip Carrier Pinouts for CMOS 4000HC and HCT Circuits	9.4%	17.6%	16.5%	44.7%

Source: EIA/IPC Surface Mount Council

In addition, many organizations worldwide have established committees to discuss issues related to surface-mount technology. A list of these is shown as follows:

- ACPI (Automated Component Placement and Insertion Group)—c/o AMP, 1000 AMP Drive, Harrisburg, PA 17112
- ANSI (American National Standards Institute)—1430 Broadway, New York, NY 10018
- ASTM (American Society of Testing and Materials)—1916 Race Street, Philadelphia, PA 19103
- BSI (British Standards Institute)—2 Park Street, London, W1A 12BS, United Kingdom
- CSA (Canadian Standards Association)—178 Rexsdale Boulevard, Rexsdale, Ontario, Canada
- DOD (U.S. Department of Defense, Naval Publications Center)—5801 Tabor Road, Philadelphia, PA 19120
- EIA (Electronic Industries Association)—2001 Eye Street N.W., Washington, D.C. 20006
- EIAJ (Electronic Industries Association of Japan)—250 West 34th Street, New York, NY 10119
- EMPF (Electronics Manufacturing Productivity Facility)—1417 North Norma Street, Ridgecrest, CA 93555
- IEC (International Electrotechnical Commission)—3 Rue de Varembe, 1211 Geneva 20, Switzerland
- IEPS (International Electronic Packaging Society)—114 North Hale Street, Wheaton, IL 60187
- IPC (The Institute for Interconnecting and Packaging Electronic Circuits)—7380 N. Lincoln Ave. Lincolnwood, IL 60646
- ISHM-I/SMT (International Society of Hybrid, and Microelectronics, Interconnect and SMT Division)—Box 2698, Reston, VA 22090
- SEMI (Semiconductor Equipment and Materials—International)—805 E. Middlefield Road, Mountain View, CA 94043
- SMART (Surface-Mount and Related Technologies Group)—3 Lattimore Rd., Wheathampstead, Herts AL4 8QF, United Kingdom
- SMC (Surface-Mount Club)—British Overseas Trade Board, 1 Victoria St., London SW1H 0ET

- SMC (Surface-Mount Council—Joint ASTM/IPC/EIA/JEDEC Committee)—c/o IPC, 7380 Lincolnwood Ave., Lincolnwood, IL 60646

- SMEMA (Surface-Mount Equipment Manufacturers Association)—71 West St., Medfield, MA 02052

- SMTA (Surface-Mount Technology Association)—5200 Wilson Road, Suite 107, Edina, MN 55424

- STACK (Standard Computer Komoponenten GmbH)—5775 Wayzata Blvd #700, Minneapolis, MN 55416

- VRCI (Variable Resistive Component Institute)—c/o Bourns, Inc., 1200 Columbia Avenue, Riverside, CA 92507

DATAQUEST CONCLUSIONS

We believe that package proliferation will continue as the ASIC market develops. Many new packaging schemes will arise to meet the speed, thermal, and density requirements needed. Custom and semicustom packaging, including multichip modules using COB and TOB, will become more prevalent. Procurement of semiconductor integrated circuits will depend upon package needs and functions in addition to the basic electrical parameters of the chip. As a result, purchasers will need to specify even more details when ordering.

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Jerry Banks
Mark Giudici

Appendix A

Package Standards

PLCC	JEDEC Publication 95, MO-047AA-AH
PQFP	JEDEC Publication 95, MS-069
QFP	EIAJ Specification IC-74-4, 1986
VQPF	EIAJ Specification IC-74-4-I, 1988
TapePak	JEDEC Publication 95, MO-071
TQFP	JEDEC Publication 95, under consideration
PGA	JEDEC Publication 95, MO-083
COB	Standards not available. Use TOB guidelines.
TOB	JEDEC UO-017 and Surface Mount Council--IPC/EIA/ASTM Publication SMC-TR-001, Guideline Introduction to Tape Automated Bonding Fine Pitch Technology
Micropak	Based on DIN 15851

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Research Newsletter

DATAQUEST SLASHES GATE ARRAY DESIGN START FORECAST

SUMMARY

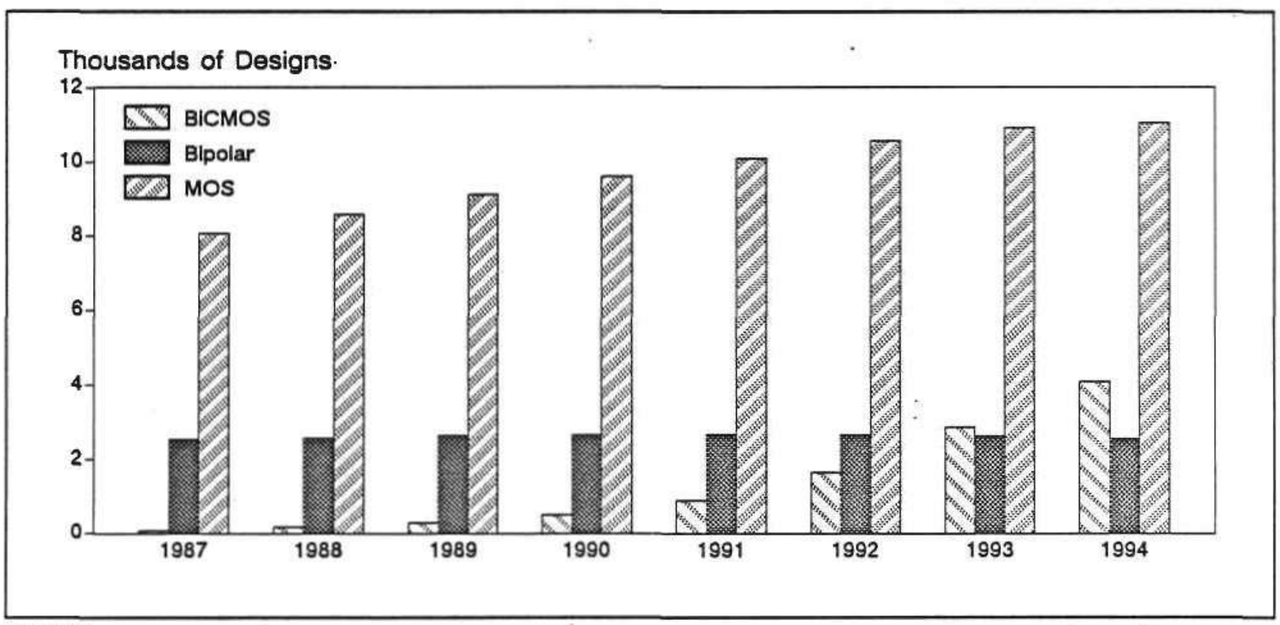
Dataquest has made a major change to its gate array design start forecast: We have decreased the five-year projection by 10,000 designs! After extensive analysis of both gate array suppliers and users, we concluded that there will be far fewer gate array design starts in the future than originally projected, primarily due to increasing chip complexity, field-programmable gate arrays (FPGAs), and chip sets/standard products.

As Figure 1 illustrates, we forecast that MOS gate array designs will have modest growth, bipolar (ECL) will be flat, and the real growth will be in BiCMOS.

INCREASING COMPLEXITY

System designers now are replacing two to three low-complexity gate arrays with one high-complexity array, which is slowing the overall growth of gate array design starts. Although complexity is increasing in all technologies, we will discuss increasing complexity in terms of MOS gate arrays in North America. During 1986, the average number of utilized gates per MOS gate array design was 5,100; in 1987, it was 6,300; in 1988, 7,700; and in 1989, it is estimated to be 9,900.

FIGURE 1
Estimated Worldwide Gate Array Design Starts by Technology



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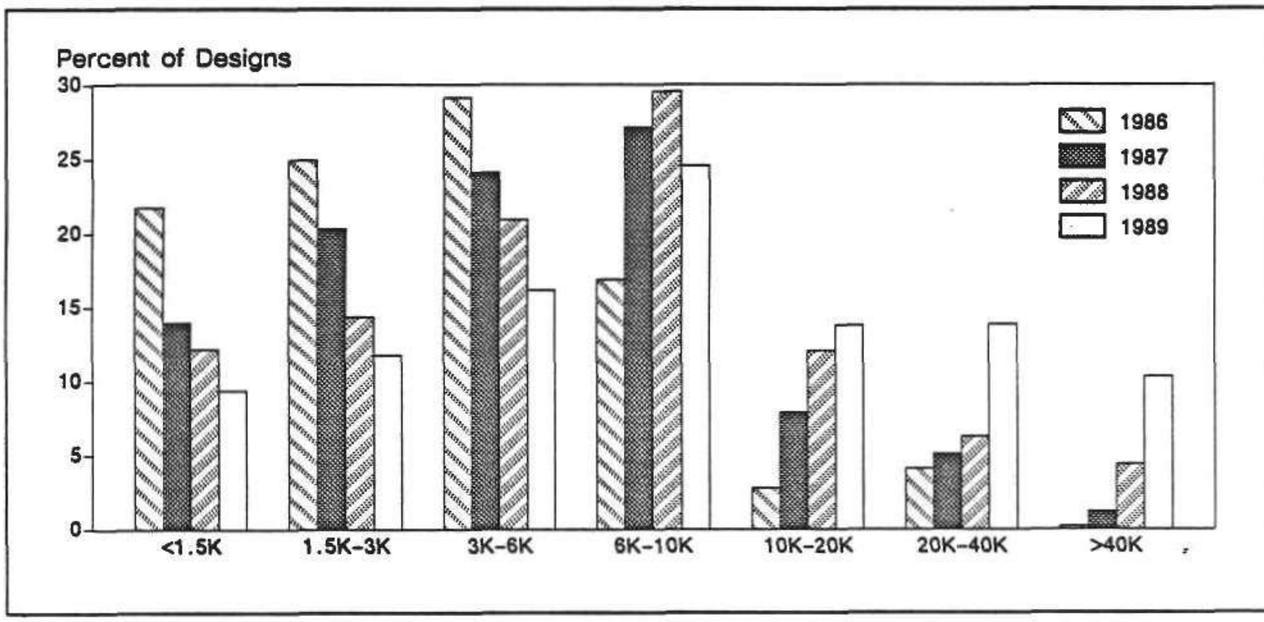
Source: Dataquest
November 1989

Dataquest Incorporated, 1290 Ridder Park Drive, San Jose, CA 95131-2398 / (408) 437-8000 / Telex 171973 / Fax (408) 437-0292

FIGURE 2
Estimated North American MOS Gate Array Design Starts by Gate Count



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Source: Dataquest
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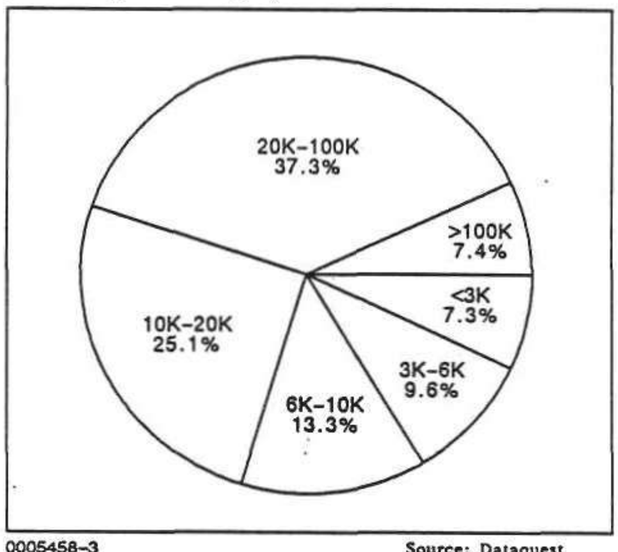
Figure 2 illustrates the percentage of MOS gate array designs captured in North America by available gates from 1986 through 1989.

Furthermore, most of the 1992 MOS gate array designs will have 20,000 to 100,000 available gates, as shown in Figure 3. Fujitsu, LSI Logic, Motorola, NEC, Toshiba, and VLSI Technology are some of the leading suppliers of high-complexity arrays.

FIGURE 3
Estimated 1992 North American MOS Gate Array Design Starts by Gate Count (Percentage of Designs)



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ENCROACHING TECHNOLOGY

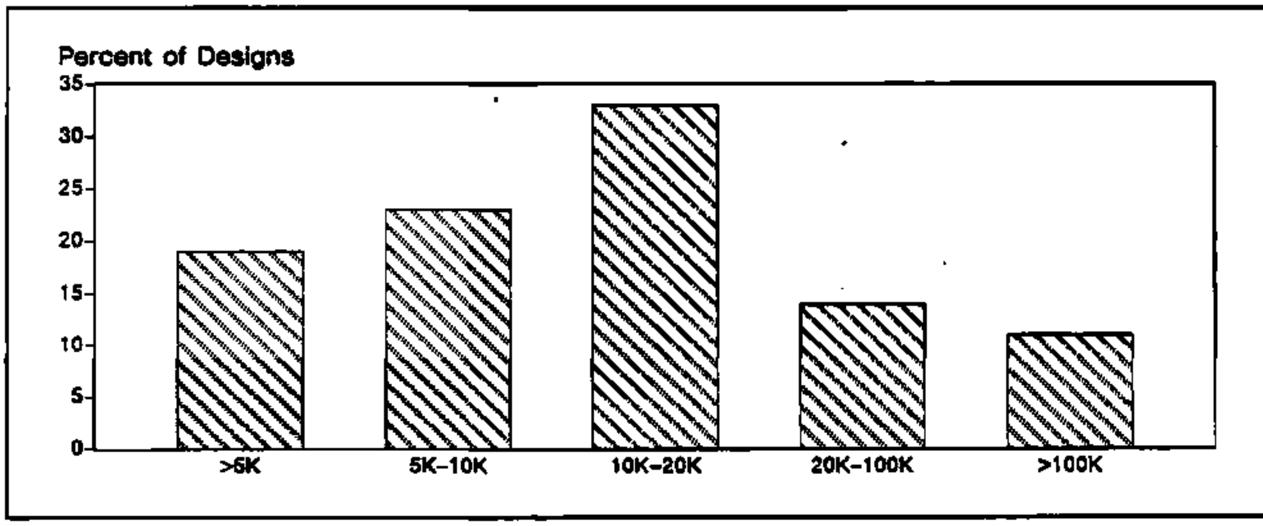
Field-Programmable Gate Arrays

FPGAs also are having an impact on the growth of gate array design starts. FPGAs are affecting low-density/low-volume gate array designs today; they also have the potential to impact medium-density/medium-volume gate array designs in the future.

Dataquest estimates that more than 4,000 cumulative FPGA development systems were installed through mid-1989. If each system was used for only 2 designs a year, that would equal 8,000 FPGA designs total. Most of the FPGA designs that have been captured to date have less than 2,500 gates.

Today, most FPGAs are used for prototyping or for applications that require less than 5,000 units for the life cycle of the design. In the past, gate arrays were used for breadboarding, which tests the logic of the system for problems. System designers now use FPGAs for this application, which saves them both development time and NRE fees.

FIGURE 4
Estimated 1989 North American MOS Gate Array Units per Design



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Source: Dataquest
November 1989

TABLE 1
Worldwide Logic Chip Set Forecast (Millions of Units)

	1987	1988	1989	1990	1991	1992	1993	CAGR 1987-1993
DOS PC Shipments	9.6	12.3	13.8	15.4	17.1	18.7	20.6	13.6%
Chip Set Shipments	3.1	8.0	12.7	15.1	16.9	18.5	20.4	36.8%
Saturation	33%	65%	92%	98%	99%	99%	99%	

Source: Dataquest
November 1989

Because the current price per gate for FPGAs is approximately 0.60 to 0.80 cents per gate and a gate array costs approximately 0.15 to 0.20 cents a gate, it is reasonable to assume that most FPGA designs have less than 5,000 units. Gate arrays are not as cost effective in low volumes because the NRE fee is only amortized over a low number of devices.

It is interesting to note that only 18 percent of the 1989 North American gate array design starts in production have unit volumes of less than 5,000 units for the life cycle of the design. If future FPGA pricing falls to less than 0.30 cents per gate during the next two years, FPGAs will affect gate array designs with unit volumes in the 5,000 to 10,000 range, which accounts for an additional 23 percent of the 1989 designs.

Figure 4 illustrates the percentage of 1989 MOS gate array designs in production by unit volumes for the life cycle of the design.

Chip Sets/Standard Products

While FPGAs are attacking low-volume applications, chip sets or standard products are attacking high-volume applications. The personal computer (PC) clone market is a prime example. The goal of a PC clone designer is to make the lowest-cost compatible system. With the use of chip sets and standard products, the system designer can get the same features as in a gate array to make the system compatible without paying the $15,000 to $75,000 NRE fees associated with each gate array.

Dataquest believes that more high-volume gate array applications will be recognized over the next five years and will be lost to chip sets. ASIC suppliers must counter this trend by also offering chip sets and standard products.

Table 1 illustrates the forecast saturation of logic chip sets in personal computers over time.

DATAQUEST CONCLUSIONS

Although Dataquest still believes that gate arrays will remain the dominant ASIC technology over the next decade, we expect overall gate array design start growth to be modest. Key products encroaching on gate arrays include FPGAs, cell-based ICs (CBICs), and chip sets/standard products. Gate array design start growth is slowing not only because of encroaching products but also because of increasing integration per chip.

What does all of this mean for the future ASIC suppliers? They must form close relationships with the end users so they can determine what standard products to offer and what cell libraries to build. We believe that suppliers and users will look toward embedded arrays for increasing integration (i.e., megacells such as RAM and RISC microprocessors embedded in gate array base wafers). BiCMOS will be the new frontier for future ASIC suppliers. Hard times may be ahead for many gate array suppliers as a result of low or negative margins. Service will rise in importance as gate array designs become more scarce.

Bryan Lewis

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Research Newsletter

MIXED-MODE ASICs: AN EDUCATIONAL CRISIS!

SUMMARY

The search for higher levels of integration continues at a fever pitch. Since the advent of the semiconductor era, system designers have looked for functions that can be integrated economically into a minimum number of devices. This effort spawned the evolution from single transistor devices, to small-scale integration (SSI) devices of less than 100 transistors, to today's ultralarge-scale integration (ULSI) devices of more than 1 million transistors.

Until now, the focus of the integration movement has been primarily digital logic components. As a result of this focus, the integration of pure digital logic is fairly well understood and has been widely implemented. Because of this success, the search for other functions that can be integrated has broadened in scope, pinpointing analog as the next focus of the integration movement. This focus is generating an increasing demand for ASICs that mix digital and analog functions on the same IC. Unfortunately, this demand is well ahead of the tools, testers, and user-based mixed-mode design and test expertise required before mixed-mode ASICs will have a significant impact on the ASIC market. A major educational program is necessary to retrain today's digital design experts to become mixed-mode design experts. Also, universities must incorporate mixed-mode design into their engineering curriculums.

A MEASURE OF PROGRESS

Advances in both IC manufacturing technology and development tools have allowed IC manufacturers to offer digital ASICs with extremely high density. These advances have provided system designers with the ability to integrate unprecedented amounts of digital logic into a minimum number of devices.

The personal computer is a good indicator of the advances made in integrating digital logic. As is shown in Figure 1, in 1984 an AT personal computer motherboard used 125 standard logic devices and 7 ASICs. A 1989 version of the AT, as shown in Figure 2, uses only 9 standard logic devices and 9 ASICs. This evolution represents more than an order-of-magnitude decrease in the standard logic component count as well as a 75 percent reduction in total board space.

Included in the standard logic parts count are drivers and buffers that typically are not integrated into an LSI component. Included in the ASIC parts count are three PLDs used for decoding and other specialty functions that are not easily integrated. Clearly, as there is very little standard logic left to integrate, system designers must look elsewhere if they wish to continue on the integration path.

WHAT'S NEXT?

The personal computer motherboard example illustrates a general industry trend toward digital integration. It applies equally well to add-in cards or systems that require both digital and analog functions. However, while the board space required to implement logic functions has been shrinking dramatically, the space required by the analog elements—such as converters and interface circuits—has remained relatively constant. Consequently, analog components use an increasingly larger percentage of a given system's board space. System designers now are faced with the problem of how to reduce the board space required by these analog components.

When they are used for interface functions such as converters or level shifters, analog components are tied quite closely to the digital logic operating on the converted data. Each device is optimized for its particular function. In these types

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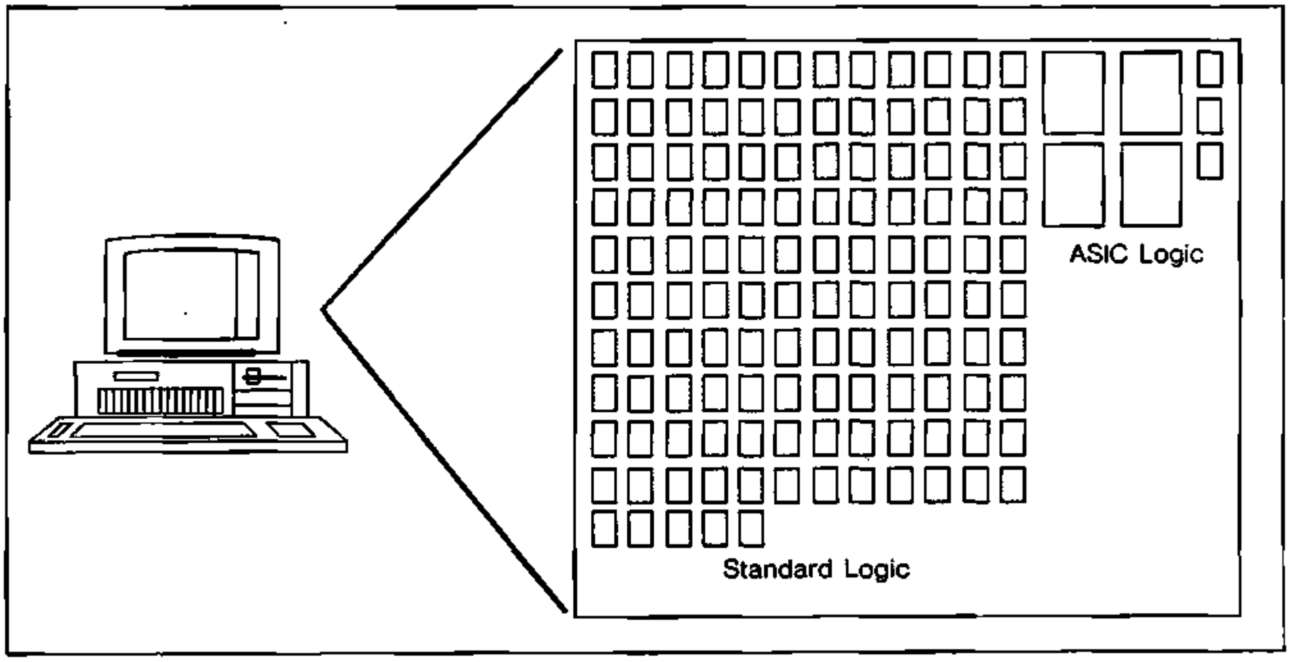
FIGURE 1
AT Personal Computer Logic Components—1984



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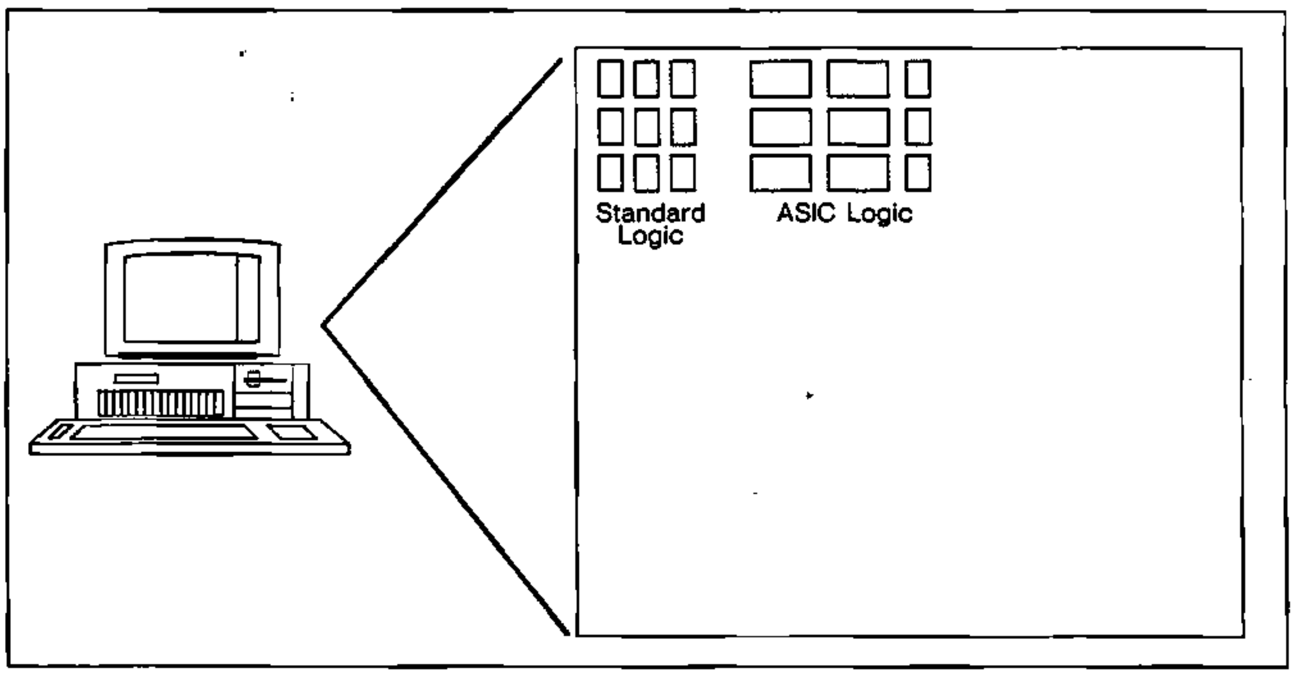
October 1989

FIGURE 2
AT Personal Computer Logic Components—1989



0005234-2

Source: Dataquest
October 1989

of applications, it is difficult to envision large analog ASICs partitioning all analog functions into one or two devices that are separate from the digital logic devices.

System partitioning is much more straightforward if the analog and digital functions can be integrated together. If we assume that the traditional benefits of integration apply to products mixing analog and digital functions, we will continue to see systems that are smaller, cheaper, faster, more powerful, and more reliable.

"Obvious" Answers Are Not Always Easy

This conclusion is, of course, "obvious" to everyone; many industry observers are expecting mixed-mode ASICs to achieve spectacular growth rates. However, the path to mixed-mode ASICs is fraught with fundamental problems yet to be overcome. Among these problems are the following:

- Mixed-mode development tools
- Mixed-mode testers
- Mixed-mode test methodology
- Mixed-mode design expertise

Although they are still in their infancy, progress is being made in the areas of mixed-mode tools and testers. Start-up companies and divisions of larger companies have dedicated significant resources to solving the problems. As a result, tools are available for an experienced analog designer to design a mixed-mode ASIC. However, these ASIC designs are primarily full-custom designs because of the amount of tweaking required in design and layout. Mixed-mode testers are becoming available now; however, testing still requires a tremendous amount of interface between supplier and user.

Education, Education, Education

Overcoming the third and fourth problems—mixed-mode test methodology and limited mixed-mode ASIC design expertise—are more difficult and challenging tasks. These two problems can be overcome only by retraining the existing design community and directing the universities to broaden their engineering curriculums to include all phases of mixed-mode design and test. This retraining is essential for the broad-based use of mixed-mode ASICs. The growth of mixed-mode ASICs will be affected directly by the speed with which mixed-mode ASIC design and test expertise can diffuse into the realm of ASIC designers.

No Quick Fixes, No Gimmicks

Although the development of efficient mixed-mode ASIC design and test tools is essential to grow the mixed-mode ASIC market, these tools will serve only to make today's designers more efficient. By themselves, tools cannot turn today's broad base of digital design experts into mixed-mode design experts. Educating designers in the fundamental basics of mixed-mode design and test is essential to capitalize on the market demand for mixed-mode ASICs. Those companies—both suppliers and users—that do not act to remedy the problem will be left behind in the race for faster, cheaper, smaller, and more powerful electronic systems.

DATAQUEST CONCLUSIONS AND RECOMMENDATIONS

Dataquest believes that education must be provided by the users, the suppliers, and the universities. Users must utilize their in-house analog design talent to bring their digital designers up to speed and gain an advantage over their competition. Suppliers must train their customers in mixed-mode design and test techniques if they want to stimulate growth of the mixed-mode ASIC market. And universities must realize that the time for purely digital designers has passed; their engineering graduates must be technically versed in mixed-mode design methodology.

Today's designers must be conversant in both digital logic and analog design. They also must be aware of the problems and/or techniques of mixing both technologies on the same substrate. Once the basic principles are understood, the tools are essential to improve efficiency. Until this occurs, each mixed-mode design will be a costly and time-consuming event.

Jerry Banks

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Research *Bulletin*

ASIC TRENDS OF THE 1990s

Application-specific integrated circuits (ASICs) are transforming the IC industry. System designers now can incorporate the microprocessor, memory, and logic on a single chip, thus reducing the size and cost of the system while improving its performance and reliability.

This research bulletin highlights the most important potential ASIC trends of the 1990s and presents a new ASIC forecast. Each of the following ASIC trends will be explored in depth by Dataquest analysts in subsequent ASIC newsletters:

- BiCMOS ASICs will be the new frontier for future ASICs; they blend the speed of bipolar with the density and low power consumption of CMOS.
- Complex PLDs such as field programmable gate arrays (FPGAs) and programmable multilevel logic devices (PMDs) will be viewed as low-risk entries into ASICs as well as nice prototyping tools. We believe that complex PLD pricing will continue to decline at a rapid rate, closing the gap on gate array pricing and thus increasing their cost-effectiveness in low- to medium-volume applications.
- System designers are demanding on-board cache memory and increased performance, which will fuel the growth for embedded arrays (megacells embedded in a gate array base wafer) and cell-based ICs.
- RISC will be the ASIC microprocessor of choice as system designers tailor their system designs to specific applications.
- As system designers strive toward single-chip system solutions, 100,000-gate ASICs will become popular.
- Reducing on-chip interconnect delays will increase in importance as ASIC suppliers move toward submicron geometries.
- ASIC suppliers will need to support open-architecture electronic computer-aided engineering (ECAE). System designers have a long list of demands including multilevel simulation (VHDL combined with gate level), seamless integration across all ECAE products (common databases), and top-down hierarchical design tools (logic synthesis in combination with logic optimization).
- Test will become a critical issue as densities climb, and we believe that JTAG will become an industry standard.
- Packaging also will be a critical issue for high-density products. We believe that suppliers must exploit state-of-the-art packaging technology now or they will not be well positioned for the 1990s.

Table 1 shows Dataquest's new ASIC forecast. The forecast includes NRE revenue, CAD software revenue, intracompany revenue (internal sales), and device production revenue. This forecast does not include the captive manufacturing of companies such as Digital Equipment, IBM, and Unisys that do not sell to the merchant market.

This list of trends proves that ASIC suppliers and users, as well as Dataquest analysts, have many issues to address in the 1990s. The ASIC market has rewards for those who effectively address the issues in a timely manner.

Bryan Lewis
Brand Parks
Jerry Banks

SIS Newsletters 1989 ASIC

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TABLE 1
Estimated Worldwide ASIC Consumption by Technology (Millions of Dollars)

	1987	1988	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Total ASIC	$6,173.4	$7,453.7	$8,736.8	$9,371.7	$11,450.4	$14,130.1	$17,353.7	$19,647.0	17.6%
MOS	4,362.7	5,367.9	$6,435.5	6,899.9	8,432.2	10,365.3	12,517.6	13,818.7	16.5%
Bipolar	1,769.7	1,998.0	2,122.7	2,140.4	2,389.1	2,599.2	2,785.9	2,941.2	6.7%
BiCMOS	41.0	87.8	178.6	331.4	629.1	1,165.6	2,050.2	2,887.1	74.5%
Gate Arrays	$2,274.9	$2,992.5	$3,766.0	$4,303.6	$ 5,573.4	$ 7,187.4	$ 9,198.5	$10,641.9	23.1%
MOS	1,408.8	1,940.5	2,500.4	2,798.2	3,634.6	4,612.9	5,716.8	6,400.0	20.7%
Bipolar	825.1	965.2	1,092.0	1,193.0	1,360.7	1,533.9	1,712.8	1,889.2	11.6%
BiCMOS	41.0	86.8	173.6	312.4	578.1	1,040.6	1,768.9	2,352.7	68.4%
Programmable Logic	$ 483.0	$ 670.0	$ 816.0	$ 872.0	$ 1,119.0	$ 1,463.0	$ 1,871.0	$ 2,098.0	20.8%
MOS	79.0	163.0	301.0	419.0	600.0	927.0	1,344.0	1,595.0	39.6%
Bipolar	404.0	507.0	515.0	453.0	519.0	536.0	527.0	503.0	(0.5%)
Cell-Based ICs	$ 949.5	$1,266.2	$1,551.0	$1,753.1	$ 2,298.9	$ 3,094.4	$ 3,994.3	$ 4,731.7	25.0%
MOS	912.9	1,214.4	1,481.5	1,659.4	2,153.9	2,843.1	3,553.8	4,015.8	22.1%
Bipolar	36.6	50.8	64.5	74.7	94.0	126.3	159.2	181.5	23.0%
BiCMOS	0	1.0	5.0	19.0	51.0	125.0	281.3	534.4	154.6%
Full-Custom ICs	$2,466.0	$2,525.0	$2,603.8	$2,443.0	$ 2,459.0	$ 2,385.3	$ 2,289.9	$ 2,175.4	(3.5%)

Source: Dataquest
October 1989

Workstations

Performance continues to increase at the high end of the workstation market, while price wars are being fought at the low end. Workstations implementing reduced-instruction-set computing (RISC) technology are forecast to overtake complex-instruction-set computing (CISC) by 1993. The systems using RISC will represent 61 percent of the total workstation revenue in 1993.

Most major workstation vendors announced a lower-priced system this year. As a result, competition is fierce in the entry-level workstation segment. In September 1989, Apollo Computer announced a low-end 68030 workstation, with prices beginning at approximately $4,000. This is the lowest-priced 68030 workstation available today, and it is also the first product announced by Apollo since its merger with Hewlett-Packard.

Digital Equipment is notifying the industry that it is committed to UNIX and RISC by announcing a family of RISC workstations. Digital is now the leader in performance/price ratio for RISC workstations, except for Data General.

In August 1989, Stardent was born with the merger of Ardent and Stellar. Stardent plans to have a unified product line with a single instruction set by early 1991.

Sun Microsystems, Inc., announced a $20 million loss for its fourth quarter of fiscal 1989, which ended in June. This is Sun's first stumble. Sun also revamped its product line. More emphasis is placed on Sun's SPARC products, while the 68xxx product family is positioned less aggressively. The SPARC family represents approximately 28 percent of 1989 fiscal year sales.

Personal Computers and Personal Computer Software

Dataquest estimates that worldwide PC shipment growth will continue at 9 to 10 percent for 1989 to 1990 (see Table 4). European growth will exceed that of the United States. So far this year, many vendors are showing increased sales over the same quarter last year.

Table 4

Personal Computers
Estimated Worldwide Revenue
(Billions of Dollars)

	1989	1990	1993	CAGR 1989-1993
Less than $10,000	$64.4	$75.6	$110.5	14.5%

Source: Dataquest
November 1989

The battery-powered true portable PC market continues to be the fastest growing segment of the market, fueled by recent introductions of lightweight, powerful notebook-size portables from Compaq, Grid, and Zenith Data Systems. Introduction of a laptop computer by Apple Computer, Inc., coupled with MS-DOS-based hand-held PC announcements from Atari, Inc., and Poqet also have excited this growth.

The MCA and EISA debate will continue, now with many more products available. We expect at least 11 vendors to introduce EISA machines and more than 16 vendors to show MCA clones at the fall Comdex show this year. Intel's 486-based machines will be news during the last quarter, with at least 10 vendors introducing 486 based systems. We expect all of these initial systems to be either EISA or MCA.

Most PC vendors enjoyed record sales in 1988; however, gross margins dropped because of extreme price cutting in the 80286 market. In 1989, many vendors are showing increased sales over the same quarter in 1988; however, profits are lower. We expect this margin issue to continue, as the channel continues to tighten. To successfully compete during 1990, vendors must find ways to differentiate their products from the competition. New technology has been the traditional vehicle for product differentiation. Although we will continue to see technological advances, success in the 1990s will be dictated by a vendor's ability to differentiate via effective marketing and service programs.

In PC software, growth rates are diminishing in the more mature market segments—such as spreadsheets, database, and word processing. Supplemental software—such as analyzers and utilities—is showing high growth. The Dataquest five-year forecast for PC software is shown in Table 5.

Table 5

Personal Computer Software
Estimated Worldwide Revenue
(Billions of Dollars)

	1989	1990	1993	CAGR 1989-1993
Productivity	$12.0	$14.5	$24.0	18.9%
Business	4.9	5.9	11.1	22.7%
Instructional	0.8	0.8	0.9	3.0%
System	8.1	10.1	19.0	23.8%
Entertainment	0.9	1.0	1.7	17.2%
Technical Engineering/Scientific	2.9	3.6	5.3	16.3%
Total	$29.6	$35.9	$62.0	20.3%

Source: Dataquest
November 1989

Applications of OS/2 that demonstrate clear ease of use and productivity advantages to the end user are becoming available quickly. Aldus PageMaker is an excellent example. The development of strategic applications is the driving force behind the adoption of OS/2 in large corporations, both in the United States and Europe.

The recent alliance of Apple and Microsoft, regarding computer typography, prepares the way for Apple's entrance into the lower-cost computer market. We expect a Macintosh priced at approximately $1,000 to be introduced next year.

The home PC market has grown significantly this year, fueled primarily by both increased computer literacy and decreased prices for more powerful systems. We expect this trend to accelerate. Dataquest survey results document a surprising increase in multimedia applications, especially in music applications.

UNIX Systems

Worldwide revenue for UNIX continues to grow strongly, especially in non-U.S. markets. From a negligible market share in 1986, growth increased dramatically and will continue to increase in 1989. See Table 6 for Dataquest's forecast for the UNIX market.

Table 6

UNIX Systems
Estimated Worldwide Revenue
(Billions of Dollars)

	1989	1990	1993	CAGR 1989-1993
Corporate Resource	$ 1.1	$ 1.6	$ 2.3	20.2%
Business Unit	2.1	2.7	4.1	18.2%
Large Department	2.6	3.2	5.0	17.8%
Small Department	4.5	6.3	7.5	13.6%
Work Group	6.0	6.8	8.8	10.0%
Single-User Enhanced	5.3	7.8	14.0	27.5%
Personal Computer	0.7	0.9	1.2	14.4%
Total	$22.3	$29.3	$42.9	17.8%

Source: Dataquest
November 1989

The Open Software Foundation is determining whether it will be able to incorporate Carnegie Mellon University's Mach into OSF/1. This incorporation would achieve the multiprocessing and increased security demanded by OSF members.

The talk from AT&T is about spinning out the UNIX Software Organization (USO) as an independent company. In order to become more profitable, USO decided to raise the UNIX licensing fees for System V, Release 4. The terms of the license fees make UNIX less expensive for PC users and low-end workstation manufacturers. However, many high-end workstation, mainframe, and supercomputer manufacturers facing fees that are 1 percent of the hardware costs will be angry.

The graphical user interface debate has heated up as Motif and Open Look proponents take sides. Motif currently has the edge in the number of companies who have chosen to implement it.

PERIPHERALS

Electronic Printers

The 1989 electronic printer markets have performed as Dataquest forecast last spring, showing an overall growth of 10 percent in terms of units and 12 percent for revenue. Page printers have overtaken serial printers in revenue and growth continues as forecast. Ink jet printers continue their high growth rates. Table 7 shows the Dataquest five-year forecast for electronic printer sales.

Table 7

Electronic Printers
Estimated Worldwide Revenue
(Billions of Dollars)

	1989	1990	1993	CAGR 1989-1993
Serial	$ 9.3	$9.8	$10.0	1.8%
Line	2.3	2.3	2.3	0
Page, Nonimpact	7.4	8.7	13.3	15.8%
Total	$19.0	$20.8	$25.6	7.7%

Source: Dataquest
November 1989

The new 24-wire dot matrix printers are gaining on the 9-wire ones, although not as quickly as expected. Lower-priced (approximately $500) 9-wire printers are showing higher growth rates than expected. The market for 24-wire printers appears to be affected by the sale of nonimpact printers, such as ink jet and low-end laser printers.

Hewlett-Packard Company's announcement of the LaserJet IIP on September 17, 1989, is a significant change to the low-end page printer market. Dataquest anticipated such a new class of 10 to 12kg page printers at approximately $1,500 at its conferences last year in Vienna and Tokyo and early this year in Monterey. The price of the IIP puts it squarely in competition with high-end dot matrix and ink jet printers, threatening the market niches those technologies had captured. Page printer revenue surpassed that for dot matrix printers in 1988 for the first time; HP's new entry will widen the gap further.

Networking, high resolution, and color are still the features to watch, as indicated last spring. Better distribution and software support strategies are still the most important marketing issues. Lower prices will force vendors to concentrate on niche markets, with higher volumes of lower-margin printers. Vendors using a two-tier distribution strategy are experiencing tremendous margin pressure from low-priced nonimpact printers that are making their way to the end user via single-tier distribution.

Sales of page printers will continue to surge in 1990, at the expense of all other technologies. Competitors will be hard pressed to match the IIP's price and performance ratio, but such matching will be the price of staying in the market. Many more significant announcements of low-end page printers are expected in the months ahead.

Computer Storage

Dataquest's forecast for the computer storage industry remains unchanged. Events since the spring have confirmed the forecast made then. The five-year Dataquest forecast for computer storage sales is shown in Table 8.

Table 8

Computer Storage
Estimated Worldwide Revenue
(Billions of Dollars)

	1989	1990	1993	CAGR 1989-1993
Rigid	$35.4	$39.8	$50.4	9.2%
Flexible	4.8	4.8	5.3	2.4%
Tape	6.9	7.6	8.0	3.8%
Optical	1.1	2.2	9.6	72.9%
Total	$48.2	$54.4	$73.3	11.0%

Source: Dataquest
November 1989

The overcapacity in the rigid disk drive markets has eased, as expected. It now appears that revenue for rigid disk drives will be within 4 percent of Dataquest's forecast for 1989. The recent introduction of a 320-megabyte, 3.5-inch disk drive from IBM has raised the ceiling for PC storage capacity. OEM pricing has stabilized. Disk arrays are coming to market.

In the flexible disk drive market, 20- to 40-megabyte drives are emerging. They have the potential to impact or replace the low-end tape market for data backup.

Optical drives continue to be the hottest portion of this market, with CD-ROMs leading the way. Although the U.S. government requested price bids for write-once, read many (WORM) drives, which are sorely needed to replace tons of paper files, no contracts have been awarded. The federal deficit situation must be clarified before purchases can be expected. Erasable optical drives are here, but, priced at approximately $6,000, they are too expensive for the bulk of the PC market.

Digital audio tape (DAT) is available but is still too expensive for the PC market. Although DAT can store up to 1.3 gigabytes, the data transfer rate is slow. These tapes may find a niche in the minicomputer market. The value of IBM's 3490 half-inch cartridge tape at $55,000 leaves the future unclear for the 3480, which is currently doing well. Reel-to-reel half-inch tape is finding a niche in the PC-to-mainframe data exchange area. Tape backups for PC in the 60-megabyte and 150-megabyte range will be the biggest sellers through 1990.

Display Terminals

Dataquest's forecast for display terminals continues to show growth in shipments for 1989, 5.1 percent over 1988, and a decline of 3.5 percent in revenue for the same period. These numbers compare to the growth between 1987 and 1988 of 3.1 percent in shipments and 1.1 percent in revenue. Display terminal sales as forecast by Dataquest are shown in Table 9.

Table 9

Display Terminals
Estimated U.S. Revenue
(Billions of Dollars)

	1989	1990	1993	CAGR 1989-1993
Minicomputer-Based	$0.90	$0.80	$0.40	(18.4%)
Non-IBM, Protocol-Specific	0.04	0.03	0.01	(29.3%)
IBM 3270-Compatible	1.20	1.10	0.60	(15.9%)
Nonhost-Specific	0.60	0.60	0.30	(15.9%)
Processing	0.20	0.30	1.10	53.1%
Total	$2.94	$2.83	$2.41	(4.8%)

Source: Dataquest
November 1989

Minicomputer-specific terminals are slightly ahead of plan for reaching the Dataquest forecast for 1989 of 942,000 units shipped. Digital remains the leader in this segment, with 126,200 units shipped during the first half of 1989, which represents 28.9 percent market share.

Unisys and Bull display terminals are well ahead of plan to reach our forecast for the year. Unisys remains the dominant leader, with 58.2 percent market share on shipments of 20,900 for the first half of 1989.

Sales of IBM 3270-type terminals are expected to improve during the second half of 1989 because of new product announcements by IBM. At midyear, the industry was behind forecast shipments on a volume of 336,100. IBM retains its strong leadership in this market, with 50.3 percent share. Memorex Telex is gaining strength, with a market share of 28.6 percent.

Host-independent/independent manufacturer terminals are slightly behind targeted midyear shipments when measured against the 1989 forecast. Shipments for the first half of the year were 530,800. Wyse Technology and its subsidiary, Link, continue to dominate this segment, with 50.4 percent market share.

Processing terminal shipments are well below expectation for the first half of 1989. This is partly the result of the lack of leadership in this segment. Dataquest now expects shipments for the year to be well below the original estimate of 102,000.

COMPUTER-INTEGRATED MANUFACTURING

The computer-integrated manufacturing (CIM) forecast remains unchanged based on the past six months' events. Computer and controller revenue will continue to slow as we originally predicted, as microprocessors and desktop computers become the primary hardware platforms.

Dataquest forecasts a higher rate of software growth for North American vendors. The market is less global in nature than the hardware or networking CIM segments. The more parochial software market is primarily due to language barriers between cultures. In addition, software development typically lags behind hardware development by several years.

The trend will be toward the purchasing of boxes, boards, and software from many different vendors versus users purchasing bundled solutions. This trend will allow a more customized product, because no one vendor's offering is the best solution for every customer. Table 10 displays Dataquest's five-year forecast for the CIM market.

Table 10

Computer-Integrated Manufacturing
Estimated Worldwide Revenue
(Billions of Dollars)

	1989	1990	1993	CAGR 1989-1993
Computer Products	$11.8	$12.8	$17.1	9.7%
Software	5.9	6.8	10.9	16.6%
Network and Data Collection	2.1	2.6	4.7	22.3%
Service	4.0	4.5	6.4	12.5%
Total	$23.8	$26.7	$39.1	13.2%

Source: Dataquest
November 1989

TELECOMMUNICATIONS

Mergers, acquisitions, and alliances continue to be widespread throughout the U.S. telecommunications industry. Customer demands for service and support require larger resources than small companies can muster. See Table 11 for Dataquest's five-year forecast for the telecommunications market.

Table 11

Telecommunications
Estimated U.S. Revenue
(Billions of Dollars)

	1989	1990	1993	CAGR 1989-1993
PBX	$ 3.6	$ 3.7	$ 3.8	1.4%
Data Communications Equipment	7.8	9.9	13.4	14.5%
Call-Processing Equipment	1.3	1.5	1.9	10.0%
Facsimile Machines	2.0	2.3	3.2	12.5%
Video Conferencing	0.1	0.1	0.2	32.1%
Public Equipment	8.0	8.4	10.5	7.1%
Public Services	135.0	141.1	159.7	4.3%
Cellular Radio Services	3.4	4.7	7.6	22.3%
Total	$161.2	$171.7	$200.3	5.0%

Source: Dataquest
November 1989

Size alone, of course, does not guarantee success. The sale of ROLM Corporation from IBM to Siemens has been completed. IBM exchanged ownership responsibilities for a marketing arrangement with Siemens for worldwide distribution of PBX equipment. However, the PBX market is flat and will remain so.

Vendors of data communications equipment are increasingly turning to international markets, especially Europe. Worldwide standards, such as Integrated Services Digital Network (ISDN) and Open System Interconnect (OSI), are making the telecommunications market truly international. We expect ISDN-related revenue for equipment and services of $742 million in 1989 to grow to $1.3 billion in 1990, reaching $3.3 billion by 1993.

Facsimile machine revenue exploded in 1988. Revenue for 1989 still will be strong, although sales will not increase as dramatically as initially estimated.

The voice-messaging systems market continues to be a hot growth area, with an increase in sales of more than 65 percent in 1988. Further growth of more than 40 percent is expected in 1989, totaling $734 million in revenue. Annual growth then will moderate, with the market topping $1 billion by 1993. Recent regulatory changes permit Regional Bell Operating Companies (RBOCs) to offer voice-messaging services, which will mean even larger systems in this booming market.

The Very Small Aperture Terminal (VSAT) market is growing rapidly after some false starts. Forecast 1989 revenue of $322 million is expected to grow at a 24.7 percent compound annual growth rate to $778 million in 1993, as widely dispersed corporate operations are tied together by these private network tools.

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ARE LOW MANUFACTURING PRODUCTION COSTS REASON ENOUGH TO RELOCATE?

INTRODUCTION

Investing in a foreign country is neither a simple nor a trivial matter for a company. This newsletter assesses the hourly compensation costs for production workers in manufacturing industries for the United States and 23 foreign economies. Compensation in manufacturing is one piece of a critical decision-making puzzle for an organization to consider in moving offshore.

In 1988, for all 23 foreign economies included in this evaluation, the trade-weighted average cost level was 86 percent of U.S. costs (in U.S. dollars). Hourly compensation costs for the majority, but not all, of the countries reached new highs in 1988 relative to the United States.

THE BUREAU OF LABOR STATISTICS INFORMATION

The Bureau of Labor Statistics (BLS) has developed a methodology by which hourly compensation costs for production workers in 23 foreign countries can be compared with those in the United States. Although there is not an "apples to apples" relationship between compensation structures among the different countries, the BLS has applied trade weights to bring an acceptable level of consistency to the data. From 1975 through 1988, U.S. hourly compensation costs increased an average of 6.0 percent per year. In comparison, the 23 foreign economies increased an average of 9.6 percent for the same period. Figures 1 and 2 show costs in the electronic manufacturing industry for the United States, West Germany, Japan, and Korea.

Hourly compensation as defined by the Bureau of Labor Statistics is payments made directly to the worker before payroll deductions of any kind. This figure also includes any employer expenditures for legally required insurance programs and contractual and private benefit plans. Compensation is measured on an hours-worked basis. Hourly compensation is one of several costs considered when evaluating total compensation.

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Changes in hourly compensation costs measured in U.S. dollars for foreign countries also reflect fluctuations in the exchange rate to the U.S. dollar. As a result, for the 23 subject economies, hourly compensation costs increased from 64 percent of the U.S. cost level in 1975 to 73 percent in 1980, decreased to 57 percent in 1985, then increased sharply to 86 percent in 1988.

Europe

In Europe, for example, average hourly compensation costs rose from 82 percent of the U.S. level in 1975 to 102 percent in 1980, then fell to 62 percent by 1985, reflecting the appreciation of the dollar. In 1988, European hourly compensation costs rose to an all-time high of 105 percent, largely as a result of the depreciation of the dollar between 1985 and 1988.

Japan

Japan has sustained moderate hourly compensation costs relative to those in the United States. This trend has been supported by a strong Japanese currency exchange rate, which was stronger than those of the other economies covered. From 1975 to 1980, Japanese hourly compensation costs rose from 48 percent to 57 percent of U.S. costs. In 1985, costs declined to 50 percent and then climbed dramatically to 91 percent by 1988.

Korea and Taiwan

Korea and Taiwan, countries traditionally known for low hourly production costs, are experiencing a rise in costs. The increase is related to the exchange rate values of the Korean won and the Taiwan dollar, which are also climbing. Since 1980, Korea maintained hourly production costs at an average of 11 percent of U.S. costs. Between 1987 and 1988, costs increased from 13 to 18 percent, the largest jump for these countries in the 13-year time span analyzed here.

DATAQUEST ANALYSIS

Although low hourly production costs are attractive at face value, they must not be considered in a vacuum. Dataquest believes that it is imperative to investigate the details of foreign trade barriers before making a decision to relocate an operation offshore. Types of foreign trade barriers are the following:

- Import policies
- Standards, testing, labeling, and certification
- Government procurement
- Export subsidies

- Lack of intellectual property protection
- Service barriers
- Investment barriers
- Barriers that encompass more than one category listed above or that affect a single sector

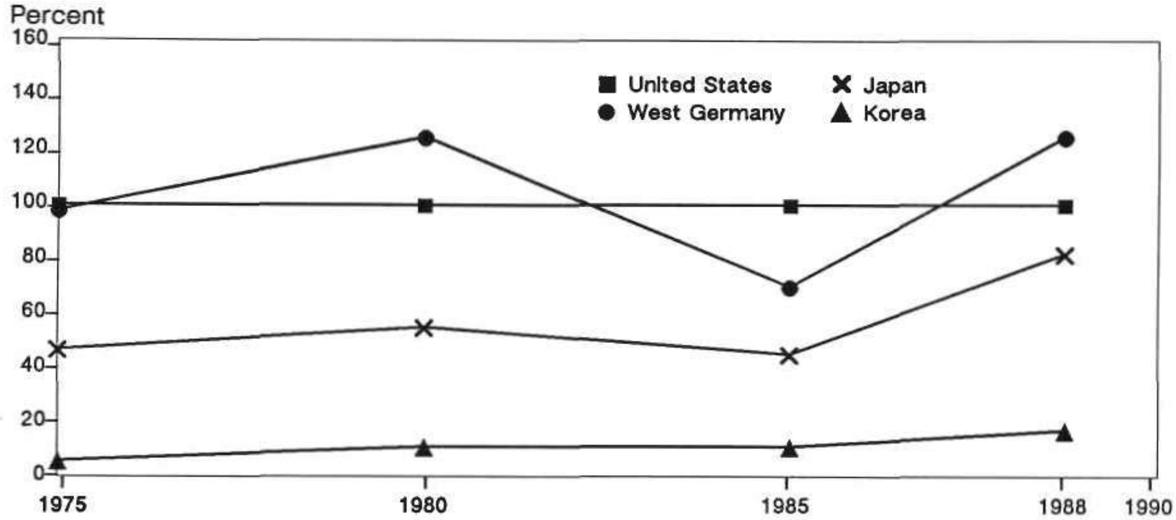
Companies giving serious thought to relocating business and/or manufacturing operations offshore must identify the strengths and weaknesses in a country's business and trade operations. Strong consideration must be given to the impact that language barriers will have on inter- and intracompany communications. Also, Dataquest believes that distance can cause unavoidable delays between the design and manufacturing phase for new products. The organization must determine its long-term objective. Is the move offshore being made to lower manufacturing costs or to become a part of the local market, i.e., manufacture in Europe to be in a better position to sell in Europe?

In moving operations to a foreign country, what may appear to be an inexpensive road may have costly pitfalls along the way.

Bernadette Cesena

Figure 1

Hourly Compensation Costs for Production Workers*
Electric and Electronic Equipment Manufacturing**
(Percentage)



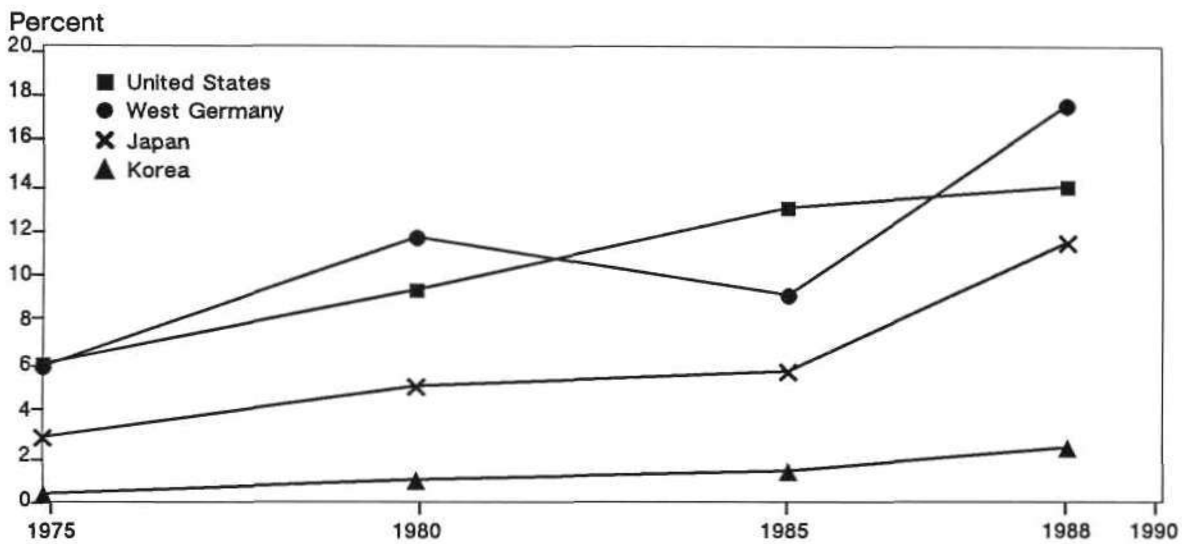
*Index: U.S. = 100
**Standard Industrial Code 36

0005445-1

Source: Dataquest
November 1989

Figure 2

Hourly Compensation Costs for Production Workers
Electric and Electronic Equipment Manufacturing*
(U.S. Dollars)



*Standard Industrial Code 36

0005445-2

Source: Dataquest
November 1989

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Research Newsletter

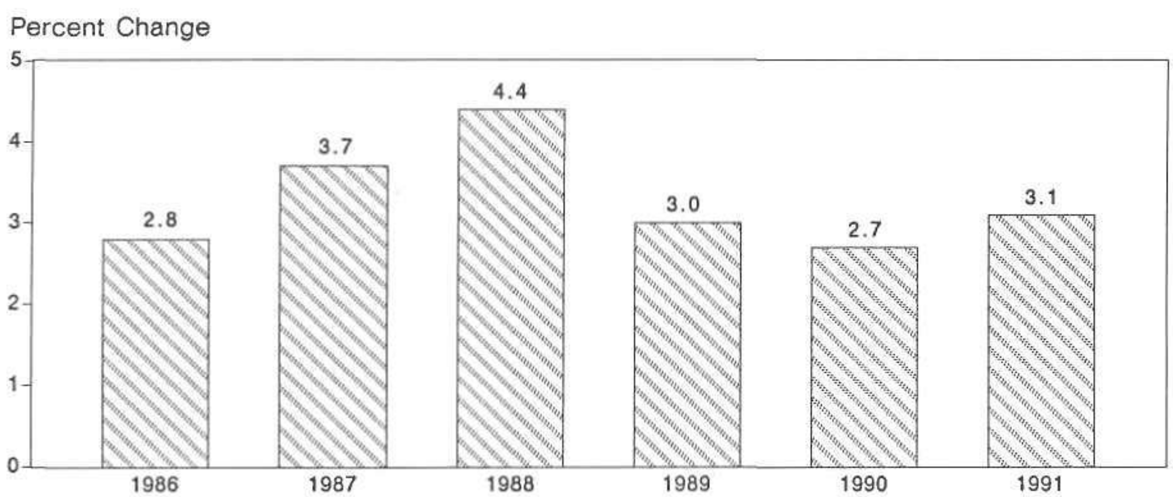
ECONOMIC OUTLOOK: THE ECONOMY HAS LANDED

SUMMARY

Real U.S. Gross National Product (GNP) growth is forecast to be 3.0 percent in 1989 and 2.7 percent in 1990 (see Figure 1). Quarterly growth is expected to decelerate through the end of this year and slowly pick up in the first quarter of 1990. Lower interest rates in 1990 should stimulate household expenditures on consumer durables and business investment in plant and equipment. As the investment climate improves, Dataquest expects electronic equipment production to follow suit, growing at a 6.4 percent pace in 1990, up from 6.1 percent this year.

Figure 1

Real GNP Growth



0005255-1

Source: The Dun & Bradstreet Corporation

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BETTER SHAPE THAN WE THOUGHT

GNP data, recently revised by the U.S. Commerce Department, indicate that during the period between 1986 and the first quarter of 1989, the economy was almost $30 billion larger than previously reported. Most of this increase was in the balance of trade, and most of that was due to an improvement in exports. The revision reflects two things. The first is a broader definition of exports that now includes more financial and business services trade (e.g., accounting and consulting). The second thing the revision shows is that consumer and investment spending increased slightly and, significantly, inventories accumulated at a much slower pace.

Slower inventory growth reduces the probability of any significant downward correction in the remainder of the year. Because inventory corrections typically trigger recessions, the likelihood of a recession beginning any time soon is less than previously expected.

THE U.S. ECONOMY, NOW ARRIVING AT GATE...

The soft landing is a situation where economic growth decelerates but remains positive enough to avert a recession, although slow enough to bring about a reduction of inflation. Second-quarter real GNP grew at a 2.5 percent annual rate, well within the nonaccelerating-rate-of-inflation growth range. This rate was lower than the 3.0 percent growth in the second quarter of 1988. Recent price indexes also show that inflation has stabilized. Thus, both requirements of the soft landing have been met, at least for the time being. Now that we've landed, how long is this stopover going to last? What's the economy's next flight plan?

DEPARTING FOR...

The latest Dun & Bradstreet forecast calls for real U.S. GNP growth to slow further this year, at 2.4 percent and 2.0 percent rates in the third and fourth quarters, respectively, putting 1989 annual growth at 3.0 percent, down from 4.4 percent in 1988.

If recent interest rate decreases are sufficient to stimulate spending without touching off a flight from dollars—and the recent strength in the dollar indicates that this is indeed happening—then the economy's next takeoff is scheduled for the first quarter of 1990. We forecast real growth of 2.3 percent in the first quarter of 1990, accelerating to 3.1 percent in the second. Third- and fourth-quarter growth are expected to be 4.1 percent and 3.7 percent, respectively, which would place 1990 annual growth at 2.7 percent over 1989.

DEMAND COMPONENTS

Consumer Expenditures

The outlook is for a modest pickup in spending. Growth has been slowing each quarter since the beginning of 1988, yet consumer confidence in the economy remains relatively optimistic. Rising interest rates were responsible for this slowdown in 1988. More recently, however, weakening spending has been attributable to increases in personal tax payments resulting from deferrals of income from 1986 and 1987 into 1988 and to a spurt in food and energy prices earlier this year. In 1990, tax rates still will increase, but only slightly, and expected lower interest rates should ease consumers' debt burdens.

Investment Expenditures

Business investment spending should improve, but not dramatically. Capital spending remained strong throughout the first half of 1989 following a period of weakness in late 1988. As in the consumer sector, lower interest rates should help stimulate this sector. However, the rally in the dollar that began last spring, if it persists, will make exploiting new export markets more difficult in 1990. Also, sharply higher (domestic) automobile prices will inhibit growth in this important area.

Government Expenditures

Last year, inflation-adjusted government expenditures fell primarily because of cutbacks in defense spending. This trend has accelerated this year and is likely to continue in 1990, given the (credible?) threat of across-the-board budget cuts, if Gramm-Rudman-Hollings deficit reduction goals are not met. Spending by state and local governments will provide some (minimal) stimuli, but their own fiscal problems will limit any significant offset.

Foreign Trade

Growth in net exports (i.e., exports less imports) also will stall compared with recent years. In 1988, net exports contributed $41 billion to real GNP growth; a $25 billion contribution is forecast in 1989. In 1990, the contribution is expected to continue to fall to less than $1 billion. Because of the recent appreciation of the dollar, export growth, while still healthy, is not likely to match the strong performance of the past two years. Meanwhile, as the economy takes off, the demand for imports will grow also.

DATAQUEST CONCLUSIONS AND RECOMMENDATIONS

Dataquest expects growth of business fixed investment in equipment to decelerate through the end of this year. Starting in the first quarter of 1990, however, we expect the pace of capital equipment spending growth to accelerate through the end of the year.

The faster rate of capital spending should, in turn, translate into a faster pace of growth in electronic-equipment production. We forecast the value of North American electronic equipment production to grow 6.1 percent in 1989, down from 6.6 percent growth last year and to grow 6.4 percent in 1990.

Notably, wide swings in growth are being moderated by manufacturers' efforts to keep a tight reign on inventories. Indeed, because equipment inventories are appropriate for the current lull in equipment shipments and orders growth, electronics manufacturers are well poised to take advantage of the quicker pace of business expected during the first half of 1990.

Until that time, however, Dataquest urges the manufacturing community to be vigilant in its commitment to run a lean, nimble shop and compete on intangibles such as customer service and satisfaction. This commitment is the surest bet to catch the next wave and the attendant market share.

Terrance A. Birkholz

Dataquest

a company of The Dun & Bradstreet Corporation

Research *Newsletter*

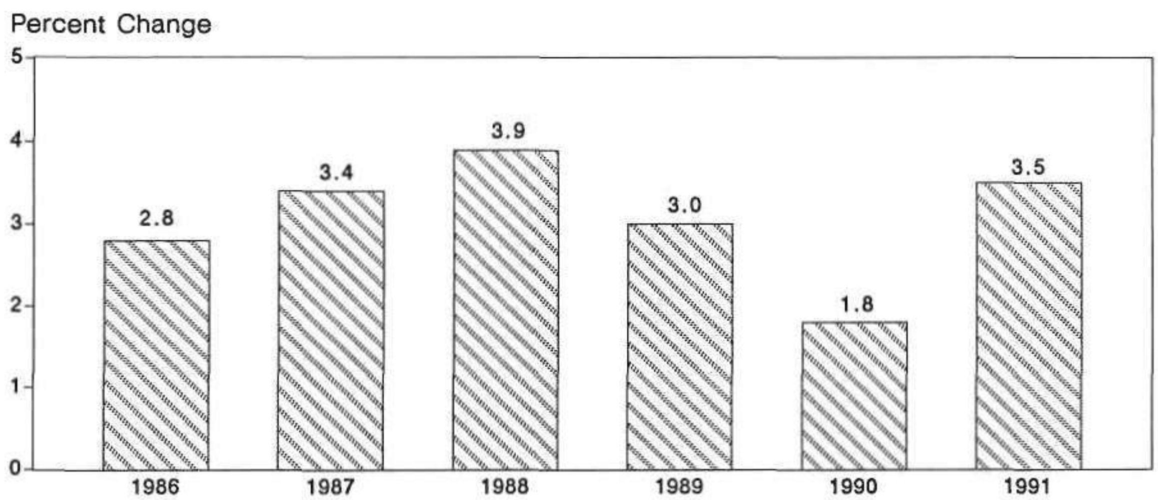
MIDYEAR ECONOMIC REVIEW AND OUTLOOK

SUMMARY

The U.S. economy has been growing continuously since November 1982--the longest U.S. economic peacetime expansion on record--and shows every sign of continuing well into its seventh year. Overall, no recession is foreseen, but an economic slowdown seems to be on the horizon. Real gross national product (GNP) growth in 1988 was 3.9 percent, an improvement from the 3.4 percent growth in 1987. A possible slowdown should result in growth rates of about 3.0 percent in 1989 and 1.8 percent in 1990, as shown in Figure 1. Beyond this, GNP growth is expected to accelerate to a 3.5 percent growth rate in 1991.

Figure 1

Real GNP Growth



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Source: Dun & Bradstreet Corporation

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Dataquest relies heavily on the economic analysis department of the Dun & Bradstreet Corporation, our parent company, to help us develop our economic forecast. A synopsis of D&B's economic outlook is discussed in this newsletter.

A SOFT LANDING IN OUR FUTURE?

Many economists are looking for evidence that the economy will experience a "soft landing" in the near term. This soft landing, which federal economic policy makers are trying to engineer, would involve a gradual slowing of economic growth without the onslaught of a recession. They believe that this policy would decelerate what appears to be recently quickening inflation, without endangering continuing economic growth.

To achieve a soft landing, the economy will have to slow from its strong 3.9 percent growth in 1988. Reduced job creation rates and consumer spending growth in the first half of 1989 indicate that a soft landing may be emerging. Inflation rates jumped upward earlier this year, creating anxiety among those who feared that the Federal Reserve Board would respond with higher interest rates. In retrospect, however, this recent acceleration in inflation is seen as transitory, the result of increases in oil and food prices. Thus, the deceleration-of-inflation component of the soft landing also appears intact.

Nonetheless, the export and investment sectors of the economy should remain relatively strong. Capital spending should continue growing at a healthy pace as manufacturers expand capacity. Also, merchandise exports, responsible for much of last year's growth, have reached new heights recently. The optimism reflected in a recent Dun & Bradstreet business expectations survey and a leveling-off of capacity utilization both suggest that there is room for exports to expand even further.

Continued investment and export growth will depend heavily on future interest rate levels and the dollar's foreign exchange value. The dollar rose about 10 percent against other major currencies from November 1988 to June 1989. A stronger dollar threatens the recent progress made on the trade deficit, because it makes imports relatively less expensive in the United States.

The strengthening dollar and falling interest rates are believed to be short-term aberrations. By year-end, it is likely that both the dollar and interest rates will be near their January levels. This is because the factors involved in this reversal are only temporary. Nothing has changed significantly in the fundamental factors, so long-term trends should predominate once again in the second half of this year.

Improvements in the merchandise trade deficit notwithstanding, the deficit probably will remain large due to increased imports--possibly $110 billion in 1989 compared with $120 billion last year. Furthermore, its position as a net debtor because of cumulative past deficits means that the United States now must service this debt. This mounting debt service now offsets most of the gains on the merchandise components.

The large trade deficit will continue to flood currency markets with dollars, which in turn should keep downward pressure on the dollar. As the dollar falls, however, interest rates are likely to increase, directly because of the Federal Reserve's attempts to stabilize and support the dollar, and indirectly because of some acceleration in inflation resulting from higher prices for imported goods.

Despite these factors, the economy should remain relatively healthy. Although a recession is not forecast, slower growth is expected this year and next year. Real GNP growth will likely slow from 3.9 percent in 1988 to 3.0 percent in 1989. Given the 4.5 percent annualized real GNP growth in the first quarter, a great deal of 1989's growth is believed to have occurred already in the first part of this year. Expected higher interest rates probably will impede growth in the second half of 1989, and growth should slow even further to 1.8 percent in 1990.

This growth path is consistent with the soft-landing expectation. However, as always, the economy is subject to unexpected shocks that could turn the soft landing into the crash landing of a full-blown recession.

THE GNP COMPONENTS

By 1991, the economy is expected to resume a quicker pace, rebounding with 3.5 percent growth. The following is an analysis of the outlook of GNP components. Statistical details of these components are shown in Table 1. Additional indicators of macroeconomic activity are given in Table 2.

Consumer Spending

Consumer expenditures constitute about two-thirds of real GNP. Recently, the volume of consumer expenditure growth has slowed because of slower income growth and higher prices for some goods. On average, 84 percent of consumer expenditures are relatively fixed items and services (e.g., food, clothing, shelter, and gasoline). Because their demand is relatively income inelastic, consumer spending growth in these areas should continue at nearly the current rates. On the other hand, spending for durable goods such as automobiles, furniture, and appliances is likely to slow. Because funds for these goods usually are borrowed, and with the outlook of higher interest rates that will raise finance costs, consumer spending on durables is likely to slow. But because only 16 percent of consumer expenditures are for durable goods, a major disruption in this sector probably will be avoided.

Investment

Dataquest predicts that equipment investment spending will be one of the strongest areas of the economy. Since many investment decisions are made 6 to 12 months in advance, the anticipated interest rate increases should not affect this sector until 1990, if at all. Stimulated by a cheap dollar and strong export demand, equipment sales to both domestic and foreign manufacturers should remain relatively buoyant. Until the dollar and interest rates stabilize, however, investment in additional plant capacity should lag somewhat. Residential investment also will remain flat as a result of higher interest rates. Inventory investment should slow by next year as manufacturers react to a riskier economic environment as a result of higher interest rates.

Table 1

Components of Real GNP and Nominal GNP (Billions of 1982 Dollars)

	Actual 1986	1987	1988
Consumption Expenditures	$2,455.2	$2,520.9	$2,592.2
Rate of Change (%)	4.2	1.9	2.8
Business Fixed Investment	$ 433.1	$ 445.2	$ 487.5
Rate of Change (%)	(4.5)	2.8	9.5
Residential Fixed Investment	$ 195.0	$ 195.2	$ 191.8
Rate of Change (%)	17.8	0.1	(1.7)
Government Purchases	$ 760.5	$ 780.2	$ 782.3
Rate of Change (%)	4.0	2.6	0.3
Change in Business Inventories	$ 15.5	$ 34.4	$ 42.5
Net Exports	($ 15.5)	($ 128.9)	($ 100.2)
Equals:			
Gross National Product (1982 $)	$3,721.7	$3,847.0	$3,996.0
Rate of Change (%)	2.8	3.4	3.9
Addendum:			
Implicit Price Deflator (Index, 1982 = 100)	114.0	117.7	121.7
Rate of Change (%)	2.7	3.2	3.4
Gross National Product (Current $)	$4,240.3	$4,526.7	$4,864.3
Rate of Change (%)	5.6	6.8	7.5

(Continued)

Table 1 (Continued)

Components of Real GNP and Nominal GNP
(Billions of 1982 Dollars)

	Forecast 1989	1990	1991
Consumption Expenditures	$2,662.1	$2,725.8	$2,812.6
Rate of Change (%)	2.7	2.4	3.2
Business Fixed Investment	$ 514.5	$ 537.1	$ 568.8
Rate of Change (%)	5.5	4.4	5.9
Residential Fixed Investment	$ 191.1	$ 187.9	$ 199.8
Rate of Change (%)	(0.3)	(1.7)	6.3
Government Purchases	$ 805.6	$ 812.2	$ 815.3
Rate of Change (%)	3.0	0.8	0.4
Change in Business Inventories	$ 31.0	$ 4.2	$ 19.8
Net Exports	($ 87.2)	($ 74.6)	($ 76.7)
Equals:			
Gross National Product (1982 $)	$4,116.9	$4,192.7	$4,339.8
Rate of Change (%)	3.0	1.8	3.5
Addendum:			
Implicit Price Deflator (Index, 1982 = 100)	127.6	134.1	140.3
Rate of Change (%)	4.8	5.1	4.6
Gross National Product (Current $)	$5,252.1	$5,623.7	$6,089.1
Rate of Change (%)	8.0	7.1	8.3

Source: Economic Analysis Department
The Dun & Bradstreet Corporation

Table 2

Major Macroeconomic Indicators

	1986	1987	1988
	Billions of Current Dollars		
Nominal GNP	$4,240.3	$4,526.7	$4,864.3
Rate of Change (%)	5.6	6.8	7.5
	Billions of 1982 Dollars		
Real GNP	$3,721.7	$3,847.0	$3,996.0
Rate of Change (%)	2.8	3.4	3.9
	Index, 1982 = 100		
GNP Deflator	114.0	117.7	121.7
Rate of Change (%)	2.7	3.2	3.4
	Billions of 1982 Dollars		
Real Disposable Income	$2,640.9	$2,686.9	$2,788.3
Rate of Change (%)	3.9	1.7	3.8
	Percent		
Personal Saving Rate	4.0	3.7	4.2
	Index, 1977 = 100		
Industrial Production	125.1	129.8	137.2
Rate of Change (%)	1.1	3.7	5.7
	Percent		
Capacity Utilization	79.7	81.0	83.5
Civil Unemployment Rate	7.0	6.2	5.5
	Millions Employed		
Employment, Establishment Basis	99.5	102.2	105.6
Rate of Change (%)	2.0	2.7	3.3

(Continued)

Table 2 (Continued)

Major Macroeconomic Indicators

	1986	1987	1988
	Billions of 1982 Dollars		
Real Final Sales	$3,843.8	$3,941.5	$4,053.7
Rate of Change (%)	3.5	2.5	2.7
	Billions of 1982 Dollars		
Private Domestic Demand	$3,083.3	$3,161.3	$3,271.5
Rate of Change (%)	3.4	2.5	3.5
	Billions of Current Dollars		
After-Tax Profits	$ 129.8	$ 137.8	$ 163.9
Rate of Change (%)	1.5	6.2	18.9
	Interest Rates (%)		
Federal Funds Rate	6.8	6.7	7.6
3-Month Treasury Bills	6.0	5.8	6.7
30-Year Treasury Bonds	7.8	8.6	9.0
	Index, March 1973 = 100		
FRB Exchange Rate	112.3	96.9	92.9
Rate of Change (%)	(21.6)	(13.7)	(4.2)
	Billions of Current Dollars		
Federal Surplus (Unified, Fiscal Year)	($ 221.1)	($ 149.0)	($ 155.0)
Rate of Change (%)	(5.8)	32.6	(4.1)

(Continued)

Table 2 (Continued)

Major Macroeconomic Indicators

	1989	1990	1991
	Billions of Current Dollars		
Nominal GNP	$5,252.1	$5,623.7	$6,089.1
Rate of Change (%)	8.0	7.1	8.3
	Billions of 1982 Dollars		
Real GNP	$4,116.9	$4,192.7	$4,339.8
Rate of Change (%)	3.0	1.8	3.5
	Index, 1982 = 100		
GNP Deflator	127.6	134.1	140.3
Rate of Change (%)	4.8	5.1	4.6
	Billions of 1982 Dollars		
Real Disposable Income	$2,866.4	$2,932.3	$3,034.9
Rate of Change (%)	2.8	2.3	3.5
	Percent		
Personal Saving Rate	5.5	5.8	5.3
	Index, 1977 = 100		
Industrial Production	142.3	145.9	151.5
Rate of Change (%)	3.7	2.5	3.9
	Percent		
Capacity Utilization	83.6	83.1	84.0
Civil Unemployment Rate	5.5	6.2	5.8
	Millions Employed		
Employment, Establishment Basis	108.2	109.5	112.9
Rate of Change (%)	2.5	1.2	3.2

(Continued)

Table 2 (Continued)

Major Macroeconomic Indicators

	1989	1990	1991
	Billions of 1982 Dollars		
Real Final Sales	$4,173.1	$4,263.1	$4,396.7
Rate of Change (%)	2.9	2.2	3.1
	Billions of 1982 Dollars		
Private Domestic Demand	$3,367.7	$3,450.8	$3,581.2
Rate of Change (%)	2.9	2.5	3.8
	Billions of Current Dollars		
After-Tax Profits	$ 172.1	$ 167.0	$ 179.5
Rate of Change (%)	5.0	(3.0)	7.5
	Interest Rates (%)		
Federal Funds Rate	9.5	9.0	8.5
3-Month Treasury Bills	8.3	8.0	7.7
30-Year Treasury Bonds	8.7	8.7	9.2
	Index, March 1973 = 100		
FRB Exchange Rate	97.4	88.3	84.0
Rate of Change (%)	4.9	(9.4)	(4.9)
	Billions of Current Dollars		
Federal Surplus (Unified, Fiscal Year)	($ 167.0)	($ 150.0)	($ 110.0)
Rate of Change (%)	(7.7)	10.2	26.7

Source: Dun & Bradstreet
U.S. Department of Commerce
Federal Reserve Board

Government

Government spending is expected to be an area of weakness in the economy. As Gramm–Rudman–Hollings (GRH) deficit–cutting measures become increasingly difficult to avoid, either reductions in federal government spending or increases in taxes (or some combination of the two) will have to be enacted, either of which will slow economic growth. The fiscal 1990 GRH target is $100 billion. The actual fiscal 1990 deficit, however, is likely to exceed official estimates by at least $40 billion to $50 billion. This shortfall will have to be made up in fiscal 1991, when the GRH deficit target will fall to $64 billion. Thus, Congress and the Bush Administration may be forced to discover more than $80 billion in federal budget deficit reductions (unlikely), revise the GRH targets (likely), or both (the most likely). In addition, large deficits in many state and local governments—57 percent of total real government spending—will force cutbacks in these areas as well.

Foreign Trade

Net exports, the contributions of the trade balance to real GNP, should improve modestly in 1989. The strong European and Japanese economies are likely to continue fueling demand for U.S. exports, particularly if the dollar weakens. Demand should be especially strong for U.S.–made industrial supplies and manufactured goods. However, imports into the United States also will continue to grow, although not as rapidly as exports. Higher oil prices, in particular, will be detrimental to the U.S. balance of trade.

DATAQUEST CONCLUSIONS

Dataquest anticipates that an economic slowdown primarily caused by higher interest rates will begin approximately at the end of this year or in early 1990. To date, the indications are that the economy probably is headed for a soft landing and that a recession can be avoided. It would be premature, however, to assume that the macroeconomic managers have repealed the business cycle, with the latest round of fine–tuning policy measures. Once interest rates peak, which probably will happen in early 1990, economic growth will slow for several months. After this, the growth pace should pick up steam and improve significantly in 1991.

Terrance A. Birkholz

26-Apr-91

ESTIMATED SEMICONDUCTOR REVENUE

Actel

	Worldwide		North America		Japan		Europe		Asia/Pacific		Rest of World (exc. Asia/Pac	
	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89
Total Semiconductor	21	200%	15	200%	1	0%	3	NA	2	100%	0	NA
Total Integrated Circuit	21	200%	15	200%	1	0%	3	NA	2	100%	0	NA
Bipolar Digital (Technology)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
TTL/Other	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
ECL	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital (Function)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Logic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS (Technology)	21	200%	15	200%	1	0%	3	NA	2	100%	0	NA
N/PMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
CMOS	21	200%	15	200%	1	0%	3	NA	2	100%	0	NA
BICMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS (Function)	21	200%	15	200%	1	0%	3	NA	2	100%	0	NA
MOS Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Micro Devices	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Logic	21	200%	15	200%	1	0%	3	NA	2	100%	0	NA
Analog	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Total Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Transistor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Diode	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Thyristor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Other Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Total Optoelectronic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA

Source: Dataquest
May 1991

26-Apr-91

ESTIMATED SEMICONDUCTOR REVENUE
Advanced Micro Devices

	Worldwide		North America		Japan		Europe		Asia/Pacific		Rest of World (exc. Asia/Pac	
	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89
Total Semiconductor	1053	-4%	516	-9%	139	-3%	273	-5%	125	24%	0	NA
Total Integrated Circuit	1053	-4%	516	-9%	139	-3%	273	-5%	125	24%	0	NA
Bipolar Digital (Technology)	407	-14%	232	-19%	47	-20%	86	-11%	42	31%	0	NA
TTL/Other	306	-24%	170	-30%	32	-35%	74	-13%	30	25%	0	NA
ECL	101	38%	62	44%	15	50%	12	0%	12	50%	0	NA
Bipolar Digital (Function)	407	-14%	232	-19%	47	-20%	86	-11%	42	31%	0	NA
Bipolar Digital Memory	65	-24%	36	-23%	5	-44%	22	-19%	2	0%	0	NA
Bipolar Digital Logic	302	-22%	184	-23%	38	-24%	51	-27%	29	-3%	0	NA
MOS (Technology)	570	4%	245	1%	80	11%	166	-1%	79	18%	0	NA
N/PMOS	252	-23%	108	-25%	35	-19%	74	-26%	35	-13%	0	NA
CMOS	318	43%	137	40%	45	55%	92	35%	44	63%	0	NA
BICMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS (Function)	570	4%	245	1%	80	11%	166	-1%	79	18%	0	NA
MOS Memory	253	-2%	115	-8%	47	15%	61	-14%	30	43%	0	NA
MOS Micro Devices	178	3%	71	-5%	18	-22%	47	38%	42	5%	0	NA
MOS Logic	139	17%	59	40%	15	88%	58	-8%	7	17%	0	NA
Analog	76	-1%	39	-5%	12	0%	21	-5%	4	100%	0	NA
Total Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Transistor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Diode	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Thyristor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Other Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Total Optoelectronic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA

Source: Dataquest
May 1991

26-Apr-91

ESTIMATED SEMICONDUCTOR REVENUE

Allegro MicroSystems

	Worldwide		North America		Japan		Europe		Asia/Pacific		Rest of World (exc. Asia/Pac	
	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89
Total Semiconductor	116	-15%	69	-22%	4	-20%	33	3%	10	-9%	0	-100%
Total Integrated Circuit	98	-14%	54	-26%	4	-20%	31	24%	9	-10%	0	-100%
Bipolar Digital (Technology)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
TTL/Other	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
ECL	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital (Function)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Logic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS (Technology)	2	-88%	0	-100%	1	NA	1	-88%	0	NA	0	NA
N/PMOS	0	-100%	0	-100%	0	NA	0	NA	0	NA	0	NA
CMOS	2	-50%	0	-100%	1	NA	1	NA	0	NA	0	NA
BICMOS	0	-100%	0	NA	0	NA	0	-100%	0	NA	0	NA
MOS (Function)	2	-88%	0	-100%	1	NA	1	-88%	0	NA	0	NA
MOS Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Micro Devices	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Logic	2	-88%	0	-100%	1	NA	1	-88%	0	NA	0	NA
Analog	96	-2%	54	-17%	3	-40%	30	76%	9	-10%	0	-100%
Total Discrete	17	-26%	14	-7%	0	NA	2	-71%	1	0%	0	NA
Transistor	11	-15%	9	-10%	0	NA	1	-50%	1	0%	0	NA
Diode	6	100%	5	67%	0	NA	1	NA	0	NA	0	NA
Thyristor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Other Discrete	0	-100%	0	-100%	0	NA	0	-100%	0	NA	0	NA
Total Optoelectronic	1	NA	1	NA	0	NA	0	NA	0	NA	0	NA

Source: Dataquest
May 1991

26-Apr-91

ESTIMATED SEMICONDUCTOR REVENUE

Altera

	Worldwide		North America		Japan		Europe		Asia/Pacific		Rest of World (exc. Asia/Pac	
	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89
Total Semiconductor	78	32%	49	26%	10	43%	15	36%	2	100%	2	100%
Total Integrated Circuit	78	32%	49	26%	10	43%	15	36%	2	100%	2	100%
Bipolar Digital (Technology)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
TTL/Other	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
ECL	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital (Function)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Logic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS (Technology)	78	32%	49	26%	10	43%	15	36%	2	100%	2	100%
N/PMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
CMOS	78	32%	49	26%	10	43%	15	36%	2	100%	2	100%
BiCMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS (Function)	78	32%	49	26%	10	43%	15	36%	2	100%	2	100%
MOS Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Micro Devices	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Logic	78	32%	49	26%	10	43%	15	36%	2	100%	2	100%
Analog	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Total Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Transistor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Diode	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Thyristor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Other Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Total Optoelectronic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA

Source: Dataquest
May 1991

26-Apr-91

ESTIMATED SEMICONDUCTOR REVENUE

Analog Devices

	Worldwide		North America		Japan		Europe		Asia/Pacific		Rest of World (exc. Asia/Pac	
	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89
Total Semiconductor	381	7%	216	19%	42	-29%	103	8%	19	-5%	1	0%
Total Integrated Circuit	380	6%	215	18%	42	-29%	103	8%	19	-5%	1	0%
Bipolar Digital (Technology)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
TTL/Other	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
ECL	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital (Function)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Logic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS (Technology)	20	0%	11	0%	3	0%	6	0%	0	NA	0	NA
N/PMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
CMOS	20	0%	11	0%	3	0%	6	0%	0	NA	0	NA
BICMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS (Function)	20	0%	11	0%	3	0%	6	0%	0	NA	0	NA
MOS Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Micro Devices	20	0%	11	0%	3	0%	6	0%	0	NA	0	NA
MOS Logic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Analog	360	7%	204	19%	39	-30%	97	9%	19	-5%	1	0%
Total Discrete	1	NA	1	NA	0	NA	0	NA	0	NA	0	NA
Transistor	1	NA	1	NA	0	NA	0	NA	0	NA	0	NA
Diode	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Thyristor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Other Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Total Optoelectronic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA

Source: Dataquest
May 1991

26-Apr-91 ESTIMATED SEMICONDUCTOR REVENUE

Appian Technology

	Worldwide		North America		Japan		Europe		Asia/Pacific		Rest of World (exc. Asia/Pac	
	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89
Total Semiconductor	50	35%	33	14%	1	NA	5	25%	11	175%	0	NA
Total Integrated Circuit	50	35%	33	14%	1	NA	5	25%	11	175%	0	NA
Bipolar Digital (Technology)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
TTL/Other	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
ECL	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital (Function)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Logic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS (Technology)	50	35%	33	14%	1	NA	5	25%	11	175%	0	NA
N/PMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
CMOS	50	35%	33	14%	1	NA	5	25%	11	175%	0	NA
BICMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS (Function)	50	35%	33	14%	1	NA	5	25%	11	175%	0	NA
MOS Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Micro Devices	38	27%	25	14%	1	NA	5	25%	7	75%	0	NA
MOS Logic	12	71%	8	14%	0	NA	0	NA	4	NA	0	NA
Analog	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Total Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Transistor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Diode	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Thyristor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Other Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Total Optoelectronic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA

Source: Dataquest
May 1991

26-Apr-91

ESTIMATED SEMICONDUCTOR REVENUE
Applied Micro Circuits Corp.

	Worldwide		North America		Japan		Europe		Asia/Pacific		Rest of World (exc. Asia/Pac	
	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89
Total Semiconductor	28	27%	27	29%	0	NA	1	0%	0	NA	0	NA
Total Integrated Circuit	28	27%	27	29%	0	NA	1	0%	0	NA	0	NA
Bipolar Digital (Technology)	24	20%	23	21%	0	NA	1	0%	0	NA	0	NA
TTL/Other	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
ECL	24	20%	23	21%	0	NA	1	0%	0	NA	0	NA
Bipolar Digital (Function)	24	20%	23	21%	0	NA	1	0%	0	NA	0	NA
Bipolar Digital Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Logic	24	20%	23	21%	0	NA	1	0%	0	NA	0	NA
MOS (Technology)	4	100%	4	100%	0	NA	0	NA	0	NA	0	NA
N/PMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
CMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
BICMOS	4	100%	4	100%	0	NA	0	NA	0	NA	0	NA
MOS (Function)	4	100%	4	100%	0	NA	0	NA	0	NA	0	NA
MOS Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Micro Devices	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Logic	4	100%	4	100%	0	NA	0	NA	0	NA	0	NA
Analog	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Total Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Transistor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Diode	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Thyristor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Other Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Total Optoelectronic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA

Source: Dataquest
May 1991

26-Apr-91 ESTIMATED SEMICONDUCTOR REVENUE

AT&T

	Worldwide		North America		Japan		Europe		Asia/Pacific		Rest of World (exc. Asia/Pac	
	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89
Total Semiconductor	861	-1%	805	-5%	7	NA	29	71%	20	186%	0	NA
Total Integrated Circuit	717	0%	673	-4%	7	NA	21	50%	16	433%	0	NA
Bipolar Digital (Technology)	59	5%	57	6%	0	NA	2	0%	0	NA	0	NA
TTL/Other	46	5%	44	5%	0	NA	2	0%	0	NA	0	NA
ECL	13	8%	13	8%	0	NA	0	NA	0	NA	0	NA
Bipolar Digital (Function)	59	5%	57	6%	0	NA	2	0%	0	NA	0	NA
Bipolar Digital Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Logic	59	5%	57	6%	0	NA	2	0%	0	NA	0	NA
MOS (Technology)	461	12%	431	8%	6	NA	18	50%	6	NA	0	NA
N/PMOS	67	20%	67	20%	0	NA	0	NA	0	NA	0	NA
CMOS	394	11%	364	6%	6	NA	18	50%	6	NA	0	NA
BICMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS (Function)	461	12%	431	8%	6	NA	18	50%	6	NA	0	NA
MOS Memory	13	0%	13	0%	0	NA	0	NA	0	NA	0	NA
MOS Micro Devices	145	3%	141	3%	0	NA	4	0%	0	NA	0	NA
MOS Logic	303	18%	277	11%	6	NA	14	75%	6	NA	0	NA
Analog	197	-21%	185	-25%	1	NA	1	NA	10	233%	0	NA
Total Discrete	130	-12%	126	-12%	0	NA	0	NA	4	0%	0	NA
Transistor	17	-11%	16	-11%	0	NA	0	NA	1	0%	0	NA
Diode	27	-13%	27	-13%	0	NA	0	NA	0	NA	0	NA
Thyristor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Other Discrete	86	-11%	83	-12%	0	NA	0	NA	3	0%	0	NA
Total Optoelectronic	14	40%	6	-14%	0	NA	8	167%	0	NA	0	NA

Source: Dataquest
May 1991

26-Apr-91

ESTIMATED SEMICONDUCTOR REVENUE

Atmel

	Worldwide		North America		Japan		Europe		Asia/Pacific		Rest of World (exc. Asia/Pac	
	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89
Total Semiconductor	123	31%	73	30%	7	-46%	35	84%	8	33%	0	NA
Total Integrated Circuit	123	31%	73	30%	7	-46%	35	84%	8	33%	0	NA
Bipolar Digital (Technology)	14	75%	8	33%	0	NA	6	200%	0	NA	0	NA
TTL/Other	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
ECL	14	75%	8	33%	0	NA	6	200%	0	NA	0	NA
Bipolar Digital (Function)	14	75%	8	33%	0	NA	6	200%	0	NA	0	NA
Bipolar Digital Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Logic	14	75%	8	33%	0	NA	6	200%	0	NA	0	NA
MOS (Technology)	98	34%	58	32%	7	17%	25	47%	8	33%	0	NA
N/PMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
CMOS	98	34%	58	32%	7	17%	25	47%	8	33%	0	NA
BICMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS (Function)	98	34%	58	32%	7	17%	25	47%	8	33%	0	NA
MOS Memory	54	15%	31	11%	3	0%	12	20%	8	33%	0	NA
MOS Micro Devices	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Logic	44	69%	27	69%	4	33%	13	86%	0	NA	0	NA
Analog	11	-15%	7	17%	0	-100%	4	NA	0	NA	0	NA
Total Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Transistor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Diode	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Thyristor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Other Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Total Optoelectronic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA

Source: Dataquest
May 1991

26-Apr-91

ESTIMATED SEMICONDUCTOR REVENUE

Bipolar Integrated Technology

	Worldwide		North America		Japan		Europe		Asia/Pacific		Rest of World (exc. Asia/Pac	
	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89
Total Semiconductor	1	0%	1	0%	0	NA	0	NA	0	NA	0	NA
Total Integrated Circuit	1	0%	1	0%	0	NA	0	NA	0	NA	0	NA
Bipolar Digital (Technology)	1	0%	1	0%	0	NA	0	NA	0	NA	0	NA
TTL/Other	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
ECL	1	0%	1	0%	0	NA	0	NA	0	NA	0	NA
Bipolar Digital (Function)	1	0%	1	0%	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Logic	0	-100%	0	-100%	0	NA	0	NA	0	NA	0	NA
MOS (Technology)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
N/PMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
CMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
BICMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS (Function)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Micro Devices	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Logic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Analog	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Total Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Transistor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Diode	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Thyristor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Other Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Total Optoelectronic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA

Source: Dataquest
May 1991

26-Apr-91 ESTIMATED SEMICONDUCTOR REVENUE

Brooktree

	Worldwide		North America		Japan		Europe		Asia/Pacific		Rest of World (exc. Asia/Pac	
	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89
Total Semiconductor	70	35%	53	26%	7	75%	7	40%	3	200%	0	NA
Total Integrated Circuit	70	35%	53	26%	7	75%	7	40%	3	200%	0	NA
Bipolar Digital (Technology)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
TTL/Other	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
ECL	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital (Function)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Logic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS (Technology)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
N/PMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
CMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
BICMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS (Function)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Micro Devices	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Logic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Analog	70	35%	53	26%	7	75%	7	40%	3	200%	0	NA
Total Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Transistor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Diode	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Thyristor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Other Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Total Optoelectronic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA

Source: Dataquest
May 1991

26-Apr-91

ESTIMATED SEMICONDUCTOR REVENUE

Burr-Brown

	Worldwide		North America		Japan		Europe		Asia/Pacific		Rest of World (exc. Asia/Pac	
	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89
Total Semiconductor	145	3%	45	2%	49	-2%	49	26%	2	-75%	0	NA
Total Integrated Circuit	145	3%	45	2%	49	-2%	49	26%	2	-75%	0	NA
Bipolar Digital (Technology)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
TTL/Other	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
ECL	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital (Function)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Logic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS (Technology)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
N/PMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
CMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
BICMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS (Function)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Micro Devices	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Logic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Analog	145	3%	45	2%	49	-2%	49	26%	2	-75%	0	NA
Total Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Transistor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Diode	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Thyristor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Other Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Total Optoelectronic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA

Source: Dataquest
May 1991

26-Apr-91

ESTIMATED SEMICONDUCTOR REVENUE
California Micro Devices

	Worldwide 1990	Worldwide % Chg 90/89	North America 1990	North America % Chg 90/89	Japan 1990	Japan % Chg 90/89	Europe 1990	Europe % Chg 90/89	Asia/Pacific 1990	Asia/Pacific % Chg 90/89	Rest of World (exc. Asia/Pac 1990	Rest of World (exc. Asia/Pac % Chg 90/89
Total Semiconductor	27	-10%	21	5%	0	NA	2	0%	4	-43%	0	-100%
Total Integrated Circuit	27	-10%	21	5%	0	NA	2	0%	4	-43%	0	-100%
Bipolar Digital (Technology)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
TTL/Other	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
ECL	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital (Function)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Logic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS (Technology)	8	0%	5	0%	0	NA	1	0%	2	0%	0	NA
N/PMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
CMOS	8	0%	5	0%	0	NA	1	0%	2	0%	0	NA
BICMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS (Function)	8	0%	5	0%	0	NA	1	0%	2	0%	0	NA
MOS Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Micro Devices	8	0%	5	0%	0	NA	1	0%	2	0%	0	NA
MOS Logic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Analog	19	-14%	16	7%	0	NA	1	0%	2	-60%	0	-100%
Total Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Transistor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Diode	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Thyristor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Other Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Total Optoelectronic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA

Source: Dataquest
May 1991

26-Apr-91

ESTIMATED SEMICONDUCTOR REVENUE
Catalyst

	Worldwide		North America		Japan		Europe		Asia/Pacific		Rest of World (exc. Asia/Pac	
	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89
Total Semiconductor	36	16%	14	8%	9	-10%	8	33%	3	NA	2	0%
Total Integrated Circuit	36	16%	14	8%	9	-10%	8	33%	3	NA	2	0%
Bipolar Digital (Technology)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
TTL/Other	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
ECL	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital (Function)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Logic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS (Technology)	35	13%	13	0%	9	-10%	8	33%	3	50%	2	NA
N/PMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
CMOS	35	13%	13	0%	9	-10%	8	33%	3	50%	2	NA
BICMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS (Function)	35	13%	13	0%	9	-10%	8	33%	3	NA	2	0%
MOS Memory	35	13%	13	0%	9	-10%	8	33%	3	NA	2	0%
MOS Micro Devices	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Logic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Analog	1	NA	1	NA	0	NA	0	NA	0	NA	0	NA
Total Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Transistor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Diode	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Thyristor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Other Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Total Optoelectronic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA

Source: Dataquest
May 1991

26-Apr-91

ESTIMATED SEMICONDUCTOR REVENUE

Cherry Semiconductor

	Worldwide		North America		Japan		Europe		Asia/Pacific		Rest of World (exc. Asia/Pac	
	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89	1990	% Chg 90/89
Total Semiconductor	36	13%	25	14%	0	NA	4	0%	7	17%	0	NA
Total Integrated Circuit	36	13%	25	14%	0	NA	4	0%	7	17%	0	NA
Bipolar Digital (Technology)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
TTL/Other	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
ECL	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital (Function)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Bipolar Digital Logic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS (Technology)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
N/PMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
CMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
BICMOS	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS (Function)	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Memory	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Micro Devices	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
MOS Logic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Analog	36	13%	25	14%	0	NA	4	0%	7	17%	0	NA
Total Discrete ,	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Transistor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Diode	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Thyristor	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Other Discrete	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA
Total Optoelectronic	0	NA	0	NA	0	NA	0	NA	0	NA	0	NA

Source: Dataquest
May 1991

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Research *Bulletin*

PHILIPS STRENGTHENS ITS POSITION IN SOUTHEAST ASIA

On October 3, 1989, N.V. Philips Gloeilampenfabrieken (Philips) informed the Board of Directors of Taiwan Semiconductor Manufacturing Company (TSMC) that it intended to exercise its option to acquire 51 percent of the shares of TSMC. Philips has stated that no management changes are planned for TSMC.

TSMC was founded in October 1986 as an integrated circuit foundry operation, jointly owned by the development fund of the Republic of China (48.3 percent), Philips of the Netherlands (27.5 percent), and a number of Taiwanese companies (24.2 percent). TSMC has shown remarkable performance during the two and one-half years of its existence. The company achieved a rapid start in early 1987 through a special arrangement with the Industrial Technology Research Institute (ITRI), which made an existing 6-inch fabrication facility available to the venture. Currently, TSMC is delivering 125,000 wafers per year. In 1988, construction began on a new wafer fabrication facility. This plant is scheduled to deliver commercial products in 1990 and ultimately will grow to an output of 480,000 6-inch wafers per year by 1993.

DATAQUEST CONFERS WITH PHILIPS' TOP MANAGEMENT

A Dataquest interview with several members of Philips Components B.U. Integrated Circuits top management revealed the following: Philips has adopted a strategy to further strengthen its global presence in the IC industry, particularly in the Far East, which Philips perceives to be the fastest-growing market of the next decade. With the Asia/Pacific region becoming a major force in the industry, Philips plans to make TSMC its bastion of the IC industry in that region. Philips believes that Asia/Pacific semiconductor consumption will surpass European consumption soon.

DATAQUEST ANALYSIS

Philips' Action—Provoking Concern

Dataquest believes that Philips and the TSMC management face some near-term challenges to assure existing and future foundry customers that all will be well. The knee-jerk reaction often associated with these types of transactions is to assume that Philips will preempt capacity for its own purposes during times of cyclical foundry shortages. Evidently, some "fabless" companies that are heavily dependent on TSMC experienced apprehension over the October 3 announcement. TSMC's decision to allocate a portion of its new capacity to provide foundry services for commodity memory products such as DRAMs and SRAMs may have exacerbated that anxiety. However, as Sigmund Freud said, "Sometimes a cigar is just a cigar." Although Dataquest is not privy to any private brainstorming in smoky Eindhoven back rooms, it appears that Philips is simply executing a well-conceived plan and following an investment strategy that would warm the hearts of most venture capitalists—i.e., to take a minority interest in the venture initially and share the risk with several partners. If the venture profits as originally promoted, Philips can continue with follow-on investments up to the option limits. The venture capitalists of Silicon Valley would be a happier lot if all their deals worked out as well as that of Philips and TSMC.

The Dutch—500 Years of Global Business Experience

For Philips to pursue any action that would not be in the best interests of its customers or would damage what appears to be a highly profitable business at TSMC would be illogical to the

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very logical Dutch, who have been conducting business on a global basis for more than 500 years. During the interview, Philips' management reminded Dataquest that the original shareholders' agreement binds Philips to guarantee that "TSMC will at all times be managed as an independent business enterprise on a commercial basis. Its profit and growth objectives shall bear the same priorities as in independent IC companies in the USA." Furthermore, we sense that Philips has decided that it must look far beyond Europe if it is going to maintain semiconductor growth levels consistent with its contemporaries on the top 10 list of worldwide semiconductor producers.

Asia/Pacific—The Economic Miracle of the 1990s

In a recent newsletter entitled "Semiconductor Megatrends of the 1990s," Dataquest predicted that the Asia/Pacific region will be the fastest growing area of the world in the 1990s in terms of electronics production, including semiconductors. That newsletter also stressed the importance of regional manufacturing and close proximity to customers from both a location and a service standpoint. Philips' decision to increase its commitment in TSMC appears to be consistent with these Dataquest concepts. Philips has action under way or has announced plans for the following:

- Marketing, selling, and order handling in Taiwan and South Korea
- Regional applications labs in Auckland, Bangkok, Bombay, Chengdu, Hong Kong, Seoul, Shanghai, Sidney, Singapore, Taipei, and Tokyo.
- IC design centers in:
  - Japan for consumer applications
  - Taiwan for industrial applications
- Manufacturing
  - Assembly in Taiwan, South Korea, Thailand, and the People's Republic of China
  - Test in Taiwan, South Korea, and Thailand
  - Fab in Taiwan and the People's Republic of China

DATAQUEST CONCLUSIONS

Given this substantial commitment to the Asia/Pacific region, Philips' recent decision to increase its participation in TSMC would appear to be entirely in order with long-term strategic goals. Assuming that Philips continues to execute its plans for the region successfully, Dataquest anticipates that Philips will be a powerful force to be reckoned with in the next decade.

David L. Angel

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Research Newsletter

SEMICONDUCTOR MEGATRENDS IN THE 1990s

INTRODUCTION

We are but a short time away from the last decade of this century. Many of our clients are now concentrating heavily on their strategies for the 1990s. What does the coming decade hold? What changes will have to be made to management philosophies in order to be a factor in the future? What new capabilities and financial and human resources will be required? What will be the major transitions in global events? This newsletter presents Dataquest's view of the elements that we believe will drive the semiconductor industry of the next decade. While it is certainly not destiny, it is an opinion based upon countless discussions with our clients throughout the world. It is a nontraditional Dataquest newsletter in that there are no hard facts, only speculation. It is our stake in the ground. We'll have to wait as long as ten years or more to see if we were right. In the meanwhile, we welcome your opinion as to how you foresee the next decade.

SEMICONDUCTOR MEGATRENDS IN THE 1990s

The following list contains our predictions for semiconductor megatrends in the '90s:

- Economic power will displace military power.
- Closeness to your customer will be an imperative.
- Electronics will pervade all aspects of society.
- Technological obsolescences will increase.
- Consolidation and retrenchment will become the norm.
- Southeast Asia's growth will lead the decade.
- The industry's capital intensity will intensify.
- Partnerships will become standard business practice.
- Software will be the king of the '90s.
- Japan will have peaked in growth and the United States will have bottomed.

Economic Power Will Displace Military Power

We believe that economic power will displace military power as the basis for worldwide dominance. Countries will shift their focus away from military spending and concentrate upon strategies to create economic might. Electronic and information transfer industries will be viewed as essential to establishing economic power. Global trade policies will become the new battleground, as entities throughout the world seek to protect or enhance their individual economic strengths. Companies that cannot compete on a global basis will realize growth rates and financial returns that are substantially less than industry averages.

The Imperative of Being Close to Your Customer

Region-based manufacturing will become an imperative of the next decade, as will an entirely new level of service. Driven by trade laws, local content requirements, and the new strategy of establishing factories close to the point of consumption, partnerships, such as the Acer/Texas Instruments consortium to produce DRAMs for the Taiwanese market, will become commonplace. This fact will hold true for the manufacture of electronic equipment as well as components. Japanese

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companies already have begun to establish substantial manufacturing capabilities in the United States, and both U.S. and Japanese companies are moving en masse into Europe with IC production factories. Product and price differentiation will be difficult; hence, service will become a new and powerful marketing tool.

Electronics Will Pervade All Aspects of Society

Electronics will become ubiquitous—a common denominator throughout all levels of society. Consumer electronics (with emphasis upon personal use) that are perceived to enhance one's life or offer opportunities for saving time will be key drivers during the early portion of the next decade. We see widespread consumption of ISDN-driven products, personal cellular telephones, home fax machines, home copiers and laser printers, home automation products, as well as personal entertainment systems. This bodes well for analog products as well as for mixed-signal and conventional digital devices. We do not see HDTV having significant impact on either consumers or IC producers until very late in the next decade.

Technological Obsolescences Will Increase

We predict that during the '90s, technological obsolescences will occur at an even faster rate than in the '80s. Product life cycles, despite increasing product complexity, will be shorter than in the past decade. Innovation, driven by astounding leaps in software technology and the information transfer industry, will place immense pressures on product survivability. Producing a product that can capture market leadership long enough to recover the investment cost of development will become a key challenge.

Consolidation and Retrenchment Will Become the Norm

The European, U.S., and Japanese semiconductor industries are expected to reach full maturation in the decade of the '90s. Annual growth rates will more closely follow those of traditional mature industries such as automobiles. Substantial consolidation will take place in the U.S. semiconductor industry, resulting in only a few, very large U.S. semiconductor producers by the end of the decade. Niche market players will become increasingly rare, finding that their markets of choice are too small to allow for annual research and development investments that are commensurate with industry averages. There will be a shakeout among the Japanese device producers as a result of too many participants entering the IC market from nontraditional sources such as the Japanese steel, chemical, and heavy industry companies. The majority of the retrenchments will come from ASIC entities that lack substantial vertical integration capabilities.

Southeast Asian Growth Will Lead the Decade

Southeast Asia will be the region exhibiting the greatest growth and the largest number of new IC ventures. Thailand will become the fifth tiger. Virtually all of the newly industrialized countries (NICs) will adopt the strategy that an indigenous semiconductor industry is essential to the development of a modern economy. The proliferation of ASIC design tools will enhance this region's goal of becoming independent of both Japan and the United States for the supply of complex ICs. India will become an important electronic equipment consumer and semiconductor device producer. The Eastern Bloc and Soviet countries will become significant electronic equipment consumers toward the end of the decade, as these entities realize the necessity of establishing economic rather than military power. China will be neither a significant consumer nor producer of semiconductors. Despite current rhetoric that China's modernization program is still top priority, the impact of the June 1989 events in Beijing will most likely continue well into the next decade.

The Industry's Capital Intensity Will Intensify

Dataquest foresees that the capital intensity of the industry will intensify. No longer will companies be able to use DRAMs as their sole process drivers. DRAM technology will pace lithography and three-dimensional events (trench capacitors); however, ASIC technology will set the cadence for multiple levels of interconnections, deposited films, and packaging developments. Consequently, broad market participants will have to make significant investments in both DRAM and ASIC technologies. Wafer fabrication facilities will be become product focused rather than process focused. Operations will be built principally for the lifetime of one specific product (e.g., 16Mb factories, 64Mb factories, 256Mb factories), with possible later-stage revamping for less demanding technologies. This scenario favors commodity memory producers over ASIC and analog producers for the greatest leverage of wafer fabrication capital investment.

Partnerships Will Become Standard Business Practice

Partnerships and technology transfer will become key strategies in the next decade. The staggering cost of technology will be only a portion of the problem to be solved. As product lifetimes decrease, the time to market for products will become predominant. Even a minor setback in product development could translate to missing an entire product cycle, recovery from which may be impossible. Partners not only will share the cost of the technology, but also will share the task of getting the product to market in time to minimize the risk of lost opportunity. The NICs will look to the established countries for technology. This know-how will be exchanged for local market access and assistance in establishing regional manufacturing capability. Companies that lack partnering skills or that cannot leverage their technology will suffer against their more adept global competitors.

Software Will Be the King of the '90s

As software standards become pervasive, hardware will become a commodity item. We predict that the Silicon Valley will realize an era of venture capital-backed software start-up companies that will rival the IC company start-up era of the '70s.

Japan Will Have Peaked in Growth; the U.S. Will Have Bottomed

Japan's amazing growth rate will peak very early in the decade. As the Japanese accept their position as the most wealthy people on earth, they will begin to enjoy the fruits of their efforts and lessen their obsession with economic survival. The younger Japanese generation, having never known the hardships of their elders, will be unwilling to make the same sacrifices of unquestioned long work hours, blind devotion to corporate goals, and lack of personal identity. This is not unique to the Japanese, but rather a continuing enactment of the drama that has portrayed every highly successful emerging nation including Ming China, the Ottoman Empire, the countries of Western Europe, Great Britain, and the United States. The United States has bottomed in its descent and is now finally addressing the decline in global competitiveness, deteriorating industries, poor product quality, the drug problem, and the seeming inability to create products that its citizens will buy. We believe that by the end of the century, Japan and the United States will be virtually at parity; however, Japan will still be slightly in the lead. Both nations will have shouldered many of the world's problems and will unite in their mutual anxiety over the ever-growing economic strength of Southeast Asia.

David L. Angel

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Research Newsletter

1990 OUTLOOK FOR CAPITAL SPENDING AND SEMICONDUCTOR SUPPLY: TWO CRITICAL FORCES FOR ELECTRONIC EQUIPMENT MAKERS

SUMMARY

The steadily growing global electronic equipment segment is a major component of worldwide economic growth and is contributing to dramatic shifts in the world's economic balance of power. In 1988, the worldwide electronic equipment market was estimated to be $760 billion (approximately 8 percent) out of $10 trillion of the worldwide output of goods and services as measured by the Organization for Economic Cooperation and Development (OECD). By 1990 , worldwide electronics equipment is forecast to be $851 billion.

In a recently completed focus report entitled *Semiconductor Industry Insights—1990,* Dataquest investigates the relationships among the economic trends in major regions of the world, the growth in capital spending as a driver of electronic equipment demand, and the relationship to semiconductor supply and demand. This newsletter is based on research from that report.

CAPITAL SPENDING—THE ULTIMATE DEMAND DRIVER

Any change in capital spending has a direct and significant impact on equipment demand, particularly in the data processing, communications, or industrial segments. Changes in consumer spending, however, have a greater direct impact on consumer electronic equipment.

The growth in worldwide demand for electronic equipment is determined by the growth in worldwide spending from the following three major economic sectors:

- Private, fixed, nonresidential investments (otherwise known as capital spending)
- Consumer spending
- Government spending

Figure 1 compares constant 1982 dollar values of worldwide consumer and capital spending with current dollar values of worldwide demand for electronic equipment. The following two observations can be made from this comparison:

- Approximately 40 percent of worldwide capital spending accounts for 60 percent of electronic equipment demand.
- Only 3 percent of worldwide consumer spending and some government spending account for the remainder (40 percent) of electronic equipment demand.

Growth of individual equipment segments is a function of the growth of the economic sectors in which the major purchases occur. For example, the data processing, industrial, and communications segments represent nearly 60 percent of the demand but are purchased mostly by the capital spending sector.

CAPITAL SPENDING OUTLOOK FOR 1990

Economic forecasts suggest a considerable slowing of worldwide capital spending through 1990. As shown in Figure 2, growth in capital spending is forecast to slow from approximately 11 percent in 1988 to less than 5 percent in 1990. This slowdown is expected to decrease the demand for electronic equipment from a 17 percent growth in 1988 to less than 5 percent growth by 1990.

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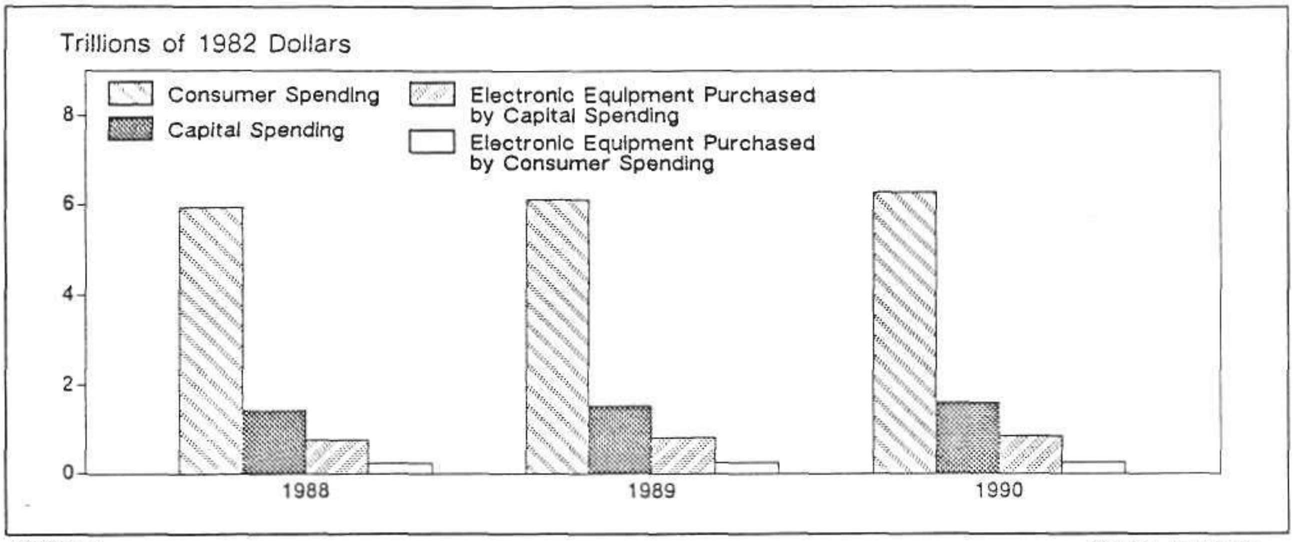
FIGURE 1
Consumer and Capital Spending versus Electronic Equipment Demand by Sector—1988-1990



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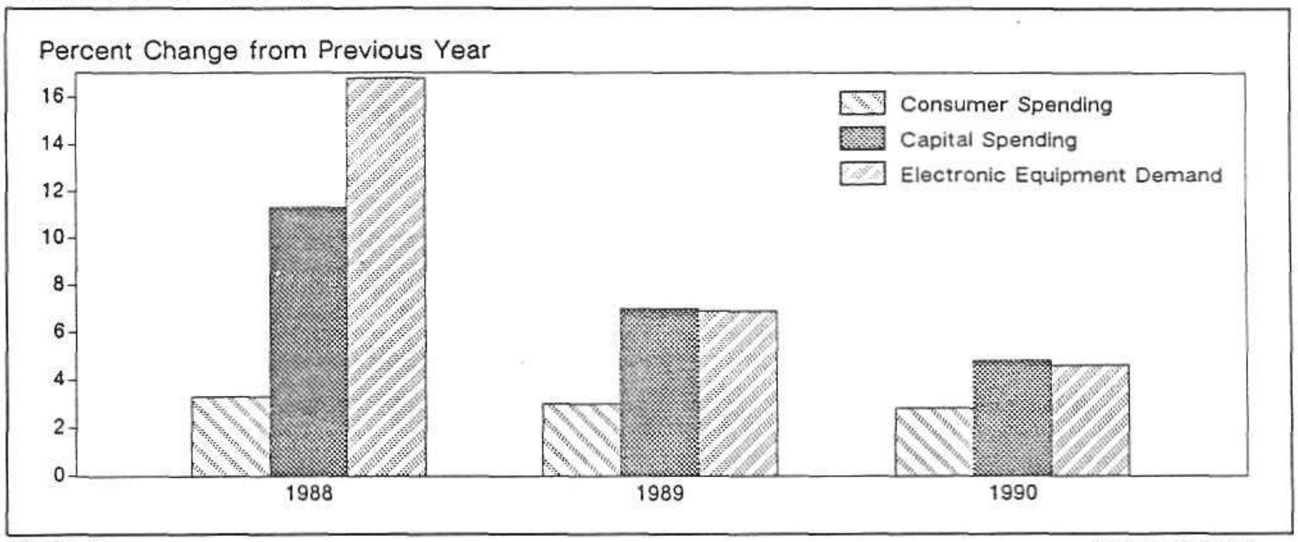
Source: Dataquest October 1989

FIGURE 2
Electronic Equipment Demand and Consumer and Capital Spending Annual Growth—1988-1990



0005241-2

Source: Dataquest October 1989

Regional Economic Outlook and the Impact on Electronic Equipment

North America

Annual U.S. GNP growth was relatively strong in the first half of 1989 but is forecast to decline sharply from its 1988 level of 4.0 percent to an annualized rate of 1.2 percent by the third quarter and to 0.6 percent by the fourth quarter of 1989 for an average 1989 annual growth of 3.0 percent. The first quarter of 1990 is forecast to decline further to an annualized growth of negative 0.6 percent before a strong recovery in the balance of 1990. This relatively mild economic slowdown is expected to have a more dramatic effect on capital spending. Capital spending through the period is expected to average about 4.0 percent real growth as opposed to the 9.5 percent growth of 1988. As a result, the growth of North American demand for electronic equipment is expected to decline from the 16.2 percent level of 1988 to 5.8 percent in 1989 and only 2.7 percent in 1990.

Europe

The European electronic equipment demand is forecast to grow at an annual rate of 5.9 percent in 1989 and 5.1 percent in 1990, down from the 1988 level of 14.5 percent. Again, this is a result of the forecast slowing of real GNP/GDP growth and its amplified impact on capital spending throughout Europe. The European countries will avoid experiencing the full slowdown in the United States, largely because of the widespread capital spending by both European and Pacific Rim countries in preparation for the European Economic Community (EEC) market consolidation of 1992.

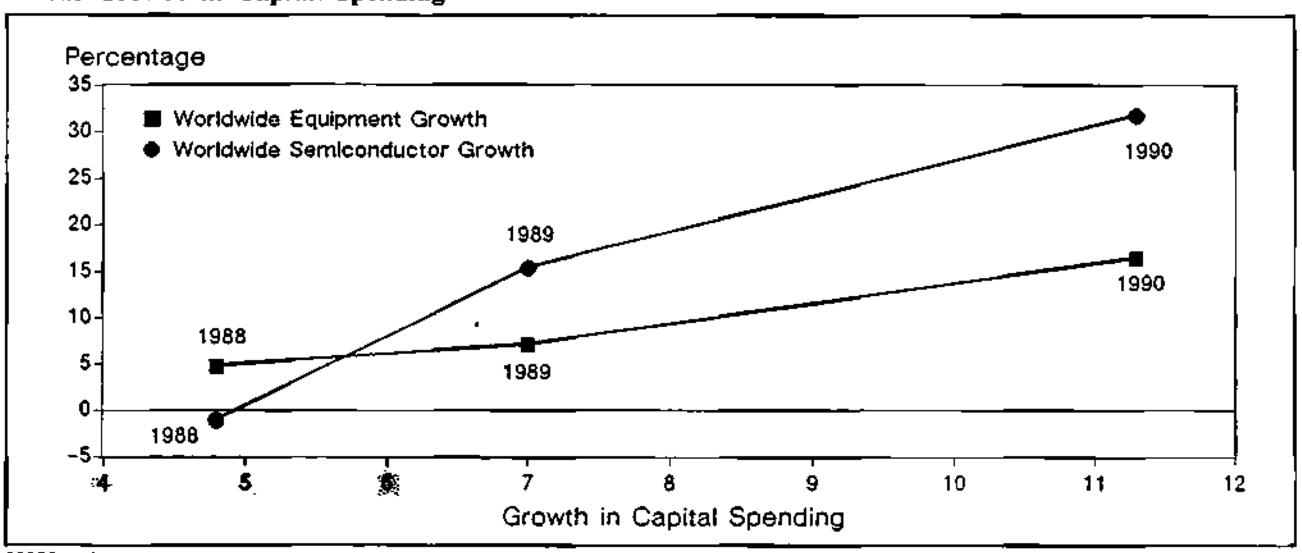
Japan and Asian ROW

Because the capital and consumer spending growth of Japan and the Asian newly industrialized countries (NICs) is not expected to fall as sharply as that of the North American and European regions, the growth rate for electronic equipment demand in these regions remains higher than in the other regions. The continued investment by Japanese electronics companies in offshore production will continue to stimulate demand growth in the Asian NICs. Consequently, the demand share for electronic equipment will continue to shift toward Asia and Japan. From 1988 to 1990, the combined share of Japanese and Asian NICs' demand is forecast to grow from 27 to 28 percent.

Semiconductor Pervasiveness

Electronic equipment production directly determines the demand for semiconductors. The success and growth of electronic equipment producers within a given region determines the size and growth of the total available market for semiconductors within that region. Electronic equipment manufacturers and semiconductor manufacturers are intertwined in the global economy. Figure 3 shows the relationship between year-to-year growth in capital spending and growth in both electronic equipment production and semiconductor consumption. Figure 4 shows the estimated value of semiconductors consumed in the United States versus the estimated value of electronic equipment produced in the United States. In addition to the growth in absolute value, the pervasiveness (semiconductor value as a percentage of total value) also grows each year. *This means that electronic*

Figure 3
Annual Growth in Electronic Equipment Demand and Semiconductor Consumption versus Growth in Capital Spending



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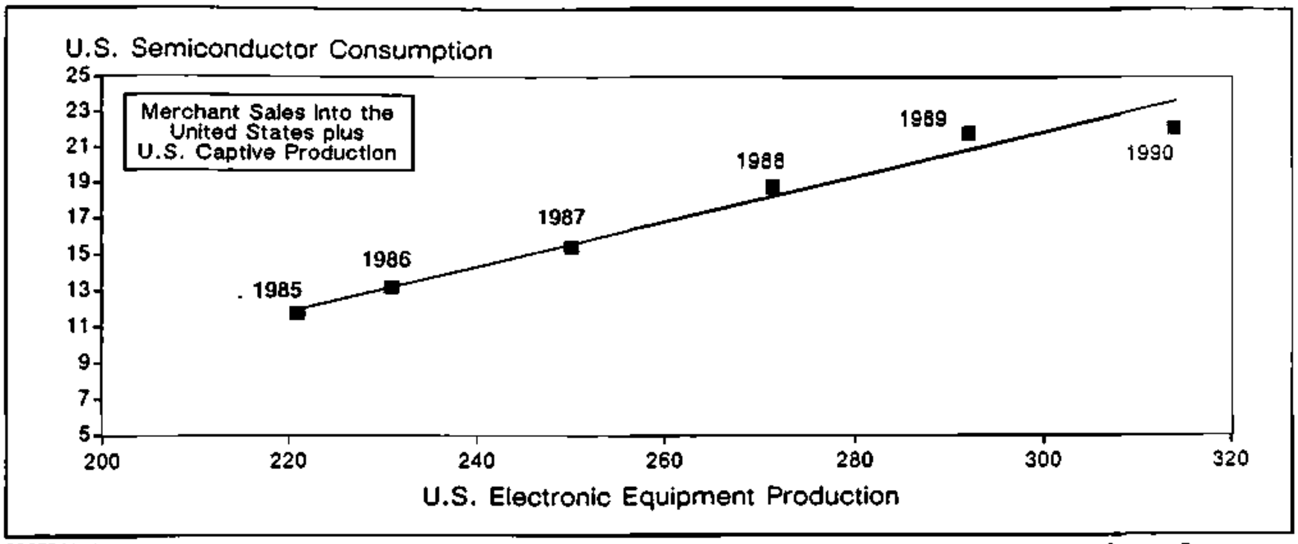
Source: Dataquest
October 1989

FIGURE 4
U.S. Semiconductor Consumption versus U.S. Electronic Equipment Production (Billions of Dollars)



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Source: Dataquest
October 1989

equipment manufacturers are becoming increasingly dependent on access to advanced semiconductor devices to remain technically competitive. Therefore, the economic outlook for the semiconductor industry and future trends in the sources of supply are critical issues for electronic equipment manufacturers.

DATAQUEST ANALYSIS—SEMICONDUCTOR CAPITAL SPENDING CHALLENGE

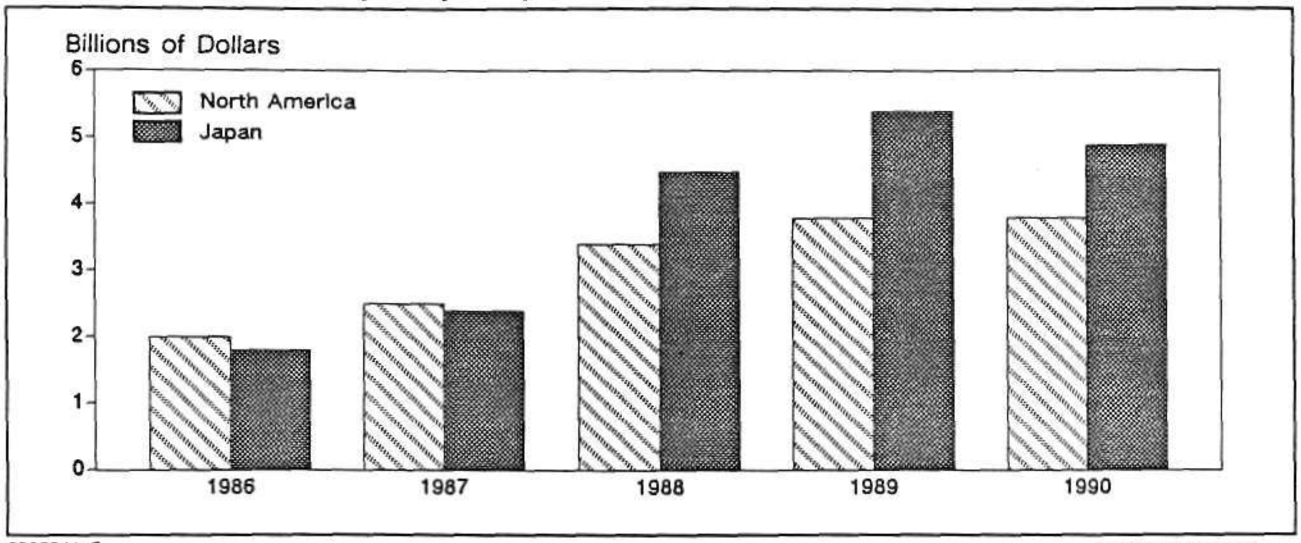
The battle among regional companies for semiconductor market share has more importance than receiving a greater share of total revenue in any given year. For U.S. companies that operate in the highly unforgiving and short-sighted financial environment of the U.S. investment community, market share is the fountainhead of reinvestment. Ultimately, access to investment capital to fund research and development and capital equipment for improving yields or expanding capacity is the lifeblood of long-term survival.

Capital spending on semiconductor production equipment for North American and Japanese companies is shown in Figure 5. A key question regarding the future of the U.S. semiconductor industry is whether or not it can obtain the funds to keep up with Japanese capital spending. In dollar terms, U.S. companies have not kept up with Japanese companies since the early 1980s. The expected Japanese spending levels exceed those of the United States by almost 50 percent and are expected to do so through 1990. The net effect of these spending-level differences is shown in Figure 6. It is clear that Japanese companies had a larger 1988 base of semiconductor production capacity than U.S. companies, and they are adding to that base at a faster pace.

Dataquest believes that U.S. semiconductor companies are failing to invest quickly enough in the rapidly growing semiconductor industry and therefore are giving away market share. A strategic question for U.S. equipment manufacturers is how to ensure a secure source of semiconductors as the manufacturing capability for leading-edge devices shifts farther and farther away.

Mel Thomsen

FIGURE 5
Estimated Semiconductor Capital Spending—1986-1990



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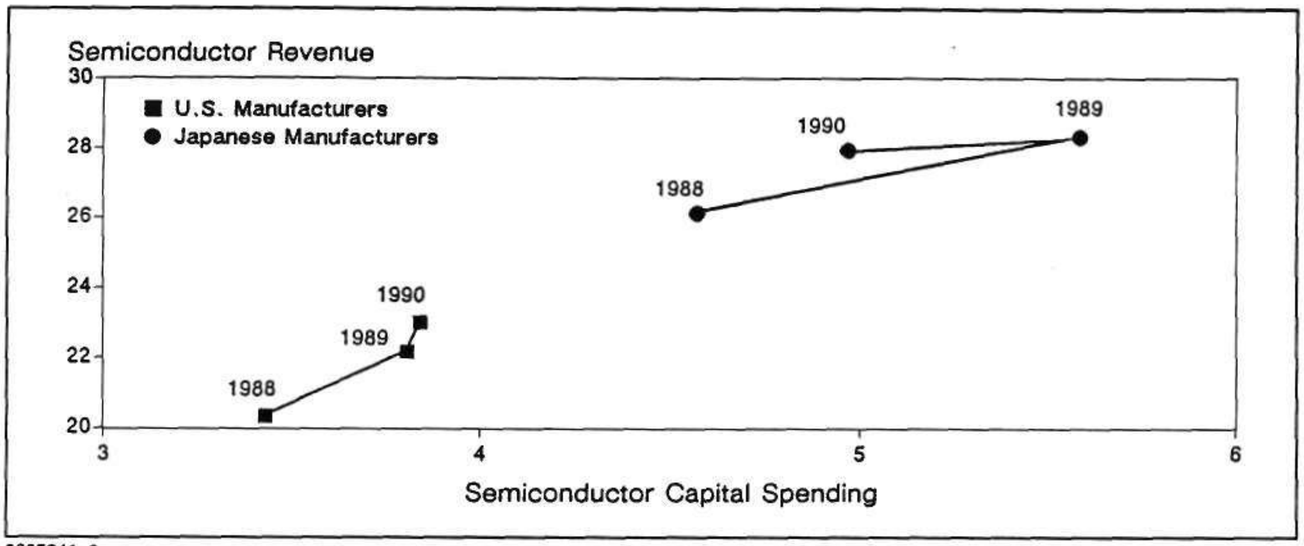
Source: Dataquest
October 1989

FIGURE 6
Semiconductor Revenue versus
Capital Spending—1988-1990



0005241-6

Source: Dataquest
October 1989

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Research Newsletter

DRAMS DROP DRAMATICALLY! (PRICES, THAT IS)

SUMMARY

Dataquest's early 1989 prediction of 1Mb DRAM prices falling lower than $10.00 by the fourth quarter of 1989 appears to be coming true. Dataquest has learned that virtually all of the major Japanese DRAM producers are rapidly scaling back production of 1Mb DRAMs in an attempt to forestall a complete collapse of 1Mb DRAM prices on the world market. We believe that several of the major producers are accumulating inventory at an acute rate. We have observed large contract prices as low as ¥1,300 ($9.29) in Tokyo, an effort, we believe, to reduce inventory and regain control over the market. It may be too late. Sources in Southeast Asia report 1Mb DRAM contracts being written in the $7.00 range. We very recently learned of a large allocation of parts entering the United States with an $8.00 price tag. All of this is occurring at a time when non-Japanese DRAM producers are increasing production and realizing substantial yield increases. Although not assiduously supported, there is a growing opinion that prices could go as low as ¥900 in Tokyo before beginning to edge upward again. In the face of all of these recent events, there is, nevertheless, the potential of a 1Mb DRAM shortage by late spring of 1990.

FIRST IMPRESSIONS ARE USUALLY LASTING

In the first quarter of 1989, Dataquest advised its semiconductor clients of the following predictions regarding 1Mb DRAMs in 1989:

- Dataquest believed that there would be a softening in the worldwide semiconductor industry in the fourth quarter of 1989.
- Dataquest believed that the supply of 100ns, 1Mb DRAMs had already exceeded the demand and that the supply of 80ns, 1Mb DRAMs would exceed demand by early summer.
- Dataquest believed that the selling price of 80ns, 1Mb DRAMs would be less that $10 by the fourth quarter of 1989.
- Dataquest believed that non-Japanese DRAM suppliers, specifically Samsung, would be major factors in the market.

IT DOESN'T ALWAYS TURN OUT THE WAY YOU PLANNED

In April of this year, the authors of this newsletter, Dave Angel and Fred Jones (head of Dataquest's memory group), visited nearly all of the major Japanese DRAM producers. We presented the scenario outlined above, which was met with less than enthusiastic acceptance. Rather, there was virtually a universal consensus, from the Japanese perspective, that the following statements more accurately represented the 1989 DRAM story:

- There would not be a decline in the semiconductor industry in 1989. Rather, the downturn would occur in the second quarter of 1990.
- Prices for 1Mb DRAMs would not fall below the $12 to $15 range in 1989.
- South Korean suppliers would not be able to ramp up production of 80ns parts fast enough to significantly affect 1989 shipments or prices.
- The Japanese suppliers were much more sophisticated than in previous semiconductor cycles and were confident in their ability to manage the situation so that severe oversupply and price erosion would not result.

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Trust Your Instincts

Although neither Dave nor Fred was entirely sanguine about this possible version of the 1989 DRAM world, it was recognized that if this many major DRAM producers believed this version to be true, combined with an obviously improved ability to manage the situation, it was possible that a sharp downturn in 1989 prices could be moderated. As such, we revised our forecast to reflect a fourth quarter selling price of $12. It now appears that we should have trusted our instincts and retained our original forecast.

DAMAGE CONTROL

Based upon information received this week, we have learned that Hitachi, NEC, and Toshiba are all cutting back production of 1Mb DRAMs. Hitachi has acknowledged a 10 percent reduction in 1Mb production; however, other sources suggest that the number is closer to 15 percent. NEC has cancelled plans to increase production from 6 million per month to 8 million per month. Toshiba earlier reduced production from 10 million to 9 million per month and is now reported to be idling to 8 million per month. We believe that virtually all of the major Japanese DRAM producers are currently redirecting production toward SRAMs and mask ROMs and away from DRAMs.

MORE BAD NEWS

Other factors that we believe will exacerbate the situation and force prices downward include the following:

- Dataquest believes that 1Mb finished goods inventories among several of the top Japanese DRAM producers has grown sharply. One leading producer may have as much as two months inventory. This is not mysterious. Like a battleship moving at top speed, it takes a certain amount of time to slow down (or redirect) production. Bear in mind that virtually all major and second-tier suppliers have been focusing all of their energies on increasing production of 1Mb DRAMs, only now to have to throw the switch into reverse on very short notice. It makes sense that the overshoot represents more than just a few million parts.
- The non-Japanese suppliers, including South Korean, U.S., and European DRAM producers, are continuing to increase production. It has been reported that Samsung is now producing 6 million 1Mb DRAMs per month, up from a previous level of 2 million to 3 million per month. This is still significantly less than Samsung's stated capacity for 1Mb DRAMs. Yield among later-starting Japanese and non-Japanese producers has improved substantially in the last quarter, particularly for the high-speed parts. Hence, even without starting more wafers, the number of die being produced is spiraling upward. Not unlike a nuclear reactor that is going critical, despite of all the best efforts to stop the action, considerable damage will be done before conditions are under control once again.

DATAQUEST ANALYSIS

We believe that the Japanese DRAM producers will take necessary steps to reduce inventories and defend falling market shares. "Necessary steps" translates to lowering prices. We have already observed large contract prices of ¥1,300 ($9.29 @ ¥140/US$1) in Tokyo. One of the top three Japanese DRAM producers has denied that it planned to lower 1Mb DRAM prices to ¥1,300 for Southeast Asian destinations. This may be largely academic at this point. Dataquest has observed 1Mb DRAM prices from South Korean sources being quoted as low as $7.80 in Southeast Asia. Nor are the United States or Europe immune from falling prices. We have learned that there are approximately 2 million 1Mb, South Korean-sourced DRAMs in stock in the United States targeted for sale in the $8.00 range.

Our view of the *average* price situation for 1Mb DRAMs at this time is as follows:

Quarter 4 1989	$10.00	Quarter 2 1990	$8.00
Quarter 1 1990	$ 8.90	Quarter 3 1990	$7.50

Haven't We Met Before?

There is one scenario that suggests that we could return to a mild 1Mb DRAM shortage by the second quarter of 1990. With the major Japanese suppliers standing on the production brake pedal, as many as 5 million to 10 million units could be pulled out of the market by early spring of 1990.

By this time, the South Korean, the U.S., and potentially the European suppliers will be experiencing severe price shock and will have concluded that they also should curtail production. All of this could occur just at the time when the electronics industry is recovering from the forecast mild slowdown in quarter 4 of 1989 and quarter 1 of 1990. Users will have all but eliminated inventory throughout the fall and winter as a defense against inventories being valued higher than existing market prices, à la Apple. The renewed demand for 1Mb devices will encounter a supply industry that has idled production and changed its focus to SRAMs. We believe that there could be an undershoot in supply of 1Mb DRAMs similar to the overshoot mentioned above.

The last remaining unknown in this complex equation is the effect of the 4Mb DRAM. Will the leading 1Mb DRAM suppliers, sensing that the high-profit days of this device are over, increase production of the 4Mb devices and combine them with price reductions to ensure retention of market leadership and induce users to convert to 4Mb devices? If so, this action could lead to an entirely new round of worldwide DRAM price cutting, given that the volume supply of 4Mb DRAMs is coming to market just at a time when memory prices are clearly soft. We will address this issue in another newsletter to be released shortly. **Have courage!**

David L. Angel
O. Fred Jones

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Research Newsletter

WORLDWIDE SEMICONDUCTOR OUTLOOK: FOURTH QUARTER 1989

INTRODUCTION

Dataquest has lowered its forecast for worldwide semiconductor industry growth in 1989 slightly, from 12.3 percent in the July forecast to 11.0 percent in this forecast. Second quarter results were slightly lower than the July forecast, and memory pricing is dropping slightly faster than anticipated in that forecast. In the short term, we now believe that the industry is experiencing a minirecession that began in the third quarter of 1989 and will continue through the first quarter of 1990. We are seeing increased semiconductor inventories at both the vendor and user levels, sharp decreases in 1Mb DRAM prices, and a definite slowing of semiconductor order rates. We believe that the situation will begin to improve in the second quarter of 1990 and that shipments will be moderately strong by the fourth quarter of 1990, with a 1.5 percent worldwide growth rate in 1990.

In the long term, Dataquest believes that the industry will experience moderate growth in 1991 and strong growth in 1992 and 1993, with the peak year of the growth cycle occurring in 1993. This forecast is based on the peaking of volume shipments of 4Mb DRAMs, the availability of 8-inch wafers for volume production, historical cyclical trends, and the 1992 effect in Europe. We believe that 1994 will be a year of significantly slower growth and could be the beginning of a major industry recession.

Dataquest expects the Asia/Pacific region to be the fastest growing region through 1994, Europe to be the second-fastest growing region, and Japan and North America to be almost on par with each other. Europe already is benefiting from a major move by both electronic equipment and semiconductor manufacturers to manufacture in Europe because of preparations for a unified Europe in 1992. We expect some of the semiconductor shipments that previously would have been consumed in North America or Japan to be consumed in Europe in the future.

Table 1 compares Dataquest's July quarterly regional forecast with the October forecast. In each region, our forecast was quite close to the actuals, which were based on Dataquest's polling of the industry. Table 2 gives our new annual forecast by region for 1989 through 1994. Table 3 provides Dataquest's worldwide forecast by product for 1989 through 1994.

REGIONAL ANALYSES

Japan

Exchange rates could again have a major effect on dollar-based Japanese semiconductor consumption. In 1985 through 1988, the yen rose dramatically, thereby artificially raising consumption in dollars. However, in 1989 the trend is reversing itself slightly, and the dollar has been appreciating against the yen. This could cause dollar growth to be lower than yen growth.

Many Japanese electronic equipment and automobile manufacturers are moving their manufacturing to North America and Europe. This relocation should cause semiconductor consumption in those regions to grow at a faster rate than Japanese consumption, thus reversing the prevailing trend of the 1980s.

Changes in consumer behavior in Japan also will have a dampening effect on semiconductor consumption. For some time, the Japanese have been ever ready to purchase the latest electronic gadgets. This trend is slowing as the Japanese consumer electronics market becomes saturated. This change will adversely affect consumer electronic equipment production and semiconductor consumption in Japan to a degree.

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TABLE 1
Worldwide Semiconductor Consumption
Comparison of July 1989 and October 1989 Forecasts
Quarter-to-Quarter Percent Change by Geographic Region

Region	1988	Q1 1989	Q2 1989	Q3 1989	Q4 1989	Total 1989
North America July	23.2%	4.7%	5.3%	0.7%	(0.9%)	15.0%
North America October	23.2%	4.7%	5.8%	(0.5%)	(1.8%)	14.4%
Japan July	39.2%	(6.7%)	3.0%	0.7%	(1.1%)	8.1%
Japan October	39.2%	(6.7%)	1.1%	0.8%	(2.3%)	6.3%
Europe July	30.7%	8.6%	(1.9%)	(3.2%)	9.2%	14.7%
Europe October	30.7%	8.6%	(1.7%)	(3.6%)	3.4%	13.1%
Asia/ROW July	45.0%	(6.5%)	6.9%	6.5%	5.6%	17.1%
Asia/ROW October	45.0%	(6.5%)	8.7%	2.6%	2.3%	15.3%
Total World July	33.0%	(0.8%)	3.3%	0.7%	1.5%	12.3%
Total World October	33.0%	(0.8%)	2.9%	(0.1%)	(0.6%)	11.0%
		Q1 1990	**Q2 1990**	**Q3 1990**	**Q4 1990**	**Total 1990**
North America July		(3.0%)	(2.4%)	3.2%	4.8%	(1.1%)
North America October		(2.5%)	1.4%	3.0%	2.5%	0.3%
Japan July		(3.2%)	1.4%	2.3%	3.8%	0.2%
Japan October		(4.1%)	3.8%	0.8%	6.6%	(0.4%)
Europe July		(0.9%)	1.7%	(0.5%)	6.7%	6.5%
Europe October		1.7%	2.0%	(2.8%)	7.4%	3.8%
Asia/ROW July		(1.2%)	2.9%	3.1%	5.2%	13.3%
Asia/ROW October		(1.7%)	2.5%	2.6%	3.7%	7.6%
Total World July		(2.5%)	0.5%	2.2%	4.8%	2.4%
Total World October		(2.3%)	2.6%	1.1%	5.1%	1.5%

Source: Dataquest
October 1989

During most of the 1980s, Japan has experienced trade problems with the United States and Europe. Changes in political leadership in Japan and its major trading partners could exacerbate these problems over the period of our forecast.

Electronics companies in the newly industrialized economies (NIEs), such as Samsung and GoldStar, are providing stiff competition to Japanese electronics firms, both equipment and semiconductor manufacturers, with their strong growth, heavy capital investment, and lower labor costs.

The following applications are driving the semiconductor market in Japan:

- Office automation—Word processors, copiers, facsimiles, and laser printers
- Computers—Laptops, mainframes, and supercomputers
- Artificial intelligence (AI)
- Satellites and military/space programs
- Automobiles
- Domestic—Microwave ovens, refrigerators, washing machines, and dishwashers

TABLE 2
Worldwide Semiconductor Consumption (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994
North America	$15,844	$18,124	$18,187	$20,770	$24,936	$32,876	$34,850
Percent Change	23.2%	14.4%	0.3%	14.2%	20.1%	31.8%	6.0%
Japan	20,772	22,082	21,998	25,114	30,061	38,642	42,111
Percent Change	39.2%	6.3%	(0.4%)	14.2%	19.7%	28.5%	9.0%
Europe	8,491	9,600	9,969	11,454	13,735	17,991	20,010
Percent Change	30.7%	13.1%	3.8%	14.9%	19.9%	31.0%	11.2%
Asia/ROW	5,752	6,633	7,141	8,573	10,675	14,803	16,308
Percent Change	45.0%	15.3%	7.7%	20.1%	24.5%	38.7%	10.2%
Total World	$50,859	$56,439	$57,295	$65,911	$79,407	$104,312	$113,279
Percent Change	33.0%	11.0%	1.5%	15.0%	20.5%	31.4%	8.6%

Source: Dataquest
October 1989

- Audio and video equipment
- High-definition television (HDTV)
- Integrated services digital network (ISDN)
- Home automation and security systems

The GDP forecast for Japan is slightly higher than for the United States and Europe, but significantly lower than the Asian economies of South Korea, Hong Kong, and Taiwan. In early 1989, Japanese consumers restrained their spending out of respect for the dying Emperor Hirohito. After months of scandal, a new Japanese Prime Minister is in office, and the socialists have become a strong influence in the Diet, campaigning on a pledge to remove the 3 percent sales tax (VAT) and replace that lost revenue with capital gains taxes.

During the next five years, domestic demand is expected to provide the main boost to Japan's growth, rising by an average of 4.25 percent. External demand is expected to contract, cutting Japan's trade surplus.

MITI forecasts corporate capital expenditure in the current fiscal year to slow to 11 percent, down from 20 percent last year. Manufacturers will increase their investments more than the average, growing 15.5 percent.

In 1988, wages increased 4 percent, while inflation was only 1 percent. Therefore, real income and private consumption increased. The proposed socialist tax reforms, if instituted, should help boost consumer spending.

Overcapacity for semiconductor production is not expected to be a problem in Japan, at least through 1993. In 1994, capacity utilization rates may drop, however, the result of large fabs that will be built in the early 1990s and a drop in demand. Dataquest expects semiconductor capital spending in Japan to grow approximately 2 percent in 1990 and resume very strong growth (between 30 and 40 percent) in 1991 through 1993. We believe that capital spending will decrease sharply in 1994.

Semiconductor inventory levels in Japan are rising. Inventories were up 7 percent at the end of the second quarter from the beginning of the year, and MOS memory inventories were up 20 percent from the beginning of the year.

North America

Surveys of semiconductor purchasers in North America show that average semiconductor orders have been declining rather dramatically since July, although lead times have remained fairly stable at about 10 weeks. Semiconductor inventory levels (at OEMs) are currently much higher than target inventory levels, primarily because of DRAM inventory levels.

The U.S. GNP is forecast to grow by only 2.6 percent in both 1989 and 1990, a definite slowdown from 1988's 4.4 percent (restated in July 1989). Dataquest expects GNP growth to pick up in the latter half of 1990 and increase to 3.2 percent growth in 1991. Dun & Bradstreet's outlook indicates that the economy will slow down in the second half of 1989 and the first half of 1990 but will stop short of recession. Overall capital spending is expected to improve, but not dramatically.

Dataquest does not anticipate a semiconductor production overcapacity situation in the United States until 1994, because U.S. manufacturers are better controlling their investment in new plants. We believe that semiconductor capital spending will be up 11 percent in 1989, will be flat in 1990, and will resume strong growth in 1991 through 1993.

Dataquest's indicators for the North American semiconductor market all show that the current slowdown is more than a seasonal "blip" for both semiconductor suppliers and users. Dataquest expects the fourth quarter to be worse than the third for suppliers as backlog built in the first half finally erodes. With orders down, inventories up, and system demand shaky, we do not foresee a recovery to occur earlier than the second quarter of 1990. System OEMs will continue to focus heavily on cost-cutting measures (e.g., pricing, inventories, and quality) that will have a negative impact on suppliers without their own cost-reduction plans in place. Dataquest believes that semiconductor suppliers must match the economizing now occurring in their customer bases.

TABLE 3
Worldwide Semiconductor Consumption (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	1994
Total Semiconductor	$50,859	$56,439	$57,295	$65,911	$79,407	$104,312	$113,279
Percent Change	33.0%	11.0%	1.5%	15.0%	20.5%	31.4%	8.6%
Total Integrated Circuit	$41,068	$46,761	$47,537	$55,111	$67,301	$90,264	$97,765
Percent Change	37.4%	13.9%	1.7%	15.9%	22.1%	34.1%	8.3%
Bipolar Digital	5,200	4,409	4,089	4,255	4,497	4,832	4,577
Percent Change	9.2%	(15.2%)	(7.3%)	4.1%	5.7%	7.4%	(5.3%)
Bipolar Memory	689	543	497	492	457	442	421
Percent Change	11.0%	(21.2%)	(8.5%)	(1.0%)	(7.1%)	(3.3%)	(4.8%)
Bipolar Logic	4,511	3,866	3,592	3,763	4,040	4,390	4,156
Percent Change	9.0%	(14.3%)	(7.1%)	4.8%	7.4%	8.7%	(5.3%)
MOS Digital	26,988	33,554	34,474	40,385	50,312	69,981	75,630
Percent Change	54.5%	24.3%	2.7%	17.1%	24.6%	39.1%	8.1%
MOS Memory	11,692	16,884	17,078	19,415	24,143	35,417	38,300
Percent Change	93.1%	44.4%	1.1%	13.7%	24.4%	46.7%	8.1%
MOS Microdevice	7,144	7,431	7,781	9,412	11,666	15,914	17,486
Percent Change	39.9%	4.0%	4.7%	21.0%	23.9%	36.4%	9.9%
MOS Logic	8,152	9,239	9,615	11,558	14,503	18,650	19,844
Percent Change	29.2%	13.3%	4.1%	20.2%	25.5%	28.6%	6.4%
Analog	8,880	8,798	8,974	10,471	12,492	15,451	17,558
Percent Change	16.0%	(0.9%)	2.0%	16.7%	19.3%	23.7%	13.6%
Total Discrete	$7,612	$7,622	$7,649	$8,424	$9,380	$10,835	$11,873
Percent Change	14.4%	0.1%	0.4%	10.1%	11.3%	15.5%	9.6%
Total Optoelectronic	$2,179	$2,056	$2,109	$2,376	$2,726	$3,213	$3,641
Percent Change	27.5%	(5.6%)	2.6%	12.7%	14.7%	17.9%	13.3%

Source: Dataquest
October 1989

Europe

The situation in Europe is more positive than in Japan and North America because of the "1992 Effect." Many Japanese and North American electronic equipment manufacturers are planning to build, are building, or have built plants in Europe in preparation for 1992. In response to this increased demand, foreign chip suppliers also are building plants in Europe. These developments have had a very strong psychological effect on many of the European manufacturers that currently have facilities in the Asia/Pacific region, causing them to move these facilities back onshore to Europe. GEC-Plessey Telecom's plan to assemble PCs in Scotland is a classic example of this European shift to production back onshore.

Consumer and telecommunications applications are driving the semiconductor market in Europe. New products include CT2 cellular telephony and satellite receivers for domestic television services. The current slowdown in the European semiconductor market is the result of reduced demand from the data processing sector (specifically PC clone manufacturers), as well as a slowdown in demand from the telecommunications central office switching gear sector, which is in the midst of European Community (EC) PTT deregulation. Dataquest's industry surveys show that semiconductor users have been in a phase of reducing inventories for the past three months. This trend is expected to continue through the end of 1989 as DRAMs and SRAMs become more easily available. The major European data processing manufacturers are in a particularly bad state currently, with more than six months of inventory in some semiconductor products. Dataquest expects the unification of European standards in 1992 to have a strongly positive effect on the development of new end-equipment markets for semiconductors in the long term. Especially promising are Group Standarde Mobile (GSM), a pan-European cellular telephone standard, and Radio Data Systems (RDS), a service that offers special-report broadcasts for car radios.

The major European economies are forecast to have GNP growth on par with or slightly above the United States in 1989 and 1990. In France, VAT rates have been reduced on luxury items, books, and public transport. Some consumer electronics goods (such as hi-fis) are subject to the luxury VAT. West Germany has inflation fears prompted by the fall of the deutsche mark, increasing consumer prices, higher oil prices, and large wage increases. Some consumer taxes are going up in West Germany. The United Kingdom is plagued by extremely high interest rates of approximately 14 percent. As a result, demand for mortgages and housing prices have dropped. Inflation is still high at 8 percent.

Asia/Pacific

The Asia/Pacific region will continue to be the fastest-growing region for semiconductor consumption during the period of this forecast. The economies of the Four Tigers and other Asian countries are expected to have continuing high GNP growth rates that range from 6.2 percent to 9.7 percent through 1989 and 1990. Problems that face the Asian market in the short term are wage hikes, domestic unrest, currency appreciation, and international trade tensions. Continuing into the long term, the governments' drives for technology development and the emergence of larger domestic markets for electronic goods will assist semiconductor shipment growth into this region.

Semiconductor capital spending continues to be very strong in Asia. Dataquest forecasts this region to have the highest capital spending increases of any region during our forecast period.

DATAQUEST CONCLUSIONS

The slowdown in the worldwide semiconductor industry has begun. A minirecession started in the third quarter and is forecast to last through the second quarter of 1990. Dataquest believes that the semiconductor industry will pick up again in the third quarter of 1990 as computer demand turns up, inventory problems are worked through, and prices begin to increase.

The Asia/Pacific region, with its fast-growing economy and aggressive capital spending, is poised to continue as the fastest-growing semiconductor market. Europe is already reaping the benefits of the 1992 Effect, which should continue to gain momentum over the coming years. We have no doubt that Europe's gains will come at the expense of the Japanese and North American markets.

Patricia S. Cox

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Research *Newsletter*

FINAL 1988 WORLDWIDE SEMICONDUCTOR MARKET SHARE ESTIMATES BY APPLICATION SEGMENT

SUMMARY

This newsletter presents Dataquest's final estimates for 1988 worldwide application segment market share by semiconductor vendor. Dataquest is publishing these data for the first time, the results of a recent survey of the top 40 worldwide semiconductor suppliers by region. The following is Dataquest's analysis based on this new information:

- Data processing emerged as the leading application market worldwide for semiconductors in 1988 with shipments of $21,606 million, representing 42.5 percent of the market.
- Not surprisingly, Japan had the largest market share, with $20,772 million in semiconductor shipments maintained by both a strong data processing and consumer base, which together represent 72.6 percent of the Japanese market.

TABLE 1
Estimated 1988 Worldwide Semiconductor Shipments by Application Segment (Millions of Dollars)

Company	Revenue	Percent
Data Processing	$21,606	42.5%
Communications	7,641	15.0
Industrial	5,912	11.6
Consumer	10,959	21.5
Military	2,257	4.4
Transportation	2,484	4.9
Total	$50,859	100.0%

Note: Does not include North American captive shipments.
Columns may not add to totals shown because of rounding.

Source: Dataquest
October 1989

- A large portion of growth within the data processing application segment was fueled by MOS digital technology, with shipments of $14,270 million, or 66.0 percent. In particular, MOS memory drove most of the growth, representing 55.6 percent of MOS digital within the data processing application segment.
- NEC was the leading vendor in the data processing segment, with shipments of $2,188 million representing 10.1 percent of the market.

Table 1 lists each of the application segments worldwide along with their respective semiconductor shipments in dollars and percentages of the market.

REGIONAL ANALYSIS

Figure 1 illustrates that Japan-based companies are leaders in both the data processing and consumer markets with $11,795 million and $7,435 million in semiconductor shipments, respectively. Japanese companies represented a 49.3 percent share of the data processing market and a 67.7 percent share of the consumer market. These companies held 48.5 percent of the total semiconductor market (including captive) in 1988.

North America was slightly ahead of Japan in a close competition in the worldwide data processing application segment with a 7 percent difference in semiconductor shipments between regions (see Figure 2). Japan holds a dominating lead in the consumer applications segment, which is virtually untapped by foreign suppliers. This situation presents a potential market opportunity for these suppliers, because the consumer applications market represented the second largest worldwide application market in 1988.

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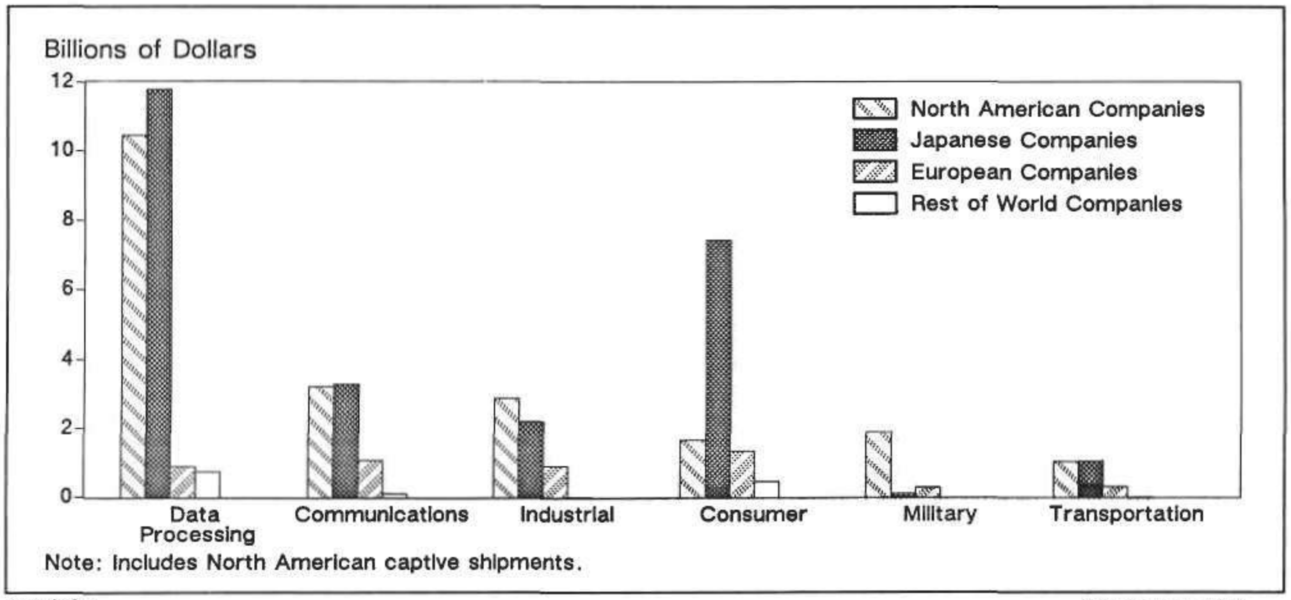
FIGURE 1
Estimated 1988 Worldwide Semiconductor Shipments by Company Base



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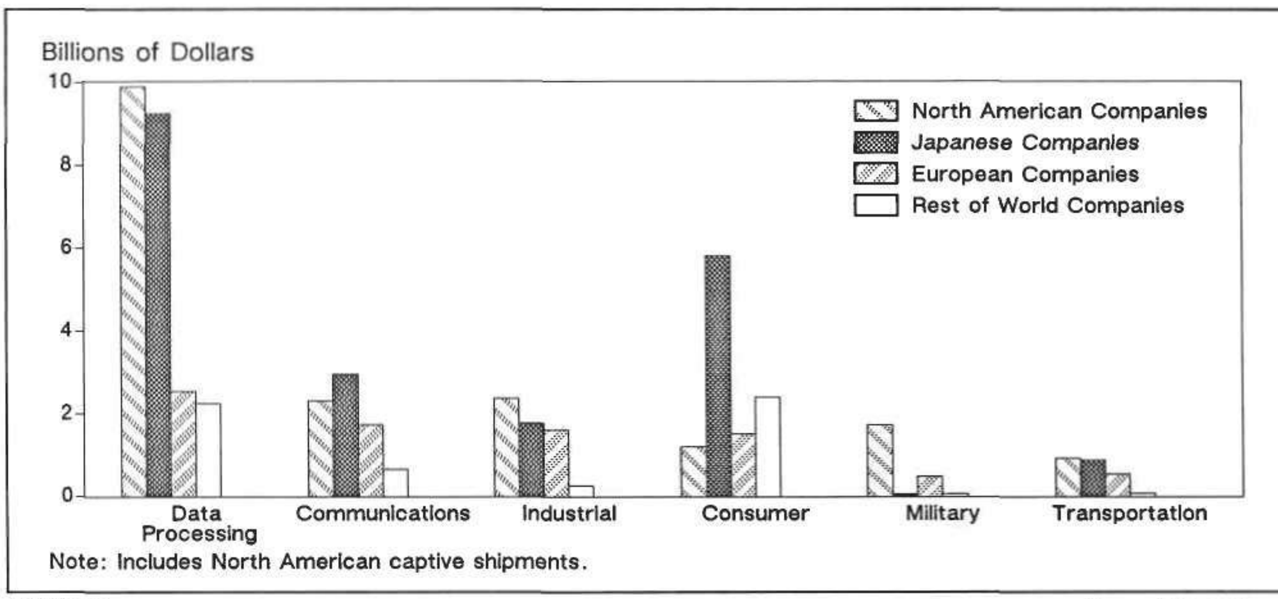
Source: Dataquest October 1989

FIGURE 2
Estimated 1988 Worldwide Semiconductor Shipments Consumption by Region



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Source: Dataquest October 1989

COMPONENT ANALYSIS

Table 2 provides an analysis of semiconductor shipments by semiconductor product type within each of the six application markets. Data processing emerged as the largest application for semiconductors, with shipments of $21,606 million representing 42.5 percent of total semiconductors shipped to all application segments. A large percentage of semiconductor shipments into the data processing segment is fueled by MOS digital, which represents 66.0 percent of the data processing segment. Of the data processing segment, a majority (55.6 percent) is fueled by MOS memory, mainly DRAMs that are supplied largely by Japanese manufacturers.

The consumer applications segment was the second-largest category, with shipments of $10,959 million representing 21.6 percent of all application segments. Predictably, a high percentage of analog shipments (33.1 percent of consumer) supported much of the consumer segment growth with a large base of regional suppliers.

VENDOR ANALYSIS

As mentioned previously, NEC emerged as the leader in the data processing segment, with semiconductor shipments of $2,188 million. The company mainly supplies DRAM memory chips used in such systems as mainframes, supercomputers, personal computers, and laptops. Toshiba and Hitachi also were very strong in this application segment with sales of $1,990 million and $1,734 million, respectively. Growth was due largely to these companies' DRAM shipments, where leading chip technologies (256K, 1Mb, and 4Mb DRAMs) pull in a premium in supporting the computer industry where demand is high. Intel ranked number four with semiconductor shipments of $1,725 million; its growth was fueled by the popularity of its 8086 family of microprocessors (especially 80286, 80386, and 80486 MPUs), which are used in many of IBM's personal computers. In 1988, Intel's microprocessor sales amounted to 46.8 percent of Intel's total worldwide semiconductor sales of $2,350 million.

NEC also emerged as the leader in communications, with sales of $858 million or 11.2 percent of the worldwide market supported by sales in mobile communications and central office switching equipment. Motorola was the number two vendor, which is not surprising because Motorola relies heavily on using its own semiconductors in the production of its communication products. Motorola sees this as a growing opportunity fueled by its line of radios and mobile and cellular phone products. Motorola held 10.5 percent of the market worldwide with sales of $806 million.

Motorola led industrial application shipments, with $510 million in shipments, or 8.6 percent of the market supplying testers and detection systems. Toshiba ranked second with sales of $463 million or 7.8 percent of the market; NEC ranked third with sales of $348 million. Both NEC and Toshiba supply semiconductors to a number of industrial equipment suppliers that support such equipment as industrial robotics, manufacturing automation, process control, and medical/diagnostic systems.

The consumer application segment is supported by many Japanese manufacturers because of Japan's heavy production of such hot consumer products as videocameras, large television receivers, compact disc players, and videocassette recorders (VCRs). However, this market is quietly

TABLE 2
Estimated 1988 Worldwide Semiconductor Market by Semiconductor Product and Application Segment (Millions of Dollars)

	Data Processing	Communications	Industrial	Consumer	Military	Transportation	Total
Total Semiconductor	$21,606	$7,641	$5,912	$10,959	$2,257	$2,484	$50,859
Integrated Circuit	$19,068	$6,020	$4,220	$ 8,170	$1,819	$1,771	$41,068
Bipolar Digital	2,828	937	551	231	497	156	5,200
Memory	460	103	31	14	84	8	700
Logic	2,368	834	31	217	413	148	4,500
MOS Digital	14,270	3,787	2,533	4,316	893	1,189	26,988
Memory	7,938	1,104	934	1,164	288	264	11,692
Micro	3,202	1,096	765	1,378	200	503	7,144
Logic	3,130	1,587	834	1,774	405	422	8,152
Analog	1,970	1,296	1,136	3,623	429	426	8,880
Discrete	$ 1,933	$1,223	$1,459	$ 1,990	$ 362	$ 645	$ 7,612
Optoelectronic	$ 605	$ 398	$ 233	$ 799	$ 76	$ 68	$ 2,179

Note: Does not include North American captive shipments.

Source: Dataquest October 1989

slowing as the yen remains strong and production begins to move offshore to the Asia/Pacific and Rest of World (ROW) regions. Matsushita emerged as the leader in this segment, with semiconductor shipments of $1,091 million.

Harris (GE/RCA) led semiconductor shipments in the military segment with $245 million or 10.9 percent of the market. This share includes Harris' recent acquisitions of GE Solid State (GESS) and GE Microelectronics Center in Research Triangle Park, North Carolina. Harris is a key supplier of radiation-hardened (rad-hard) devices, gallium arsenide (GaAs) components, and custom/semicustom circuits to the military. Harris' development of new technologies such as silicon-on-insulator (SOI), which is used to increase circuit speed and radiation hardness, has ensured Harris' place as a major supplier in this market.

In the transportation application segment, Motorola emerged as the leader, with sales of $360 million or 14.5 percent of the worldwide market. Motorola is a major supplier to the three largest North American automobile manufacturers (Chrysler, Ford, and GM). Interestingly enough, it is not surprising to find both Hitachi and Toshiba as leading vendors to the transportation industry, with semiconductor shipments of $244 million and $215 million, respectively, because Japanese car production in 1988 was approximately equal to that of North America.

Tables 3 through 8 list the top 10 vendors within each of the six application segments, as well as their respective market shares in both dollars and percentage of the market.

Table 3
Estimated 1988 Worldwide Semiconductor Market Share Rankings
Data Processing Segment
(Millions of Dollars)

Company	Revenue	Percent
NEC	$ 2,188	10.1%
Toshiba	1,990	9.2
Hitachi	1,734	8.0
Intel	1,725	8.0
Fujitsu	1,677	7.8
Texas Instruments	1,359	6.3
Mitsubishi	1,034	4.8
Motorola	771	3.6
Advanced Micro Devices	667	3.1
National Semiconductor	652	3.0
Total—Top 10 Companies	$13,797	63.9%
Total North America*	$ 8,125	37.6%
Total Japan	11,795	54.6
Total Europe	915	4.2
Total Rest of World	771	3.6
Total—All Companies	$21,606	100.0%

*Does not include North American captive shipments
Note: Columns may not add to totals shown because of rounding.
Source: Dataquest October 1989

Table 4
Estimated 1988 Worldwide Semiconductor Market Share Rankings
Communications Segment
(Millions of Dollars)

Company	Revenue	Percent
NEC	$ 858	11.2%
Motorola	806	10.5
AT&T	628	8.2
Toshiba	599	7.8
Fujitsu	586	7.7
Texas Instruments	485	6.3
Hitachi	411	5.4
Philips-Signetics	367	4.8
SGS-Thomson	229	3.0
National Semiconductor	225	2.9
Total—Top 10 Companies	$5,194	68.0%
Total North America*	$3,176	41.6%
Total Japan	3,296	43.1
Total Europe	1,044	13.7
Total Rest of World	125	1.6
Total—All Companies	$7,641	100.0%

*Does not include North American captive shipments
Note: Columns may not add to totals shown because of rounding.
Source: Dataquest October 1989

TABLE 5
Estimated 1988 Worldwide Semiconductor Market Share Rankings
Industrial Segment
(Millions of Dollars)

Company	Revenue	Percent
Motorola	$ 510	8.6%
Toshiba	463	7.8
Hitachi	348	5.9
Mitsubishi	326	5.5
Texas Instruments	322	5.4
NEC	319	5.4
National Semiconductor	326	5.5
Philips-Signetics	243	4.1
SGS-Thomson	231	3.9
Harris	220	3.7
Total—Top 10 Companies	$3,308	56.0%
Total North America*	$2,741	46.4%
Total Japan	2,229	37.7
Total Europe	926	15.7
Total Rest of World	16	0.3
Total—All Companies	$5,912	100.0%

*Does not include North American captive shipments
Note: Columns may not add to totals shown because of rounding.

Source: Dataquest October 1989

TABLE 6
Estimated 1988 Worldwide Semiconductor Market Share Rankings
Consumer Segment
(Millions of Dollars)

Company	Revenue	Percent
Matsushita	$ 1,091	10.0%
Toshiba	1,069	9.8
NEC	1,032	9.4
Hitachi	798	7.3
Mitsubishi	750	6.8
Philips-Signetics	710	6.5
Sanyo	698	6.4
Sharp	522	4.8
Sony	468	4.3
Motorola	377	3.4
Total—Top 10 Companies	$ 7,515	68.6%
Total North America*	$ 1,665	15.2%
Total Japan	7,435	67.8
Total Europe	1,368	12.5
Total Rest of World	491	4.5
Total—All Companies	$10,959	100.0%

*Does not include North American captive shipments
Note: Columns may not add to totals shown because of rounding.

Source: Dataquest October 1989

DATAQUEST CONCLUSIONS

Indigenous semiconductor suppliers have a majority of market share across all application segments within their regional markets. Two of these segments, data processing and consumer, are especially significant because of the global opportunities they create and the technological expertise they imply.

The data processing market, where strong regional growth is expected to continue, provides semiconductor suppliers with both a growing domestic revenue source and an opportunity for increased global participation. The importance of data processing applications in sustaining worldwide competitiveness can be seen by regional consortia efforts such as JESSI (Europe) and Sematech (United States)—both of which are evidence that developing technology is likely to remain onshore in support of domestic application markets.

To compete effectively within this application segment, regional suppliers will need to balance new semiconductor technology developments in memory—especially high-density DRAMs (256K, 1Mb, 4Mb), high-end microprocessors (32/64-bit RISC and CISC), and leading-edge ASICs (gate arrays, PLDs)—with strategic partnerships and alliances and consortium participation and support to remain effective within a forming global market.

The consumer market, which is the second-largest application market in semiconductor shipments, presents ample opportunity for regional suppliers that should not be ignored. Currently, Japan-based companies hold a dominating lead of 68 percent worldwide in consumer applications. A scattering of regional participants such as Motorola, Philips, SGS-Thomson, Siemens, and Texas Instruments supply analog, memory (nonvolatile), microcontroller, and discrete devices to this market.

Table 7
Estimated 1988 Worldwide Semiconductor Market Share Rankings Military Segment (Millions of Dollars)

Company	Revenue	Percent
Harris	$ 245	10.9%
Motorola	211	9.3
Texas Instruments	207	9.2
National Semiconductor	194	8.6
Advanced Micro Devices	154	6.8
Analog Devices	92	4.1
Philips-Signetics	86	3.8
SGS-Thomson	83	3.7
LSI Logic	82	3.6
Intel	73	3.2
Total—Top 10 Companies	$1,427	63.2%
Total North America*	$1,814	80.4%
Total Japan	123	5.4
Total Europe	320	14.2
Total Rest of World	0	0
Total—All Companies	$2,257	100.0%

*Does not include North American captive shipments
Note: Columns may not add to totals shown because of rounding.

Source: Dataquest October 1989

Table 8
Estimated 1988 Worldwide Semiconductor Market Share Rankings Transportation Segment (Millions of Dollars)

Company	Revenue	Percent
Motorola	$ 360	14.5%
Toshiba	244	9.8
Hitachi	215	8.7
Texas Instruments	124	5.0
NEC	123	5.0
National Semiconductor	117	4.7
SGS-Thomson	113	4.5
Harris	109	4.4
Oki Semiconductor	102	4.1
Intel	97	3.9
Total—Top 10 Companies	$1,604	64.6%
Total North America*	$1,065	42.9%
Total Japan	1,064	42.8
Total Europe	344	13.8
Total Rest of World	11	0.4
Total—All Companies	$2,484	100.0%

*Does not include North American captive shipments
Note: Columns may not add to totals shown because of rounding.

Source: Dataquest October 1989

The opportunity in consumer applications is present for regional vendors that want to supply *high-end* consumer products to the market. It is within the high-end portion of the market that regional suppliers can leverage their technology know-how to become fairly successful. Concentrating on the low-end commodity consumer portion of the market, where minimum manufacturing costs and technology know-how are required to participate effectively, does not present as great an opportunity for regional suppliers; it is best left to those regions that are more cost effective.

Carolyn Doles

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Research Newsletter

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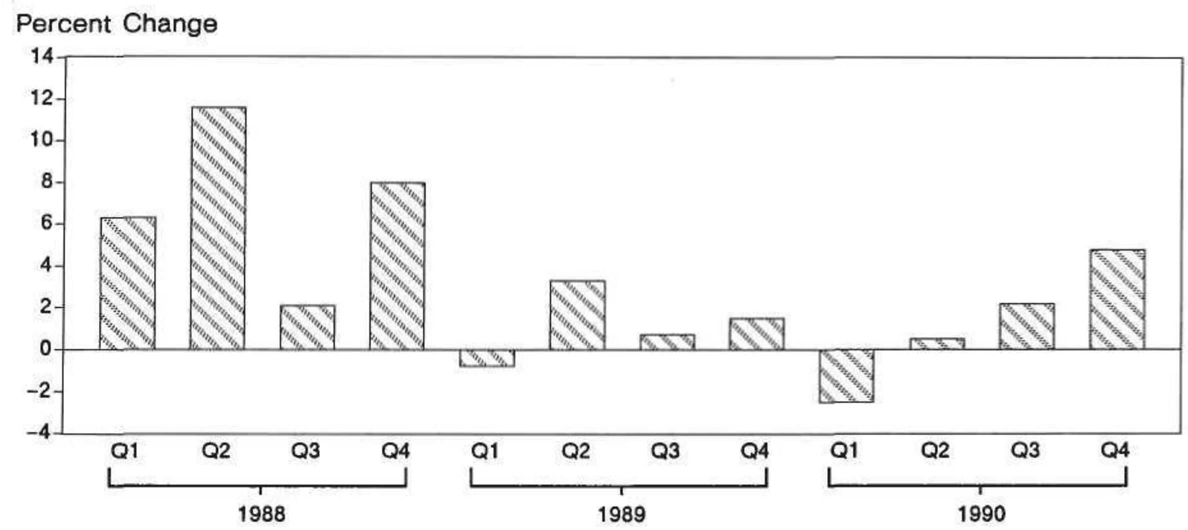
WORLDWIDE SEMICONDUCTOR OUTLOOK: THIRD QUARTER 1989

SUMMARY

The worldwide semiconductor industry recession we have been forecasting to begin in third quarter 1989 appears to be under way. Surprisingly, it began in Japan and Asia/Rest of World (ROW) in the first quarter, but was not recognized by Dataquest at that time. The North American and European markets were quite strong in the first quarter, in stark contrast to Japan and Asia. During the second quarter, North America continued to show strength, Europe showed a definite slump, and Japan and Asia recovered from their first-quarter declines. Our latest quarterly worldwide semiconductor consumption growth forecast is shown in Figure 1.

Figure 1

Worldwide Semiconductor Consumption
Quarter-to-Quarter Percent
Change in U.S. Dollars



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Source: Dataquest
July 1989

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COMPARISON WITH OUR PREVIOUS FORECAST

Table 1 compares Dataquest's current quarterly consumption forecast with the forecast we published in April. The North American forecast is somewhat more positive now for both 1989 and 1990, although we continue to believe that 1990 will be a negative year for the North American market. Our Japan forecast has been revised downward for 1989, due to a disastrous first quarter that had not been predicted in our previous forecast. Our European forecast is even more optimistic than previously, a result of continued growth of foreign company manufacturing in Europe. Our Asia forecast has been downgraded for 1989 because of an extremely poor first quarter.

Table 1

Worldwide Semiconductor Consumption
Comparison of April 1989 and July 1989 Forecasts
Quarter-to-Quarter Forecast
Percent Change by Geographic Region

Region	1988	Q1/89	Q2/89	Q3/89	Q4/89	1989
North America April	24.7%	7.3%	4.3%	(1.8%)	(5.2%)	14.6%
North America July	23.2%	4.7%	5.3%	0.7%	(0.9%)	15.0%
Japan April	35.6%	1.8%	2.3%	(1.4%)	(4.7%)	14.9%
Japan July	39.2%	(6.7%)	3.0%	0.7%	(1.1%)	8.1%
Europe April	31.0%	3.4%	2.2%	(3.4%)	1.5%	10.2%
Europe July	30.7%	8.6%	(1.9%)	(3.2%)	9.2%	14.7%
Asia/ROW April	42.6%	7.5%	4.9%	0.5%	(1.6%)	26.3%
Asia/ROW July	45.0%	(6.5%)	6.9%	6.5%	5.6%	17.1%
Total World April	31.9%	4.4%	3.2%	(1.6%)	(3.5%)	15.3%
Total World July	33.0%	(0.8%)	3.3%	0.7%	1.5%	12.3%
		Q1/90	Q2/90	Q3/90	Q4/90	1990
North America April		(1.9%)	(0.3%)	2.3%	3.9%	(3.8%)
North America July		(3.0%)	(2.4%)	3.2%	4.8%	(1.1%)
Japan April		(2.8%)	3.5%	3.2%	4.5%	(1.3%)
Japan July		(3.2%)	1.4%	2.3%	3.8%	0.2%
Europe April		0.4%	2.2%	(1.3%)	4.9%	2.5%
Europe July		(0.9%)	1.7%	(0.5%)	6.7%	6.5%
Asia/ROW April		1.2%	3.0%	3.2%	4.3%	6.5%
Asia/ROW July		(1.2%)	2.9%	3.1%	5.2%	13.3%
Total World April		(1.5%)	2.0%	2.2%	4.3%	(0.5%)
Total World July		(2.5%)	0.5%	2.2%	4.8%	2.4%

Source: Dataquest
July 1989

OUR CURRENT FORECAST

Table 2 gives our current quarterly forecast by region for 1989 and 1990. Tables 3 and 4 give the worldwide quarterly forecast by product, in dollars and percent, respectively.

Table 2

Worldwide Semiconductor Consumption
(Millions of Dollars)

	1988	Q1/89	Q2/89	Q3/89	Q4/89	1989
North America	$15,844	$ 4,375	$ 4,606	$ 4,640	$ 4,600	$18,221
Percent Change	23.2%	4.7%	5.3%	0.7%	(0.9%)	15.0%
Japan	20,772	5,483	5,650	5,687	5,626	22,446
Percent Change	39.2%	(6.7%)	3.0%	0.7%	(1.1%)	8.1%
Europe	8,491	2,455	2,408	2,330	2,545	9,738
Percent Change	30.7%	8.6%	(1.9%)	(3.2%)	9.2%	14.7%
Asia/ROW	5,752	1,527	1,632	1,738	1,836	6,733
Percent Change	45.0%	(6.5%)	6.9%	6.5%	5.6%	17.1%
Total World	$50,859	$13,840	$14,296	$14,395	$14,607	$57,138
Percent Change	33.0%	(0.8%)	3.3%	0.7%	1.5%	12.3%

	Q1/90	Q2/90	Q3/90	Q4/90	1990
North America	$ 4,463	$ 4,356	$ 4,495	$ 4,711	$18,025
Percent Change	(3.0%)	(2.4%)	3.2%	4.8%	(1.1%)
Japan	5,448	5,525	5,652	5,867	22,492
Percent Change	(3.2%)	1.4%	2.3%	3.8%	0.2%
Europe	2,523	2,567	2,554	2,724	10,368
Percent Change	(0.9%)	1.7%	(0.5%)	6.7%	6.5%
Asia/ROW	1,814	1,867	1,925	2,025	7,631
Percent Change	(1.2%)	2.9%	3.1%	5.2%	13.3%
Total World	$14,248	$14,315	$14,626	$15,327	$58,516
Percent Change	(2.5%)	0.5%	2.2%	4.8%	2.4%

Source: Dataquest
July 1989

Table 3

Worldwide Semiconductor Consumption (Millions of Dollars)

	1988	Q1/89	Q2/89	Q3/89	Q4/89	1989
Total Semiconductor	$50,859	$13,840	$14,296	$14,395	$14,607	$57,138
Total IC	$41,068	$11,427	$11,873	$11,982	$12,188	$47,470
Bipolar Digital	$ 5,200	$ 1,128	$ 1,162	$ 1,118	$ 1,124	$ 4,532
Memory	689	149	135	125	119	528
Logic	4,511	979	1,027	993	1,005	4,004
MOS	$26,988	$ 8,119	$ 8,466	$ 8,600	$ 8,757	$33,942
Memory	11,692	4,077	4,335	4,524	4,590	17,526
Microdevices	7,144	1,790	1,810	1,809	1,835	7,244
Logic	8,152	2,252	2,321	2,267	2,332	9,172
Analog	$ 8,880	$ 2,180	$ 2,245	$ 2,264	$ 2,307	$ 8,996
Discrete	$ 7,612	$ 1,893	$ 1,892	$ 1,880	$ 1,901	$ 7,566
Optoelectronic	$ 2,179	$ 520	$ 531	$ 533	$ 518	$ 2,102

	Q1/90	Q2/90	Q3/90	Q4/90	1990
Total Semiconductor	$14,248	$14,315	$14,626	$15,327	$58,516
Total IC	$11,939	$11,970	$12,237	$12,795	$48,941
Bipolar Digital	$ 1,038	$ 1,043	$ 1,056	$ 1,095	$ 4,232
Memory	116	121	121	121	479
Logic	922	922	935	974	3,753
MOS	$ 8,641	$ 8,603	$ 8,850	$ 9,277	$35,371
Memory	4,550	4,485	4,613	4,825	18,473
Microdevices	1,809	1,844	1,939	2,040	7,632
Logic	2,282	2,274	2,298	2,412	9,266
Analog	$ 2,260	$ 2,324	$ 2,331	$ 2,423	$ 9,338
Discrete	$ 1,819	$ 1,828	$ 1,850	$ 1,972	$ 7,469
Optoelectronic	$ 490	$ 517	$ 539	$ 560	$ 2,106

Source: Dataquest
July 1989

Table 4

Worldwide Semiconductor Consumption (Percent Change in Dollars)

	1988	Q1/89	Q2/89	Q3/89	Q4/89	1989
Total Semiconductor	33.0%	(0.8%)	3.3%	0.7%	1.5%	12.3%
Total IC	37.4%	0.1%	3.9%	0.9%	1.7%	15.6%
Bipolar Digital	9.2%	(3.2%)	3.0%	(3.8%)	0.5%	(12.8%)
Memory	11.0%	(12.9%)	(9.4%)	(7.4%)	(4.8%)	(23.4%)
Logic	9.0%	(1.5%)	4.9%	(3.3%)	1.2%	(11.2%)
MOS	54.5%	3.1%	4.3%	1.6%	1.8%	25.8%
Memory	93.1%	7.0%	6.3%	4.4%	1.5%	49.9%
Microdevices	39.9%	(2.7%)	1.1%	(0.1%)	1.4%	1.4%
Logic	29.2%	1.4%	3.1%	(2.3%)	2.9%	12.5%
Analog	16.0%	(8.3%)	3.0%	0.8%	1.9%	1.3%
Discrete	14.4%	(3.5%)	(0.1%)	(0.6%)	1.1%	(0.6%)
Optoelectronic	27.5%	(9.6%)	2.1%	0.4%	(2.8%)	(3.5%)

	Q1/90	Q2/90	Q3/90	Q4/90	1990
Total Semiconductor	(2.5%)	0.5%	2.2%	4.8%	2.4%
Total IC	(2.0%)	0.3%	2.2%	4.6%	3.1%
Bipolar Digital	(7.7%)	0.5%	1.2%	3.7%	(6.6%)
Memory	(2.5%)	4.3%	0.0%	0.0%	(9.3%)
Logic	(8.3%)	0	1.4%	4.2%	(6.3%)
MOS	(1.3%)	(0.4%)	2.9%	4.8%	4.2%
Memory	(0.9%)	(1.4%)	2.9%	4.6%	5.4%
Microdevices	(1.4%)	1.9%	5.2%	5.2%	5.4%
Logic	(2.1%)	(0.4%)	1.1%	5.0%	1.0%
Analog	(2.0%)	2.8%	0.3%	3.9%	3.8%
Discrete	(4.3%)	0.5%	1.2%	6.6%	(1.3%)
Optoelectronic	(5.4%)	5.5%	4.3%	3.9%	0.2%

Source: Dataquest
July 1989

North America

Following strong first and second quarters of 1989, our outlook for the North American market is for real softening of shipments beginning in the third quarter and continuing through the second quarter of 1990. We expect third and fourth quarter 1990 to show a resumption of strong growth. MOS memory will continue to outpace the general semiconductor market growth. Although we forecast 1989 total semiconductor growth to be 15 percent, it would be 0 percent if MOS memory were out of the picture.

Signs in the market are mixed. Distribution appears to be soft, and the automotive market is flat. For some companies, the electronic data processing (EDP) market remains good; for others, it is flat. Digital Equipment Corporation and Sun Microsystems have announced cost-cutting plans that include layoffs and salary reductions. IBM has become very conservative in its purchasing plans. Several companies—both semiconductor suppliers and users—are expected to announce decreased earnings in the second quarter. From a macroeconomic point of view, interest rates fell slightly, creating a better climate for capital investment; however, the index of leading indicators is falling.

Japan

The first quarter was a disaster in Japan, with semiconductor consumption down 6.7 percent. Both consumer and industrial electronics production were down, with consumer production declining by 18 percent. Particularly hard hit were color televisions (down 29 percent) and VCRs (down 19 percent). We believe that consumers in Japan delayed purchasing these items because of new tax laws that took effect April 1. As of April 1, a flat 3 percent sales tax on all items went into effect; previously, only luxury items (including color TVs and VCRs) were taxed, but at a 10 percent rate.

Europe

Second quarter 1989 was down by 1.9 percent in Europe, the result of a stronger U.S. dollar (which has the effect of lowering the growth rate expressed in dollar terms), 2 to 3 percent decreases in 1Mb DRAM prices, and a slight slowdown in the personal computer build rate. The outlook for the third quarter is for a seasonally based negative growth as well as a 5 percent drop in 1Mb DRAM prices. The 14.7 percent growth forecast for 1989 in dollars is equivalent to more than 19.0 percent growth in local currency terms. In 1990, we expect the 1992 effect to continue, although slower growth is forecast for the first half of 1990. We already are witnessing a shifting of semiconductor total available market (TAM) from Asia and Japan as more companies (including Apple, Canon, Citizen, Epson, NEC, Oki, Samsung, Sanyo, Sun, and Toshiba) begin the process of procuring semiconductors in Europe for their European production facilities.

Asia/ROW

The Asia/ROW market declined 6.5 percent in the first quarter of 1989. We believe that a very high inventory situation existed in the first quarter and worked its way out during the second quarter. Personal computer clone production in Asia softened during the first quarter also. Additionally, several Taiwanese electronics companies have been moving their manufacturing operations to less developed nations, such as Thailand and Malaysia, thus disrupting current production.

DATAQUEST CONCLUSIONS

We at Dataquest stand by our earlier predictions that 1989 and 1990 will be slow years for the worldwide semiconductor industry. Worldwide growth is expected to be 12.3 percent in 1989 and 2.4 percent in 1990, both of which estimations are well below the historical average growth rate of 17.0 percent. Because there is not an overcapacity situation in the industry, and purchasers are managing their inventories much better than in previous silicon cycles, we do not foresee a devastating depression of the type that occurred in 1985. DRAM prices are remaining at levels higher than previously forecast; we believe that this justifies our current outlook.

Patricia S. Cox

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Research Bulletin

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MEMORIES: YESTERDAY AND TOMORROW

Yesterday there were four U.S. merchant DRAM suppliers with silicon fabrication facilities: Alliance Semiconductor, Micron Technology, Motorola, and Texas Instruments. Soon there will be five. The new player on the U.S. scene is U.S. Memories.

U.S. Memories is an independent company started with seed money from seven U.S. semiconductor companies. The seven are: Advanced Micro Devices, Digital Equipment Corporation, Hewlett-Packard, Intel, International Business Machines, LSI Logic, and National Semiconductor. U.S. Memories currently is a company in the process of formation. For it to become a going concern, the company has listed the following preconditions: 1) that several more semiconductor companies provide financial backing; 2) that several systems companies provide financial backing and that this backing exceed the contributions made by the semiconductor manufacturers; 3) that participating systems companies guarantee to purchase 50 percent of U.S. Memories' output; 4) that negotiations for the transfer of IBM's submicron 4Mb DRAM technology be successfully completed; and 5) that a detailed business plan be completed. Full funding is contingent upon completion of these tasks.

The venture will require about $1 billion, with approximately half in the form of an equity investment and the other half from the financial community. By the end of 1989, the company hopes to have all of its preconditions met and to select a site. U.S. Memories plans to have a new fab built and producing in volume by the first half of 1991.

The president and CEO of the new company is Sanford (Sandy) Kane, who will be resigning soon from his present position as vice president of technology at IBM. Mr. Kane was instrumental in SEMATECH's founding and site selection. The chairman of the new company is Wilfred (Wilf) Corrigan, Chairman and CEO of LSI Logic.

DATAQUEST ANALYSIS

U.S. Memories emerged as a result of ongoing efforts by the Semiconductor Industry Association (SIA) to rejuvenate the present U.S. semiconductor industry. Successful formation of a large-scale company based on collaboration of multiple American semiconductor suppliers and systems manufacturers will be unique; this may be the first time in electronics industry history that a number of U.S. semiconductor manufacturers and their customers have shared resources, risk, and output. The purchase guarantee of 50 percent of the company's output will make the company structurally similar to many of its vertically integrated competitors such as Fujitsu and Hitachi, which also consume a large fraction of their own DRAMs.

The company believes that government support is crucial for its success. It does not expect support to be in the form of direct funding or subsidies, but rather, in the form of knocking down potential antitrust barriers. U.S. Memories believes that the federal government will be helpful in this regard.

U.S. Memories' targeted first half 1991 entry date into the 4Mb DRAM market is aggressive from a start-up development standpoint. Although the company's introduction date is ahead of the forecast peak year for 4Mb DRAMs, most Japanese DRAM manufacturers will be ramping up 4Mb DRAM production during 1990, and customer samples of 16Mb DRAMs will be available in 1991. Those companies that have reached volume production levels of 4Mb DRAMs by the time that U.S. Memories enters the market in 1991 could competitively price their products too low for a late entrant to compete, particularly when the FMV regulations elapse in 1991.

Obviously, a maverick cooperative project of this type has innumerable potential problems. However, the strong leadership of Sanford Kane, the endorsement and assistance from some of the most respected executives in the industry, and affiliation with the SIA all provide credence to this unusual start-up company. In addition, we believe that all of these factors should positively impact U.S. Memories' fund-raising efforts.

Yesterday there were four U.S. merchant DRAM manufacturers. Soon there will be five. Yesterday U.S. systems companies were uneasy about their perceived dependance on one set of "foreign suppliers." Tomorrow, with the advent of U.S. Memories, they hope to have taken a significant step toward regaining control of their own destinies. Yesterday U.S. semiconductor manufacturers were worried about losing control of the technology driver DRAMs. With the formation of Sematech last year and U.S. Memories this year, they believe that these efforts will improve their technological position.

George Burns
Fred Jones

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Research Bulletin

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FIRST QUARTER GROWTH FALLS SHORT OF EXPECTATIONS

OVERVIEW

Europe and the United States on Target but Japan and ROW Down

Worldwide shipments of semiconductor devices in the first quarter of 1989 were down approximately 0.6 percent from those of the fourth quarter of 1988, according to WSTS statistics. The WSTS report shows worldwide semiconductor shipments of $13,952 billion in Q4 1988 and $13,869 billion in Q1 1989. Although this was not entirely a surprise to Dataquest, we and others had predicted that Q1 1989 would be up from Q4 1988 by as much as 4.0 percent. The chief factors that produced the down quarter were negative growth in Japan and the Rest of World (ROW) region. Japan's and ROW's semiconductor consumption was down 6.3 and 6.5 percent, respectively, compared with Q4 1988. However, Q1 1989 semiconductor consumption in Europe and the United States was up 8.8 and 4.7 percent, respectively, compared with Q4 1988. Many of our clients have asked if this is the beginning of the semiconductor recession that most forecasters suggest is not far off. This concern is exacerbated by a softening in several business segments experienced by many IC producers in May.

Current Business Conditions

A survey of Dataquest's clients worldwide, both IC producers and consumers, provided very mixed signals, including the following:

- A definite slowing in non-DRAM business is occurring in Europe. European and U.S. sources reported soft distribution sales in Europe in May, and they expect the European book-to-bill ratio for May to be less than one.
- Distribution in the United States became soft during the first part of June, although there are some exceptions. Most distributors told us that they are experiencing a slowing of "short-term" orders. One major Silicon Valley distributor reported that "the phone stopped ringing ten days ago."
- The worst toll appears to be in the sale of logic ICs, while analog chip sales vary from "terrible" to "surprisingly good." Of three major analog IC suppliers surveyed, one reported flat sales, one reported "severe price erosion," and the third reported that its analog business was good enough to raise prices on June quotes. Even with the best software the industry can produce, it is difficult, with these data, to see a trend developing.
- Several Japanese suppliers of non-DRAM products to the United States confirmed slow sales in May.

- Memory sales continue to be stable.
- The PC business is still good. Motorola and Intel report greater than 1:1 book-to-bill ratios for their Apple- and IBM-related microprocessors.

DATAQUEST ANALYSIS

Poor Q1 Japanese Consumer Electronics Sales

The Q1 anomaly originated in Japan. As stated herein, the WSTS reports Q1 to be down 6.3 percent, while MITI reports Q1 to be negative 9.1 percent compared with Q4 1988. Very slow sales in consumer electronics appear to be at fault. VCR production was off 19 percent in Q1 1989 in Japan, and color television production was down 29.0 percent. MITI forecasts a significant improvement in Japan during Q2 1989, stating that Japanese semiconductor production in April was up 25.6 percent over April 1988, with MOS up 39.5 percent over April 1988. Virtually all memory suppliers report stable conditions with "no signs of price declines in sight." We are not quite as sanguine. We are observing reports of increased memory return material authorization (RMA) activity and more liberal cancellation options for DRAM orders that are not at the customers' shipping docks on the contract due dates. This situation infers that most DRAM users are in comfortable inventory situations and are managing their inventories to avoid overstocking. A representative of a major consumer of memory devices advised us last week that the company was still on its purchasing plan, had no plans to increase its memory purchases beyond the current plan, and was watching the next few months "very cautiously." This suggests to us that the stable memory situation could become very turbulent by fall if the industry softness we are seeing in May continues. A second indicator is the level of inquiry activity received by Dataquest's memory analysts. Memory inquiries have nearly tripled in the last two weeks, which also suggests a change in the wind. In the past, this type of increased concern often has been accompanied by changing market conditions.

Inventory Growth in Non-DRAM Products

Some understanding of May's softness can be gained via an analysis of the current inventory situation. In May, the non-DRAM inventory target for Dataquest's population of IC users was 21 inventory days. Actual inventory days in May were 25 days for non-DRAM ICs. In June, the target is 21 inventory days. However, to date, the actual inventory is running nearly 34 days, an increase from May of 9 days. We believe that users will want to see their actual inventories return closer to the 22- to 23-day range before the industry will see an improvement in new non-DRAM bookings.

Current Thoughts on the Remainder of 1989

Dataquest will release its revised forecast for 1989 and 1990 in July; however, the hallway consensus is as follows. We believe that Q2 1989 will still show positive growth, probably in the 3 percent range worldwide, as compared with Q1. Japan's substantial improvement in Q2 seems to support this contention. We think that Q3 1989 will range from flat to very slightly positive, largely dependent on what happens in memories and PCs. Negative growth will begin in Q4 and will continue into Q1 and perhaps Q2 1990. Essentially, the aggregate of all inputs suggests that flat to slightly negative business conditions will prevail for the remainder of the year, rather than a sharp drop in sales. However, with inputs as diverse as those we received this week, this situation could change with little notice. We will continue to advise our clients on this situation.

David Angel

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Research Newsletter

Components Group 1989 Newsletters
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FINAL 1988 WORLDWIDE SEMICONDUCTOR MARKET SHARE ESTIMATES

SUMMARY

This newsletter presents Dataquest's final estimates of 1988 worldwide semiconductor revenue for the major semiconductor suppliers of the world. After publishing our preliminary estimates in January, we received updated information on several companies, most notably Advanced Micro Devices, Fujitsu, Mitsubishi, National Semiconductor, NEC, Philips, Sony, and Toshiba. In addition, we have added several companies to our data base, including Mosel, a U.S. SRAM supplier, and Quality Technologies, a U.S. optoelectronics supplier (formerly the Optoelectronic Division of General Instruments).

Our research also resulted in an increase in our estimates of the total semiconductor market size in 1989, to $50,859 million. Japanese companies supplied 51 percent of that amount, North American companies supplied 37 percent, European companies 10 percent, and rest of world (ROW) companies supplied almost 3 percent. We consider these numbers to be final and do not anticipate any changes to 1988 data from now on.

Changes in rank occurred among the top 20 companies during the time between the preliminary market share newsletter and the final statistics. SGS-Thomson moved up to 12th place, and Advanced Micro Devices moved down to 13th place. Sony moved up to 16th place, and Oki moved down to 17th place.

Table 1 shows the total 1988 semiconductor revenue of all companies surveyed, both by company base and by region sold into.

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Table 1

Final Estimated 1988 Market Share Analysis (Millions of Dollars)

	Regional Market				
Company Base	North America	Japan	Europe	ROW	World
North America	$11,146	$ 1,965	$3,664	$1,811	$18,586
Percent of Regional Market	70%	9%	43%	31%	37%
Percent of Company Sales	60%	11%	20%	10%	100%
Japan	$ 3,277	$18,630	$1,466	$2,569	$25,942
Percent of Regional Market	21%	90%	17%	45%	51%
Percent of Company Sales	13%	72%	6%	10%	100%
Europe	$ 1,006	$ 115	$3,196	$ 600	$ 4,917
Percent of Regional Market	6%	1%	38%	10%	10%
Percent of Company Sales	20%	2%	65%	12%	100%
ROW	$ 415	$ 62	$ 165	$ 772	$ 1,414
Percent of Regional Market	3%	0	2%	13%	3%
Percent of Company Sales	29%	4%	12%	55%	100%
World	$15,844	$20,772	$8,491	$5,752	$50,859
Percent of Regional Market	100%	100%	100%	100%	100%
Percent of Company Sales	31%	41%	17%	11%	100%

Source: Dataquest
June 1989

WORLDWIDE MARKET AND RANKINGS

Table 2 shows Dataquest's estimates of the worldwide semiconductor market by product for 1987 and 1988. Total market growth was 33.0 percent, led by MOS memory and MOS microdevices, which grew 93.1 percent and 39.9 percent, respectively.

Table 2

Estimated Worldwide Semiconductor Market
(Millions of Dollars)

	1987	1988	Percent Change
Total Semiconductor	$38,251	$50,859	33.0%
Total Integrated Circuit	$29,887	$41,068	37.4%
Bipolar Digital	$ 4,760	$ 5,200	9.2%
Bipolar Memory	$ 621	$ 689	11.0%
Bipolar Logic	$ 4,139	$ 4,511	9.0%
ASIC	$ 1,677	$ 1,863	11.1%
Standard Logic	$ 2,264	$ 2,399	6.0%
Other Logic	$ 198	$ 249	25.8%
MOS Digital	$17,473	$26,988	54.5%
MOS Memory	$ 6,056	$11,692	93.1%
MOS Micro Device	$ 5,108	$ 7,144	39.9%
MOS Logic	$ 6,309	$ 8,152	29.2%
ASIC	$ 4,242	$ 5,836	37.6%
Standard Logic	$ 1,126	$ 1,307	16.1%
Other Logic	$ 941	$ 1,009	7.2%
Analog	$ 7,654	$ 8,880	16.0%
Monolithic	$ 6,376	$ 7,418	16.3%
Hybrid	$ 1,278	$ 1,462	14.4%
Discrete	$ 6,655	$ 7,612	14.4%
Optoelectronic	$ 1,709	$ 2,179	27.5%

Source: Dataquest
June 1989

Figure 1 lists the top 20 semiconductor suppliers worldwide in 1988, led by NEC at $4,543 million. The fastest-growing company among the top 20 was Samsung, which increased its revenue by 175.9 percent. This growth was a result of tremendous growth in DRAM sales. Within the top 10 companies, the highest growth was recorded by Intel, at 57.6 percent, a result of its predominant position in the microprocessor market and its decision to sole-source the popular 80386.

Tables 3 through 10 list the top 20 companies worldwide in the categories of total integrated circuit, total bipolar digital, total MOS digital, MOS memory, MOS microdevice, analog, total discrete, and total optoelectronic.

Figure 1

Final Estimated 1988 World Semiconductor Market Share Ranking
Top 20 Manufacturers

Company	1988 Rank	1987 Rank	1987 Sales	1988 Sales	Percent Change
			(Millions of Dollars)		
NEC	1	1	3,368	4,543	34.9%
Toshiba	2	2	3,029	4,395	45.1%
Hitachi	3	3	2,618	3,506	33.9%
Motorola	4	4	2,434	3,035	24.7%
Texas Instruments	5	5	2,127	2,741	28.9%
Fujitsu	6	6	1,801	2,607	44.8%
Intel	7	10	1,491	2,350	57.6%
Mitsubishi	8	9	1,492	2,312	55.0%
Matsushita	9	11	1,457	1,883	29.2%
Philips-Signetics	10	7	1,602	1,738	8.5%
National Semiconductor	11	8	1,506	1,650	9.6%
SGS-Thomson	12	13	859	1,087	26.5%
Advanced Micro Devices	13	12	986	1,084	9.9%
Sanyo	14	14	851	1,083	27.3%
Sharp	15	18	590	1,036	75.6%
Sony	16	19	571	950	66.4%
Oki	17	17	651	947	45.5%
Samsung	18	23	328	905	175.9%
AT&T	19	15	802	859	7.1%
Siemens	20	16	657	784	19.3%

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Source: Dataquest June 1989

Table 3

Final Estimated
1988 World Semiconductor Market Share Ranking—Top Twenty
Total Integrated Circuit
(Millions of Dollars)

1988 Rank	1987 Rank	Company	1987 Revenue	1988 Revenue	Percent Change
1	1	NEC	2,795	3,884	39.0%
2	2	Toshiba	2,194	3,316	51.1%
3	4	Hitachi	1,946	2,729	40.2%
4	3	Texas Instruments	2,024	2,637	30.3%
5	6	Fujitsu	1,660	2,420	45.8%
6	7	Intel	1,491	2,350	57.6%
7	5	Motorola	1,758	2,259	28.5%
8	9	Mitsubishi	1,239	1,975	59.4%
9	8	National Semiconductor	1,431	1,575	10.1%
10	11	Matsushita	994	1,328	33.6%
11	10	Philips	1,186	1,281	8.0%
12	12	Advanced Micro Devices	986	1,084	9.9%
13	14	Oki	619	902	45.7%
14	22	Samsung	291	850	192.1%
15	13	SGS-Thomson	646	833	28.9%
16	16	Sanyo	556	811	45.9%
17	17	Sharp	367	751	104.6%
18	15	AT&T	595	688	15.6%
19	18	Sony	361	621	72.0%
20	20	Siemens	354	483	36.4%
		Total Market	29,887	41,068	37.4%
		Japanese Companies	13,981	20,375	45.7%
		U.S. Companies	12,496	15,990	28.0%
		European Companies	2,845	3,429	20.5%
		Rest of World (ROW) Companies	565	1,274	125.5%

Source: Dataquest
June 1989

Table 4

Final Estimated
1988 World Semiconductor Market Share Ranking—Top Twenty
Total Bipolar Digital
(Millions of Dollars)

1988 Rank	1987 Rank	Company	1987 Revenue	1988 Revenue	Percent Change
1	1	Texas Instruments	854	940	10.1%
2	4	Fujitsu	495	653	31.9%
3	2	National Semiconductor	521	550	5.6%
4	3	Advanced Micro Devices	500	536	7.2%
5	5	Hitachi	463	501	8.2%
6	6	Motorola	429	435	1.4%
7	7	Philips	405	413	2.0%
8	8	NEC	247	292	18.2%
9	10	Mitsubishi	122	127	4.1%
10	9	Toshiba	125	108	(13.6%)
11	12	Plessey	68	94	38.2%
12	17	Harris	30	62	106.7%
13	11	AT&T	79	61	(22.8%)
14	14	Raytheon	51	55	7.8%
15	18	Sanyo	29	41	41.4%
16	16	Oki	32	38	18.8%
17	13	Siemens	63	36	(42.9%)
18	22	Goldstar	22	32	45.5%
19	21	Chips & Technologies	25	30	20.0%
20	20	Matsushita	26	30	15.4%
		Total Market	4,760	5,200	9.2%
		Japanese Companies	1,540	1,791	16.3%
		U.S. Companies	2,589	2,761	6.6%
		European Companies	594	598	0.7%
		Rest of World (ROW) Companies	37	50	35.1%

Source: Dataquest
June 1989

Table 5

Final Estimated
1988 World Semiconductor Market Share Ranking—Top Twenty
Total MOS Digital
(Millions of Dollars)

1988 Rank	1987 Rank	Company	1987 Revenue	1988 Revenue	Percent Change
1	1	NEC	2,006	3,123	55.7%
2	2	Toshiba	1,593	2,639	65.7%
3	3	Intel	1,473	2,328	58.0%
4	4	Hitachi	1,173	1,885	60.7%
5	5	Fujitsu	1,014	1,616	59.4%
6	7	Mitsubishi	812	1,453	78.9%
7	6	Motorola	990	1,399	41.3%
8	8	Texas Instruments	784	1,271	62.1%
9	9	Matsushita	592	875	47.8%
10	10	Oki	566	841	48.6%
11	18	Samsung	242	765	216.1%
12	15	Sharp	312	682	118.6%
13	11	National Semiconductor	415	485	16.9%
14	12	Advanced Micro Devices	414	482	16.4%
15	13	SGS-Thomson	344	461	34.0%
16	14	Philips	342	402	17.5%
17	16	AT&T	300	380	26.7%
18	17	LSI Logic	262	375	43.1%
19	28	Micron Technology	115	331	187.8%
20	23	Siemens	171	327	91.2%
		Total Market	17,473	26,988	54.5%
		Japanese Companies	8,921	14,494	62.5%
		U.S. Companies	6,880	9,754	41.8%
		European Companies	1,250	1,684	34.7%
		Rest of World (ROW) Companies	422	1,056	150.2%

Source: Dataquest
June 1989

Table 6

Final Estimated
1988 World Semiconductor Market Share Ranking—Top Twenty
Total MOS Memory
(Millions of Dollars)

1988 Rank	1987 Rank	Company	1987 Revenue	1988 Revenue	Percent Change
1	2	Toshiba	679	1,516	123.3%
2	1	NEC	838	1,490	77.8%
3	4	Hitachi	576	1,114	93.4%
4	3	Fujitsu	634	1,067	68.3%
5	5	Mitsubishi	492	966	96.3%
6	6	Texas Instruments	445	834	87.4%
7	9	Samsung	170	650	282.4%
8	7	Intel	326	392	20.2%
9	8	Oki	193	353	82.9%
10	11	Sharp	130	344	164.6%
11	12	Micron Technology	115	331	187.8%
12	16	Motorola	89	236	165.2%
13	15	Matsushita	91	230	152.7%
14	10	Advanced Micro Devices	155	207	33.5%
15	13	NMB Semiconductor	104	199	91.3%
16	14	SGS-Thomson	95	185	94.7%
17	24	Siemens	52	150	188.5%
18	17	Integrated Device Technology	85	135	58.8%
19	18	National Semiconductor	80	135	68.8%
20	28	Hyundai	30	106	253.3%
		Total Market	6,056	11,692	93.1%
		Japanese Companies	3,909	7,597	94.3%
		U.S. Companies	1,701	2,836	66.7%
		European Companies	235	464	97.4%
		Rest of World (ROW) Companies	211	795	276.8%

Source: Dataquest
June 1989

Table 7

Final Estimated
1988 World Semiconductor Market Share Ranking—Top Twenty
Total MOS Microdevice
(Millions of Dollars)

1988 Rank	1987 Rank	Company	1987 Revenue	1988 Revenue	Percent Change
1	1	Intel	1,087	1,835	68.8%
2	2	NEC	566	790	39.6%
3	3	Motorola	520	699	34.4%
4	4	Hitachi	402	525	30.6%
5	6	Mitsubishi	267	381	42.7%
6	5	Toshiba	283	346	22.3%
7	9	Texas Instruments	169	234	38.5%
8	7	Matsushita	199	230	15.6%
9	10	Fujitsu	146	202	38.4%
10	8	Advanced Micro Devices	178	183	2.8%
11	11	National Semiconductor	140	150	7.1%
12	12	Oki	101	134	32.7%
13	15	Chips & Technologies	87	130	49.4%
14	14	SGS-Thomson	95	118	24.2%
15	13	Philips	100	114	14.0%
16	17	Western Digital	70	100	42.9%
17	16	Zilog	75	90	20.0%
18	23	Siemens	44	88	100.0%
19	18	Sanyo	53	70	32.1%
20	22	Harris	44	62	40.9%
		Total Market	5,108	7,144	39.9%
		U.S. Companies	2,663	3,872	45.4%
		Japanese Companies	2,096	2,817	34.4%
		European Companies	310	401	29.4%
		Rest of World (ROW) Companies	39	54	38.5%

Source: Dataquest
June 1989

Table 8

Final Estimated
1988 World Semiconductor Market Share Ranking—Top Twenty
Total Analog
(Millions of Dollars)

1988 Rank	1987 Rank	Company	1987 Revenue	1988 Revenue	Percent Change
1	3	Toshiba	476	569	19.5%
2	2	National Semiconductor	495	540	9.1%
3	6	Sanyo	377	471	24.9%
4	1	NEC	542	469	(13.5%)
5	4	Philips	439	466	6.2%
6	5	Texas Instruments	386	426	10.4%
7	8	Motorola	339	425	25.4%
8	7	Matsushita	376	423	12.5%
9	10	Mitsubishi	305	395	29.5%
10	14	Sony	217	386	77.9%
11	11	SGS-Thomson	282	352	24.8%
12	9	Hitachi	310	343	10.6%
13	12	Analog Devices	280	340	21.4%
14	13	Rohm	235	271	15.3%
15	15	AT&T	216	247	14.4%
16	21	Sanken	119	157	31.9%
17	16	Fujitsu	151	151	0
18	17	Harris	139	146	5.0%
19	19	Burr-Brown	120	144	20.0%
20	23	Silicon Systems	88	125	42.0%
		Total Market	7,654	8,880	16.0%
		Japanese Companies	3,520	4,090	16.2%
		U.S. Companies	3,027	3,475	14.8%
		European Companies	1,001	1,147	14.6%
		Rest of World (ROW) Companies	106	168	58.5%

Source: Dataquest
June 1989

Table 9

Final Estimated
1988 World Semiconductor Market Share Ranking—Top Twenty
Total Discrete
(Millions of Dollars)

1988 Rank	1987 Rank	Company	1987 Revenue	1988 Revenue	Percent Change
1	1	Toshiba	703	864	22.9%
2	2	Motorola	652	752	15.3%
3	3	Hitachi	625	707	13.1%
4	4	NEC	518	571	10.2%
5	5	Philips	390	432	10.8%
6	6	Matsushita	318	377	18.6%
7	7	Mitsubishi	227	310	36.6%
8	13	Rohm	200	287	43.5%
9	11	Fuji Electric	206	279	35.4%
10	9	SGS-Thomson	213	254	19.2%
11	10	Sanyo	210	210	0
12	14	Sanken	162	207	27.8%
13	8	Siemens	218	201	(7.8%)
14	16	International Rectifier	151	192	27.2%
15	18	General Instrument	132	164	24.2%
16	12	AT&T	200	161	(19.5%)
17	15	ITT	160	146	(8.8%)
18	17	General Electric	146	145	(0.7%)
19	19	Powerex	106	115	8.5%
20	23	Sony	72	112	55.6%
		Total Market	6,655	7,612	14.4%
		Japanese Companies	3,376	4,056	20.1%
		U.S. Companies	2,051	2,171	5.9%
		European Companies	1,125	1,250	11.1%
		Rest of World (ROW) Companies	103	135	31.1%

Source: Dataquest
June 1989

Table 10

Final Estimated
1988 World Semiconductor Market Share Ranking—Top Twenty
Total Optoelectronic
(Millions of Dollars)

1988 Rank	1987 Rank	Company	1987 Revenue	1988 Revenue	Percent Change
1	1	Sharp	223	285	27.8%
2	4	Sony	138	217	57.2%
3	5	Toshiba	132	215	62.9%
4	2	Hewlett-Packard	186	213	14.5%
5	3	Matsushita	145	178	22.8%
6	10	Rohm	70	109	55.7%
7	9	Fujitsu	71	105	47.9%
8	7	Siemens	85	100	17.6%
9	11	NEC	55	88	60.0%
10	8	Telefunken Electronic	77	74	(3.9%)
11	12	Hitachi	47	70	48.9%
12	6	Sanyo	85	62	(27.1%)
13	14	Texas Instruments	39	41	5.1%
14	30	Quality Technologies	0	40	
15	13	TRW	43	36	(16.3%)
16	19	Oki	25	36	44.0%
17	15	Honeywell	30	30	0
18	17	Mitsubishi	26	27	3.8%
19	18	Philips	26	25	(3.8%)
20	20	Motorola	24	24	0
		Total Market	1,709	2,179	27.5%
		Japanese Companies	1,093	1,511	38.2%
		U.S. Companies	383	425	11.0%
		European Companies	230	238	3.5%
		Rest of World (ROW) Companies	3	5	66.7%

Source: Dataquest
June 1989

DATAQUEST CONCLUSIONS

As we stated in our preliminary market share newsletter, in 10 years the Japanese semiconductor companies have grown from 28 percent of the worldwide market to 51 percent. North American companies' market share has decreased correspondingly during the same period, dropping from 55 percent of the market in 1978 to 37 percent in 1988. ROW companies did not enter the arena until 1982, and their rapid growth and decision to focus on DRAM and SRAM products propelled them to an almost 3 percent position worldwide in 1988.

Because of continuing strong growth in the MOS memory market in 1989, we believe that Japanese and ROW companies stand to further penetrate the world market, although very depressed Q1'89 results in their domestic markets could counteract any growth in Europe and North America. Because of extremely strong growth in the European market, domestic European manufacturers are poised to have an extraordinarily good year as preparations begin in earnest for a unified European Community in 1992.

Patricia S. Cox

Note: Complete worldwide market share listings will be published in the Semiconductor Industry Service (SIS) and Semiconductor User Information Service (SUIS) binders in July. For more information before then, please contact the Components Group Client Inquiry Center at (408) 437-8099.

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Research Newsletter

JAPAN'S SEMICONDUCTOR TRADE PRACTICES ESCAPE SUPER 301 DESIGNATION

SUMMARY

On May 25, United States Trade Representative (USTR) Carla Hills put an end to speculation about Japan's inclusion on the "Super 301" list for semiconductor trade practices. Although Japan will be investigated under U.S. trade law for committing "priority practices" (i.e., trade barrier erection) in connection with telecommunications satellites and supercomputers, semiconductors will not be a subject of the USTR's investigative focus. Among those that believe they should be is the Semiconductor Industry Association (SIA). The SIA had submitted a petition under Section 301 of U.S. trade law to investigate Japan for violation of the semiconductor trade agreement signed in 1986—specifically because of the lack of progress perceived by the SIA in the further opening of the Japanese market to U.S. semiconductor manufacturers.

Although the specific reasons for Ms. Hills' decision not to include Japan's semiconductor trade practices on the 301 list are unknown to us, her decision would seem to vindicate the position taken by the Electronic Industries Association of Japan (EIAJ). This newsletter provides a look at Japan's side of the semiconductor trade issue, as put forward by the EIAJ, and at the likely obstacles to its future negotiations with the SIA.

THE EIAJ's POSITION

The EIAJ's arguments against inclusion on the 301 list can basically be reduced to the following position: identifying Japan as a "priority country" on the basis of semiconductor trade practices can serve no useful purpose, since a means of addressing such issues already exists through the U.S.-Japan Semiconductor Trade Arrangement (hereafter referred to as the Arrangement). Among the EIAJ's many valid points are the following:

- The Super 301 adds nothing new because all of the important issues concerning semiconductor trade are already subject to negotiation under the terms of the Arrangement.

- Super 301's new enforcement authority is unnecessary because there is authority under prior Section 301 provisions to impose remedies for breach of the Arrangement.

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- Super 301 designation would be redundant, since the negotiations contemplated by Super 301 have been under way for more than two and one-half years.

- The Arrangement is already accomplishing the objectives of Super 301 by having established a framework for ongoing negotiations seeking increased U.S. exports to Japan.

In addition to the well-reasoned arguments stated above, the EIAJ countered the SIA's petition to the USTR with a threat to terminate the Arrangement. The Arrangement, reasoned the EIAJ, was entered into as a means to suspend the existing Section 301 proceeding, which would have imposed punitive duties on Japanese memory products. Reinstating such proceedings under the guise of the new Super 301 label would have "altered the basis" of the Arrangement, and under its termination provisions would have given Japan a legal basis to abandon it.

LIGHTING A FIRE UNDER MITI

Faced with such a compelling, and no doubt earnest, threat, it is quite likely that the USTR chose not to muddy the waters of semiconductor trade between Japan and the United States by moving the issues out of their current forum. If so, the USTR's decision was the wisest course of action. Surprisingly, the SIA has so far expressed no outrage over Ms. Hills' actions. But then again, the SIA has not really lost any ground. Any additional negotiating leverage that the Super 301 may have offered had it been applied to the issue of semiconductor trade was most likely realized through the act of petitioning the USTR. Since the SIA filed its petition for action under section 301, Japan's Ministry of International Trade and Industry (MITI) has stepped up its campaign to increase foreign semiconductor market share in Japan. On April 17, MITI assembled approximately 160 Japanese companies in Tokyo and instructed them to submit action plans concerning how they would increase semiconductor purchases from foreign suppliers. MITI also introduced an 11-point plan aimed at resolving U.S. market barrier complaints. To enforce its market access proposals, MITI has committed to the following actions:

- MITI will encourage semiconductor user companies to make action plans and update them biannually. MITI will follow up on their implementation.

- MITI will conduct periodic surveys regarding procurement of foreign semiconductors and will publicize the results in statistical form.

- MITI will survey, when appropriate, the implementation of design-ins and the establishmemt of long-term relationships between Japanese electronics companies and foreign component suppliers.

MEASURING MARKET ACCESS: THE EYE OF THE STORM

To date, much of the furor over the implementation of the Arrangement has centered on the issue of measuring market access—and this issue has in turn centered on the interpretation of the now infamous "side letter," dated September 1, 1986, between Ambassador Matsunaga of Japan and Ambassador Yeutter of the United States. One particularly controversial section of the letter reads:

> The Government of Japan recognizes the U.S. semiconductor industry's expectation that semiconductor sales in Japan of foreign capital-affiliated companies will grow to at least slightly above 20 percent of the Japanese market in five years. The Government of Japan considers that this can be realized and welcomes its realization. The attainment of such an expectation depends on competitive factors, the sales efforts of the foreign capital-affiliated companies, the purchasing efforts of the semiconductor users in Japan and the efforts of both Governments.

Not surprisingly, the EIAJ's contention is that the above wording does not constitute a market share guarantee, but rather an admission that given the "underlying competitiveness" of foreign semiconductor suppliers, a 20 percent market share penetration of the Japanese semiconductor market would be a realistic achievement. Given this premise, the EIAJ has naturally balked at the SIA's efforts to judge the market access goals of the Arrangement by a linear projection of market share, beginning with third quarter 1986, that aims at a 20 percent penetration by 1991.

The EIAJ states a number of reasons why it would rather see market access judged by the implementation of policy rather than by adherence to a percentage target. The core of these reasons, which will no doubt form the basis of continuing talks between the SIA and the EIAJ, comprise the following points:

- Consumer electronics applications account for nearly 40 percent of semiconductor consumption in Japan. Because the United States lacks an indigenous consumer electronics production base, U.S. semiconductor suppliers are not geared to the needs of this market.

- Although the data processing market in Japan is now growing at a faster rate than the consumer electronics segment (by Dataquest's reckoning, it is now the largest segment of Japan's electronics industry), foreign companies would have to provide nearly 40 percent of this segment's semiconductor needs to reach the SIA's 20 percent market share target. Unfortunately, the EIAJ estimates that 40 percent of the data processing end market comprises semiconductor memory products—mainly DRAMs.

- Although sales of MOS microcomponents have contributed to tremendous revenue gains in the Japanese market by companies such as Intel and Motorola (65 and 54 percent sales growth in yen, respectively, in 1988), the EIAJ notes that this market segment accounts for only about 14 percent of the total Japanese semiconductor market.

- ASIC demand is rising sharply in the Japanese market. At present, however, many ASICs sold by U.S. companies are actually produced in Japanese foundries. The EIAJ also points out that competitive pressures have driven a number of U.S. companies from the standard gate array market and into special product niches. Although the margins in such markets may be better, they represent considerably less significant revenue opportunities.

SOLUTIONS OR SANCTIONS?

It would be a serious mistake to interpret the recent decision of the USTR as a softening of semiconductor trade resolve within the U.S. government. In a question-and-answer session following the Super 301 announcements, Ms. Hills left no doubt as to her position on U.S./Japan semiconductor trade: "The United States is closely monitoring Japan's compliance with the 1986 Semiconductor Arrangement in the context of an existing Section 301 proceeding. We imposed sanctions in 1987 for noncompliance with the Arrangement, and are prepared to do so again if warranted."

Resolution of the issues facing the EIAJ and SIA will not be easy, and while the Japanese maintain that policy and patience are the solution, the SIA's position (and perhaps that of the USTR) is that only the "crowbar" of trade sanctions will produce results. A recent newsletter written by David Angel, director of Dataquest's Semiconductor Industry Service, nevertheless noted that "Dataquest believes that Japan is sincerely concerned about the trade issues. The major Japanese companies and MITI genuinely believe that they are taking the hard steps that will ultimately lead to markets more open to foreign suppliers of semiconductor components, and evidence indicates that this is true."

The alternatives to compromise, under both the Arrangement and the Super 301, unfortunately include sanctions. The USTR allows 150 days for consultation with foreign governments whose nations have been placed on the Section 301 list—theoretically, the U.S.-Japan Semiconductor Trade Arrangement has until its expiration in 1991 to work its desired results. In the event that these negotiations fail, the United States may find its flexibility in imposing effective sanctions to be somewhat limited. In an increasingly global economy, trade retaliation aimed at the defense of one industry may impair the competitiveness of another. A case in point is the current "hit list" of Japanese products that may face 100 percent tariffs in the wake of the Super 301 proceedings. This list includes semiconductor manufacturing equipment—specifically e-beam lithography equipment, wafer steppers, and die-bonding and wire-bonding assembly equipment.

DATAQUEST CONCLUSIONS

However the sanctioning of Japanese semiconductor manufacturing equipment may affect the balance of trade for U.S. telecommunications equipment and supercomputers, it would put U.S. chipmakers at a competitive disadvantage by requiring them to pay a 100 percent premium for Japanese semiconductor manufacturing equipment. The growing dependence of U.S. chip producers on Japan-based equipment suppliers is epitomized by the fact that the industry's flagship consortium effort, Sematech, will rely initially on stepper equipment from Nikon in transferring the AT&T SRAM process to its Austin facility. In 1988, Nikon ranked as the world's largest stepper supplier.

The original list of sanctioned Japanese products, created by the Reagan administration in response to the semiconductor trade situation, was carefully arrived at in an effort to minimize any negative impact on U.S. systems companies. The sanctions list recently proposed by the USTR may, in an ironic turnabout, compromise the interests of the U.S. semiconductor industry on behalf of systems manufacturers. The message that should be coming through in all this is that nobody wins in an adversarial approach to trade problems.

Michael J. Boss

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PACIFIC STOCK EXCHANGE PLANS DRAM FUTURES: GOOD-BYE, LEARNING CURVE—HELLO, SPOT AND LONG

Beginning in 1990, the Pacific Stock Exchange (PSE) in San Francisco plans to trade futures contracts in DRAMs. An application will be filed soon with the Commodity Futures Trading Commission. Pricing of DRAMs has been influenced by the industry's well-understood learning curve, but if the idea of futures contracts works, the dynamics of DRAM pricing will be very different.

From time to time, DRAMs vary widely in selling price, causing users to be uncertain about their buying strategy, which in turn tends to destabilize the market. Futures contracts will be offered for 1,000 chips per contract for periods of three, six, or nine months into the future. According to a PSE spokesperson, the contracts will stabilize prices of these critical computer components, thereby giving equipment manufacturers greater certainty about future costs of goods.

This move by the PSE is a significant departure from the traditional commodity business, representing the first time for futures contracts to be traded for something other than farm products, oil, or precious metals. Many differences exist between traditional commodities, such as wheat and gold, and DRAMs, just as many differences exist between the commodity industries and the semiconductor industry. Consequently, members of the stock exchange as well as the buyers and sellers will themselves have an opportunity for a learning experience.

Similarities as well as differences exist between DRAMs and true commodities, especially pertaining to the manufacturers. Oil, gold, and DRAMs have relatively few manufacturers; these manufacturers communicate rapidly and efficiently among themselves, they all have large capital investments, and they control the market channel.

Nevertheless, the essential differences between a manufactured product and natural resources are many. Three essential characteristics separating commodities from manufactured goods are product life cycle, product differentiation, and uncontrollable influences upon supply. Wheat and gold have long life cycles, while generations of DRAMs come and go in just a few years. The most important difference is that the supply of agricultural products is strongly influenced by random events, such as the weather, while the supply of manufactured goods usually is dependent on business decisions. One of the strongest parameters in business decisions, ironically, is the consideration of future prices.

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A ROSE IS A ROSE IS A ROSE—BUT ALL DRAMs ARE NOT ALIKE

Considerable differentiation occurs among DRAMs. Speed range, package style, testing parameters, quality, and other features create a wide variety of product options that do not exist in traditional commodities. The proliferation of futures contracts required to cover these variants may be traded so sparsely as to keep the concept from meeting the economists' definition of an efficient market. Industry trends clearly are against a commodity market. Manufacturers are trying to distance themselves from competitors by creating unique product variations based on parameters, packaging, and architecture (video RAMs, for example). Enough perceived differences exist among various manufacturers to create confusion about how futures contracts will work.

THE KEY QUESTIONS

Several key questions arise. Will futures contracts really stabilize market pricing or actually make it more volatile? If this idea catches on, will spot and long futures prices become the de facto price standards, set by speculators rather than by honest negotiation between sellers and buyers? Will DRAM manufacturers be able to make more money by buying futures and then influencing the supply rather than selling chips in the open market? Will DRAM buyers really understand how to use this tool as a hedge for future price protection? Can futures possibly work in a market environment that has many government controls such as the present Semiconductor Chip Agreement and its foreign market value provisions?

Probably the most important questions is: What is in it for the manufacturers? This idea obviously will not work without the consensus of most of the major DRAM manufacturers. If futures prices become the standard by which purchase orders are written, then this concept offers manufacturers an opportunity to participate in a form of forward pricing without violating provisions of the chip agreement.

DATAQUEST ANALYSIS

This idea is unusual and has many industry veterans scratching their heads over procedures and possible benefits. We believe that any idea with the potential to solve industry problems should be given due consideration. However, we also believe that not many semiconductor buyers have enough experience with commodities markets to take advantage of this trading vehicle. Eventually, only the largest buyers will be in a position to understand and use this hedge. These are the very companies that do not need such a hedge, because they usually write purchase contracts that specify the price for at least as long as the options.

Supply and demand of commodity products is fairly stable and tied to demographics and other well-understood factors such as acres planted or rainfall. Futures contracts provide price protection against random events causing variations in the supply side. This is not the case with the DRAM market, where the major perturbations are caused by fluctuations in demand that are large compared with the short-term supply. This happens because buyers cannot anticipate their own future needs accurately. Consequently, we wonder just how futures contracts can serve as a market stabilizer in that environment.

Mel Thomsen

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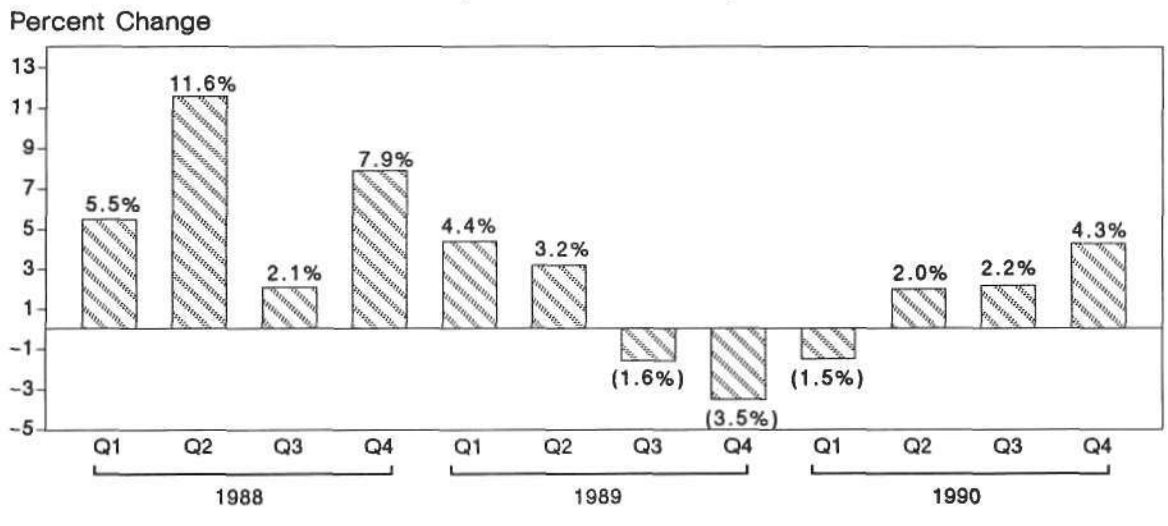
WORLDWIDE SEMICONDUCTOR INDUSTRY UPDATE: WHERE IS THE CLIFF?

INTRODUCTION

The worldwide semiconductor industry is continuing to ride the crest of the boom wave of 1988. Following the fourth quarter of 1988, in which the industry grew 7.9 percent worldwide, Dataquest forecasts first-quarter growth of 4.4 percent in 1989 and second-quarter growth of 3.2 percent, fueled mainly by surprisingly strong shipments of MOS memory. The effect of MOS memory on first-quarter growth is such that if it were excluded from the numbers, the industry growth would be only 1 percent. For all of 1989, we forecast 15.3 percent growth worldwide, with negative growth beginning in the third quarter and continuing through the first quarter of 1990. We believe that the industry will resume positive growth in the second quarter of 1990, resulting in negative 0.5 percent growth for the year 1990. Figure 1 shows the quarter-to-quarter growth rates for the worldwide semiconductor industry through 1990.

Figure 1

**Worldwide Semiconductor Consumption
Quarter-to-Quarter Growth Rates
(Percent of Dollars)**



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Source: Dataquest April 1989

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Table 1 shows the worldwide quarterly growth forecast by regions of the world.

Table 1

Worldwide Semiconductor Consumption
Quarter-to-Quarter Forecast by Geographic Region
(Millions of Dollars)

	1988	Q1/89	Q2/89	Q3/89	Q4/89	1989
North America	16,013	4,543	4,739	4,655	4,411	18,348
Percent Change	24.7%	7.3%	4.3%	(1.8%)	(5.2%)	14.6%
Japan	20,332	5,852	5,987	5,901	5,625	23,366
Percent Change	35.6%	1.8%	2.3%	(1.4%)	(4.7%)	14.9%
Europe	8,491	2,332	2,384	2,303	2,338	9,357
Percent Change	31.0%	3.4%	2.2%	(3.4%)	1.5%	10.2%
Asia/Rest of World	5,650	1,724	1,807	1,816	1,786	7,133
Percent Change	42.6%	7.5%	4.9%	0.5%	(1.6%)	26.3%
Total World	50,486	14,451	14,918	14,675	14,160	58,204
Percent Change	31.9%	4.4%	3.2%	(1.6%)	(3.5%)	15.3%

	Q1/90	Q2/90	Q3/90	Q4/90	1990
North America	4,327	4,316	4,415	4,585	17,643
Percent Change	(1.9%)	(0.3%)	2.3%	3.9%	(3.8%)
Japan	5,466	5,656	5,837	6,101	23,060
Percent Change	(2.8%)	3.5%	3.2%	4.5%	(1.3%)
Europe	2,346	2,398	2,367	2,483	9,594
Percent Change	0.4%	2.2%	(1.3%)	4.9%	2.5%
Asia/Rest of World	1,807	1,862	1,921	2,003	7,593
Percent Change	1.2%	3.0%	3.2%	4.3%	6.4%
Total World	13,947	14,231	14,540	15,172	57,890
Percent Change	(1.5%)	2.0%	2.2%	4.4%	(0.5%)

Source: Dataquest
April 1989

In January 1989, we forecast 9.0 percent growth for the worldwide semiconductor industry in 1989. We have raised that forecast to 15.3 percent growth now, in response to a changed scenario that includes the following:

- Revision of fourth-quarter shipment numbers by WSTS, Inc., which brought the fourth-quarter growth rate up significantly

- Very low January 1989 billings, followed by dramatic growth in February billings, which led us to a more bullish outlook for both first and second quarters of 1989

- Firmness in MOS memory prices for the first quarter and slight decreases forecast for the second quarter, combined with strong fourth quarter 1988 bookings for MOS memory

FORECAST BY PRODUCT

The driving force behind the 1989 industry growth is MOS memory, particularly DRAMs and SRAMs. Pricing in the first quarter of 1989 stayed firm with the fourth quarter of 1988, and second quarter 1989 pricing appears to be headed down only slightly. However, by the third quarter, we expect prices to be much lower. Overall unit growth of memories will be up approximately 10 percent over 1988, while dollar growth will be up 46.6 percent. New applications for DRAMs will include digital copiers, digital fax machines, digital VCRs, and HDTV.

The outlook for microdevices and logic is significantly different. Microdevice growth began to slow in the fourth quarter of 1988 because of overbuying of key microprocessors such as the 80386, combined with a sluggish personal computer industry. The PC industry is expected to grow more slowly in 1989 than in 1988, at about 12 percent in units. We expect microdevice growth in 1989 to be 5.6 percent. MOS logic growth, at 11.3 percent, we expect to be fairly stable.

The bipolar memory and logic markets both did extremely poorly in the second half of 1988, and we expect this negative growth to continue in 1989, as many applications switch to CMOS and BiCMOS. Pricing on bipolar PLDs and bipolar standard logic dropped severely in the fourth quarter of 1988.

We expect all product areas to begin recovering in the last three quarters of 1990, with the exception of MOS memory, which will begin its recovery one quarter later.

Tables 2 and 3 show our worldwide quarterly semiconductor consumption forecast by product type.

Table 2

Worldwide Semiconductor Consumption
Quarter-to-Quarter Forecast by Product
(Millions of Dollars)

	1988	Q1/89	Q2/89	Q3/89	Q4/89	1989
Total Semiconductor	50,486	14,451	14,918	14,675	14,161	58,204
Total IC	40,800	11,826	12,241	12,034	11,579	47,680
Bipolar Digital	5,197	1,135	1,171	1,150	1,126	4,582
Memory	670	162	157	146	137	601
Logic	4,527	973	1,014	1,004	990	3,981
MOS	26,780	8,350	8,653	8,465	8,020	33,487
Memory	11,571	4,277	4,446	4,322	3,918	16,963
Microdevice	7,127	1,861	1,915	1,882	1,868	7,526
Logic	8,082	2,212	2,292	2,261	2,233	8,998
Analog	8,823	2,341	2,417	2,420	2,433	9,611
Discrete	7,543	2,011	2,040	2,023	1,990	8,064
Optoelectronic	2,143	614	637	618	591	2,461

	Q1/90	Q2/90	Q3/90	Q4/90	1990
Total Semiconductor	13,947	14,231	14,540	15,172	57,890
Total IC	11,379	11,579	11,839	12,354	47,151
Bipolar Digital	1,069	1,078	1,102	1,144	4,393
Memory	135	142	143	144	565
Logic	933	936	959	1,000	3,829
MOS	7,926	7,993	8,225	8,617	32,761
Memory	3,831	3,793	3,890	4,068	15,582
Microdevice	1,891	1,996	2,069	2,159	8,115
Logic	2,203	2,204	2,266	2,390	9,064
Analog	2,385	2,508	2,512	2,592	9,997
Discrete	1,972	2,022	2,048	2,138	8,180
Optoelectronic	596	629	653	681	2,558

Source: Dataquest
April 1989

Table 3

Worldwide Semiconductor Consumption
Quarter-to-Quarter Forecast by Product
(Percent Change)

	1988	Q1/89	Q2/89	Q3/89	Q4/89	1989
Total Semiconductor	31.9%	4.4%	3.2%	(1.6%)	(3.5%)	15.3%
Total IC	36.4%	4.4%	3.5%	(1.7%)	(3.8%)	16.9%
Bipolar Digital	9.1%	(2.2%)	3.2%	(1.9%)	(2.0%)	(11.8%)
Memory	7.9%	(0.7%)	(3.1%)	(7.0%)	(6.5%)	(10.2%)
Logic	9.3%	(2.4%)	4.2%	(1.1%)	(1.4%)	(12.1%)
MOS	53.1%	6.9%	3.6%	(2.2%)	(5.3%)	25.0%
Memory	90.3%	13.5%	3.9%	(2.8%)	(9.3%)	46.6%
Microdevice	39.8%	1.3%	2.9%	(1.7%)	(0.7%)	5.6%
Logic	28.1%	0.4%	3.6%	(1.4%)	(1.2%)	11.3%
Analog	15.3%	(0.9%)	3.3%	0.1%	0.6%	8.9%
Discrete	13.2%	3.4%	1.5%	(0.8%)	(1.6%)	6.9%
Optoelectronic	25.4%	8.7%	3.6%	(2.9%)	(4.3%)	14.8%

	Q1/90	Q2/90	Q3/90	Q4/90	1990
Total Semiconductor	(1.5%)	2.0%	2.2%	4.3%	(0.5%)
Total IC	(1.7%)	1.8%	2.2%	4.4%	(1.1%)
Bipolar Digital	(5.1%)	0.9%	2.2%	3.8%	(4.1%)
Memory	(0.9%)	5.1%	0.7%	0.3%	(6.1%)
Logic	(5.7%)	0.3%	2.4%	4.3%	(3.8%)
MOS	(1.2%)	0.8%	2.9%	4.8%	(2.2%)
Memory	(2.2%)	(1.0%)	2.6%	4.6%	(8.1%)
Microdevice	1.2%	5.6%	3.6%	4.4%	7.8%
Logic	(1.3%)	0	2.8%	5.5%	0.7%
Analog	(2.0%)	5.2%	0.2%	3.2%	4.0%
Discrete	(0.9%)	2.6%	1.3%	4.4%	1.4%
Optoelectronic	0.7%	5.6%	3.7%	4.3%	4.0%

Source: Dataquest
April 1989

LONG-TERM FORECAST

Tables 4 and 5 show our five-year outlook for the worldwide semiconductor industry by region. Table 4 gives the dollars and percent growth, while Table 5 shows the changes in each region as a percentage of the total market. As expected, the Rest of World (ROW) region will grow fastest over time, increasing its share of the worldwide market at the expense of Japan, North America, and Europe.

Table 4

Worldwide Semiconductor Consumption
by Geographic Region
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	CAGR 88-93
North America	16,013	18,348	17,643	20,304	24,585	33,340	15.8%
Percent Change	24.7%	14.6%	(3.8%)	15.1%	21.1%	35.6%	
Japan	20,332	23,366	23,060	26,656	31,931	42,548	15.9%
Percent Change	35.6%	14.9%	(1.3%)	15.6%	19.8%	33.2%	
Europe	8,491	9,357	9,594	11,126	14,564	17,135	15.1%
Percent Change	31.0%	10.2%	2.5%	16.0%	30.9%	17.7%	
Asia/Rest of World	5,650	7,133	7,593	9,374	11,954	16,337	23.7%
Percent Change	42.6%	26.2%	6.4%	23.5%	27.5%	36.7%	
Total World	50,486	58,204	57,890	67,460	83,034	109,360	
Percent Change	31.9%	15.3%	(0.5%)	16.5%	23.1%	31.7%	16.7%

Source: Dataquest
April 1989

Table 5

Worldwide Semiconductor Consumption
by Geographic Region
as a Percentage of Worldwide Consumption
(Percent of Dollars)

	1988	1989	1990	1991	1992	1993
North America	31.7%	31.5%	30.5%	30.1%	29.6%	30.5%
Japan	40.3	40.1	39.8	39.5	38.5	38.9
Europe	16.8	16.1	16.6	16.5	17.5	15.7
Asia/Rest of World	11.2	12.3	13.1	13.9	14.4	14.9
Total World	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest
April 1989

The worldwide five-year forecast by product is shown in Table 6.

Table 6

Worldwide Semiconductor Consumption
Five-Year Forecast by Product
(Millions of Dollars)

	1988	1989	1990	1991	1992	1993	CAGR 88-93
Total Semiconductor	50,486	58,204	57,890	67,460	83,034	109,360	16.7%
Total IC	40,800	47,679	47,152	55,515	69,427	93,767	18.1%
Bipolar Digital	5,197	4,582	4,394	4,654	5,085	5,623	1.6%
Memory	670	601	565	553	512	494	(5.9%)
Logic	4,527	3,981	3,829	4,101	4,573	5,129	2.5%
MOS	26,780	33,486	32,761	39,226	50,303	71,093	21.6%
Memory	11,571	16,962	15,582	18,383	23,550	36,561	25.9%
Microdevice	7,127	7,526	8,115	9,870	12,835	16,801	18.7%
Logic	8,082	8,998	9,064	10,973	13,918	17,731	17.0%
Analog	8,823	9,611	9,997	11,635	14,039	17,051	14.1%
Discrete	7,543	8,064	8,180	9,060	10,265	11,677	9.1%
Optoelectronic	2,143	2,461	2,558	2,885	3,342	3,916	12.8%

Source: Dataquest
April 1989

Historically, the semiconductor industry has enjoyed a boom every four to five years. Most recently, the booms have occurred in 1984 and 1988, with a runover still occurring in the first half of 1989. We believe that the next worldwide boom year will be 1993, with growth of 31.7 percent. Given the fact that the industry experienced severe recessions in 1975 and 1985, we believe that another serious downturn could occur in the 1994 to 1995 time frame, although that is beyond the time period covered in this forecast.

Europe

The European market is the one to watch over the next few years, as both multinational and local companies plan for the opening of the single European market in 1992. Currently, several Japanese and U.S. OEMs are building plants in Europe to take advantage of the expected "1992 Effect." To take advantage of the tax system, these plants will find it necessary to purchase most of their semiconductor needs locally. As a result, several new semiconductor plants also are in the works to supply those needs. In addition, major European multinational companies—such as Siemens—are planning to move more manufacturing into Europe. We believe that semiconductor consumption will be shifted to some degree from North America and Japan into Europe. We believe that, because of 1992, European consumption will peak in 1992 before the peak hits in the other regions of the world. Therefore, Europe will gain share of the worldwide market in 1992. After 1992, however, we expect normal growth patterns to resume.

Japan

Japanese consumption continues to be fueled by domestic demand. New applications such as extended-definition television (EDTV)—to be followed by high-definition television (HDTV) in the 1990s—and POS terminals are expected to be very strong markets. The POS terminal demand is a response to the new sales tax instituted in Japan in April of this year; terminals that can automatically calculate the tax and total a sale will be needed. Automatic teller machine (ATM) growth continues to be strong, as does demand for personal computers at securities firms and laptop computers at midsize companies. Capital spending by semiconductor companies will be well below 1984 yen levels in 1989 and 1990. Return on investment for semiconductor capital expenditures is now above 1 in Japan, for the first time since 1984.

North America

The North American market will experience a slowdown in GNP and capital spending in the second half of 1989. We expect U.S. capital spending plans currently in place to be maintained, but higher interest rates will scare off spending plans for the second half of 1989.

Capital spending by semiconductor companies will be back up to 1984 dollar levels in 1989 and 1990, but capital spending as a percent of revenue will be about half that of 1984. We expect it to creep up in the 1991 to 1993 time frame.

Asia-Pacific/Rest of World

The Asian semiconductor market will be driven by consumer applications, as the domestic markets of China and Thailand heat up from unleashed consumer demand. Communications applications are expected to have extremely strong growth as well, as the newly industrialized and developing countries of Asia improve their telecommunications infrastructure. In addition, the personal computer industry in Taiwan, which experienced strong growth in 1988, is expected to continue to be a driving factor.

DATAQUEST CONCLUSIONS

As evidenced by the 32 percent worldwide growth experienced in 1988, the semiconductor industry is still a strong, dynamic industry, with the capability to surprise skeptics.

In spite of Asia's strong growth, we believe that the ROW region will not overtake Europe in total dollar size until sometime after 1993. Europe will get a new lease on life as a result of the single European market scheduled for 1992.

MOS memory, which drove the industry in 1988 and will continue to do so in 1989, will remain the fastest-growing product through 1993. Microdevices will grow the second fastest.

Dataquest believes that the semiconductor industry will begin its descent over the cliff in the second half of 1989. It will have a gentle landing in 1989 and 1990, however, compared with the crash landing the industry experienced in 1985. From 1991 through 1993, we expect the worldwide semiconductor industry to be healthy and growing.

Patricia S. Cox

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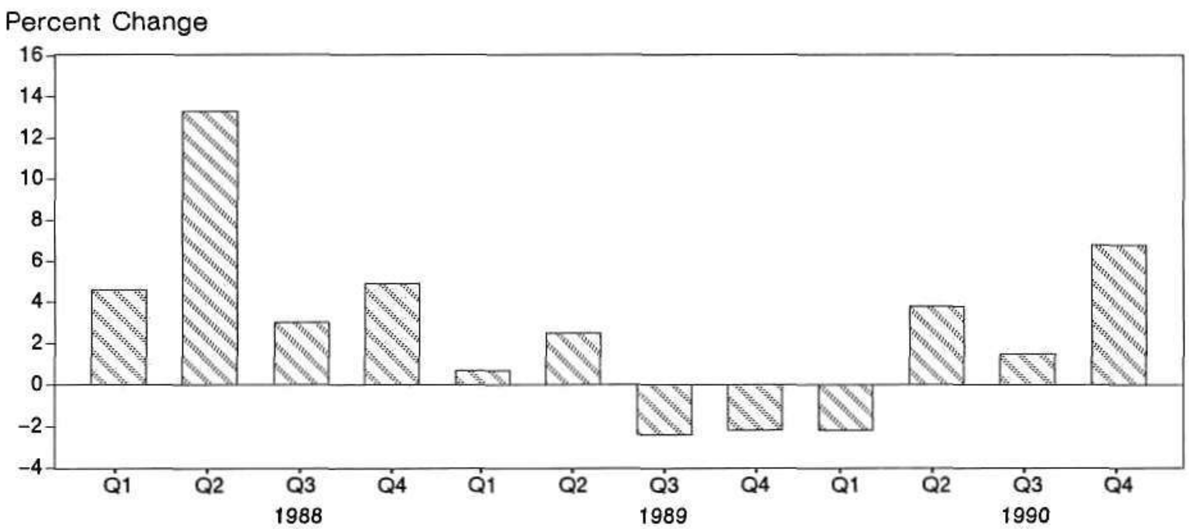
WORLDWIDE SEMICONDUCTOR OUTLOOK: FIRST QUARTER 1989

SUMMARY

As we promised in December, we have reexamined the outlook for the worldwide semiconductor industry through 1989 and 1990. The general picture has not changed; basically, events are occurring according to our October forecast assumptions. The major change is that fourth quarter 1988 was lower than forecast for the U.S. and ROW markets. In the case of the U.S. market, this was mainly due to inventory corrections. In the ROW market, a definite softening in the PC market occurred. We expect most regions to be fairly strong in the first half of 1989, with the exception of Japan, which experienced unusually strong growth in fourth quarter 1989. We retain our forecast of three negative quarters beginning in the third quarter of 1989, as memory prices fall and the U.S. economy softens slightly. The second half of 1990 should be a period of recovery. Figure 1 shows our quarterly forecast for the worldwide semiconductor industry.

Figure 1

**Worldwide Semiconductor Consumption
Quarter-to-Quarter Percent Change in U.S. Dollars**



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Source: Dataquest
February 1989

MARKET CONDITIONS

Table 1 gives our total semiconductor estimates and forecast by region and by quarter for 1988 through 1990.

Table 1

Worldwide Semiconductor Consumption (Millions of Dollars)

	1988 Q1	Q2	Q3	Q4	Total
United States	$ 3,560	$ 4,025	$ 4,279	$ 4,149	$16,013
Percent Change	2.2%	13.1%	6.3%	(3.0%)	24.7%
Japan	4,405	4,995	5,160	5,772	20,332
Percent Change	2.3%	13.4%	3.3%	11.9%	35.6%
Europe	1,967	2,203	2,084	2,237	8,491
Percent Change	11.6%	12.0%	(5.4%)	7.3%	31.0%
ROW	1,235	1,424	1,499	1,497	5,655
Percent Change	10.1%	15.3%	5.3%	(0.1%)	42.8%
Total	$11,167	$12,647	$13,022	$13,655	$50,491
Percent Change	4.6%	13.3%	3.0%	4.9%	31.9%

	1989 Q1	Q2	Q3	Q4	Total
United States	$ 4,294	$ 4,393	$ 4,394	$ 4,280	$17,361
Percent Change	3.5%	2.3%	0	(2.6%)	8.4%
Japan	5,610	5,717	5,488	5,203	22,018
Percent Change	(2.8%)	(1.9%)	(4.0%)	(5.2%)	8.3%
Europe	2,262	2,314	2,122	2,217	8,915
Percent Change	1.1%	2.3%	(8.3%)	4.5%	5.0%
ROW	1,579	1,661	1,742	1,745	6,727
Percent Change	5.5%	5.2%	4.9%	0.2%	19.0%
Total	$13,745	$14,085	$13,746	$13,445	$55,021
Percent Change	0.7%	2.5%	(2.4%)	(2.2%)	9.0%

	1990 Q1	Q2	Q3	Q4	Total
United States	$ 4,194	$ 4,110	$ 4,110	$ 4,316	$16,730
Percent Change	(2.0%)	(2.0%)	0	5.0%	(3.6%)
Japan	4,891	5,361	5,618	6,129	21,999
Percent Change	(6.0%)	9.6%	4.8%	9.1%	(0.1%)
Europe	2,270	2,340	2,282	2,474	9,366
Percent Change	2.4%	3.1%	(2.5%)	8.4%	5.1%
ROW	1,794	1,832	1,841	1,874	7,341
Percent Change	2.8%	2.1%	0.5%	1.8%	9.1%
Total	$13,149	$13,643	$13,851	$14,793	$55,436
Percent Change	(2.2%)	3.8%	1.5%	6.8%	0.8%

Source: Dataquest
February 1989

United States

The outlook in the U.S. market is for modest growth in the first half of 1989, then slowing in the second half of the year and the first half of 1990. Recovery will begin in the fourth quarter of 1990. Economic signs are mixed. Although the U.S. economy is expected to experience slower growth in 1989—2.5 percent—than in 1988, inflation is still low, and unemployment is at its lowest point in 14 years. However, the trade and budget deficits and the savings-and-loan industry crisis are clouding up the scene. On the bright side, Dun & Bradstreet surveys show that, while total capital spending may not be strong in 1989, investment in the high-tech area—i.e., for computer systems, office equipment, and automation—will remain high as companies strive for increased efficiency and modernization.

Dataquest surveys of semiconductor purchasing managers show that actual semiconductor inventory levels are coming down, and are only one to two days above target levels. Dataquest forecasts 1989 total computer shipments to be up by 9.4 percent and all electronic equipment production to be up 7.6 percent, versus 8.5 percent in 1988. Workstation growth is expected to be very high. In the PC arena, several new products have already been introduced this year by Apple and Digital Equipment Corporation.

The first half of 1989 will be helped along by latent demand from 1988. Many systems either were not shipped because of lack of memory chips or were shipped without memories, which will be added in 1989.

The Japanese companies that dominate the DRAM market are slowing their annual production increases in an attempt to prevent serious market gluts such as the one experienced in 1984 and 1985. As a result, the supply-demand situation in DRAMs will be kept in check. Also, the price curve for 4Mb DRAMs is higher than for previous generations, so price erosion will not be as serious. We expect DRAM prices to fall during 1989 and come back up in 1990 as 4Mb models become more widespread.

Japan

Japanese market growth will be about the same as U.S. market growth in 1989. We expect 1990 growth to be flat. Pricing will decline about 5 percent by the end of 1989, but some memory prices, particularly of 1Mb DRAMs, will be down 50 percent.

Electronic equipment growth will be 7.6 percent in 1989, about the same as in the United States. The Japanese economy is forecast to be quite strong in 1989, with real GNP growth of 4 percent.

Europe

We expect the European market to grow about 5.0 percent in both 1989 and 1990. Worldwide growth will be 9.0 percent and 0.8 percent, respectively, in those years. Although Europe will likely continue to experience the seasonal negative third quarter in both years, we believe that Europe will avoid the recession affecting the U.S. and Japanese markets largely because of the "1992 effect," when the European Economic Community becomes one market. This has already led to increased manufacturing by foreign companies in the European market. For example, Citizen, Compaq, NEC, Oki, and Sanyo are manufacturing computers and office equipment in Europe. Because of stringent local content laws, these companies will be forced to increase their local purchases of semiconductors within Europe drastically. This will have an adverse effect on Japanese market growth.

We believe that first quarter 1989 billings ASPs will be firm compared with fourth quarter 1988, but bookings ASPs will soften, leading to lower billings ASPs in second quarter 1989. Main areas of price pressure will be in DRAMs, some areas of specialized analog, and programmable logic devices.

On a positive note, we expect some new applications to take off by the middle of 1989. Chief among these is cellular telephone technology.

ROW

The ROW market, as usual, is expected to surpass all other regions in growth for both 1989 and 1990, growing 19 percent in 1989 and 9 percent in 1990. Fourth quarter 1988 growth was flat due to a soft PC market. Growth in 1989 will likely be fueled by a 21 percent increase in consumer electronics production and a 14 percent increase in data processing production.

Although a more protectionist U.S. market is expected as Congress tries to deal with the trade deficit, we see strong growth in trade activity <u>among</u> the ROW countries, which will help to counteract the U.S. import restrictions.

Foreign investment in the region has been and is likely to continue to be very strong. Japan is leading the way in offshore activity within ROW. U.S. governmental technology-flow restrictions will be greatly relaxed in 1989, which will help China's electronics industry growth.

DATAQUEST CONCLUSIONS

The years 1989 and 1990 will be slow ones for the worldwide semiconductor industry, following the two very strong years of 1987 and 1988. Bright spots include increased activity in Europe because of the 1992 effect and continuing strong growth in ROW. Japan, Europe, and the United States are all involved in high-definition television (HDTV) research and development. This, along with cellular telephone technology, could evolve into a major driver of the semiconductor industry, leading to the industry recovery we expect in the final quarter of 1990.

Patricia S. Cox

(Note: The total semiconductor consumption statistics in this newsletter are consistent with our company semiconductor market share data base, to be published in February and included in the Semiconductor Industry Service (SIS), Japanese Semiconductor Industry Service (JSIS), North American Semiconductor Markets (NASM) service, and the European Semiconductor Industry Service (ESIS) research reference binders.)

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PRELIMINARY 1988 WORLDWIDE SEMICONDUCTOR MARKET SHARES: JAPANESE GAIN SHARE; MEMORIES AND MICROS DOMINATE MARKET

SUMMARY

Dataquest's preliminary 1988 semiconductor market share survey has been completed. An analysis of the data shows the following:

- Worldwide market growth slowed in the fourth quarter of 1988 after a very strong showing in the first three quarters, resulting in total market growth of 32.9 percent.
- Japanese companies gained market share on all fronts, taking 50 percent of the worldwide market.
- U.S. companies gained market share in Japan for the first time since 1984.
- MOS memory and microdevices drove the market; those companies with memory and micro strength did extremely well.

Table 1 shows the total 1988 semiconductor revenue of the 112 companies surveyed by company base and by region sold into.

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Table 1

Preliminary 1988 Market Share Analysis—Top 112 Companies
(Millions of Dollars)

Company Base	Regional Market: North America	Japan	Europe	ROW	World
North America	11,262	1,956	3,725	1,859	18,802
Percent of Regional Market	70%	10%	44%	33%	37%
Percent of Company Sales	60%	10%	20%	10%	100%
Japan	3,242	17,913	1,438	2,496	25,089
Percent of Regional Market	20%	89%	17%	44%	50%
Percent of Company Sales	13%	71%	6%	10%	100%
Europe	1,056	106	3,163	600	4,925
Percent of Regional Market	7%	1%	37%	11%	10%
Percent of Company Sales	21%	2%	64%	12%	100%
ROW	420	62	165	704	1,351
Percent of Regional Market	3%	0	2%	12%	3%
Percent of Company Sales	31%	5%	12%	52%	100%
Total World	15,980	20,037	8,491	5,659	50,167
Percent of Regional Market	100%	100%	100%	100%	100%
Percent of Company Sales	32%	40%	17%	11%	100%

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
January 1989

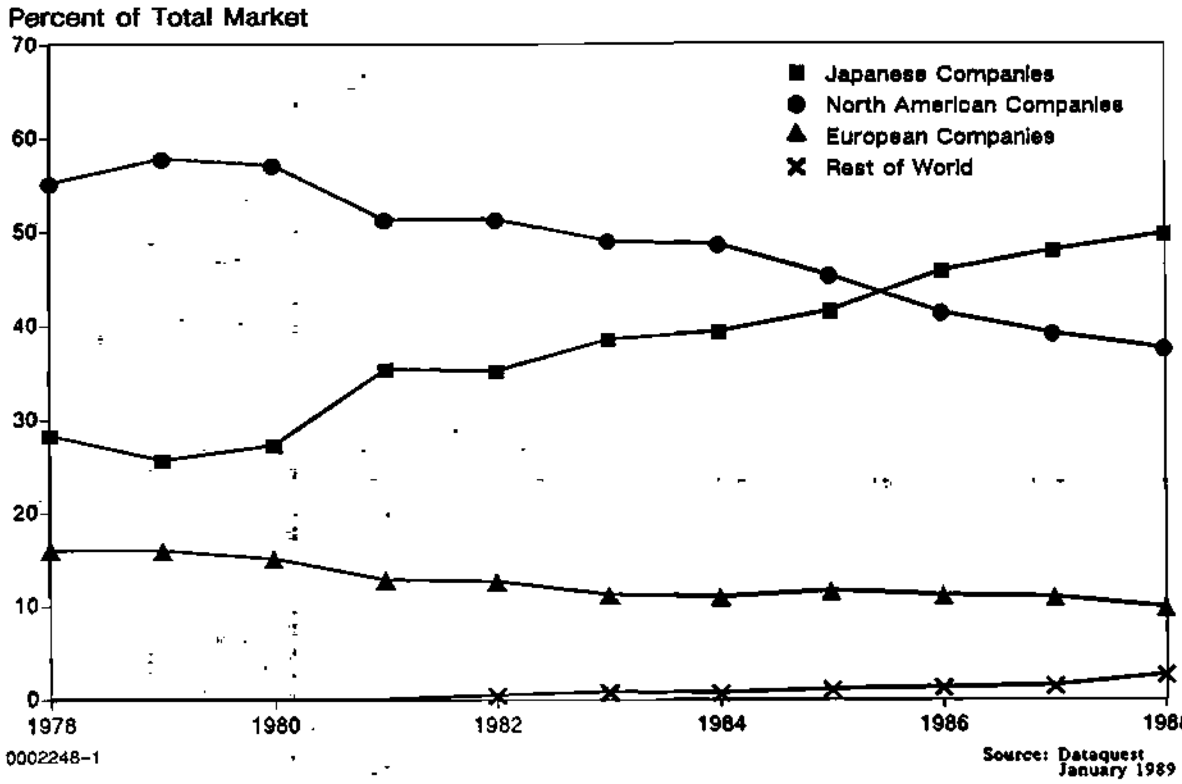
WORLDWIDE MARKET

Dataquest's preliminary survey of 1988 results for the top 112 worldwide semiconductor suppliers shows that the worldwide semiconductor industry grew 32.9 percent. This figure is less than our current forecast of 35.8 percent, mainly due to a slowdown in the North American and Rest of World (ROW) markets in the fourth quarter. Although the ranking of the top five suppliers in the market remained the same as in 1987, the market dynamics were clearly different in 1988. As Table 1 shows, North American companies' sales accounted for 10 percent of the total Japanese semiconductor market; this is the highest market share the United States has attained since 1984. On the other hand, Japanese companies' sales accounted for 20 percent of the North American market in 1988. This is an all-time record for the Japanese, due mainly to their dominance in DRAMs.

As also shown in Table 1, Japanese companies grew in 1988 to 50 percent of the worldwide semiconductor market, while North American companies dropped to 37 percent of the worldwide market. European companies also dropped to 10 percent, and ROW companies grew to 3 percent (up from 1.6 percent in 1987). Figure 1 illustrates the market share trends from 1978 through 1988.

Figure 1

Worldwide Semiconductor Market Shares by Company Base



RANKINGS

The Companies

Looking back to 1978, the top five semiconductor companies were Texas Instruments, Motorola, Philips, NEC, and Hitachi. In 1983, things changed substantially. The ranking at that time was Motorola, Texas Instruments, NEC, Hitachi, and Toshiba. In 1988, the companies were the same, but the ranking was NEC, Toshiba, Hitachi, Motorola, and Texas Instruments. No European company has been among the top five semiconductor companies since 1982. Toshiba is aggressively moving to surpass NEC as the number one supplier; however, that event did not occur in 1988. Among companies in the top 10, Intel had the highest growth, at 57.6 percent, due to its tremendous strength in microprocessors and the high demand for its 80386. One ROW company—Samsung—jumped from number 23 in 1987 to number 18 in 1988, becoming the first ROW company to join the top 20 ranking. Figure 2 lists the top 20 semiconductor companies worldwide.

Figure 2

Top 20 Worldwide Semiconductor Manufacturers for 1988

Company	1988 Rank	1987 Rank		1987 Sales	1988 Sales	Percent Change
				(Millions of Dollars)		
NEC	1	1		3,368	4,534	34.6%
Toshiba	2	2		3,029	4,302	42.0%
Hitachi	3	3		2,618	3,506	33.9%
Motorola	4	4		2,431	3,035	24.8%
Texas Instruments	5	5		2,127	2,741	28.9%
Fujitsu	6	6		1,801	2,359	31.0%
Intel	7	10		1,491	2,350	57.6%
Mitsubishi	8	9		1,492	2,278	52.7%
Matsushita	9	11		1,457	1,886	29.4%
Philips-Signetics	10	7		1,602	1,764	10.1%
National Semiconductor	11	8		1,506	1,700	12.9%
Advanced Micro Devices	12	12		986	1,106	12.2%
Sanyo	13	14		851	1,085	27.5%
SGS-Thomson	14	13		859	1,083	26.1%
Sharp	15	18		590	1,037	75.8%
Oki	16	17		651	947	45.5%
Sony	17	19		574	924	61.0%
Sansung	18	23		327	905	176.8%
AT&T	19	15		802	859	7.1%
Siemens	20	16		657	784	19.3%

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Source: Dataquest
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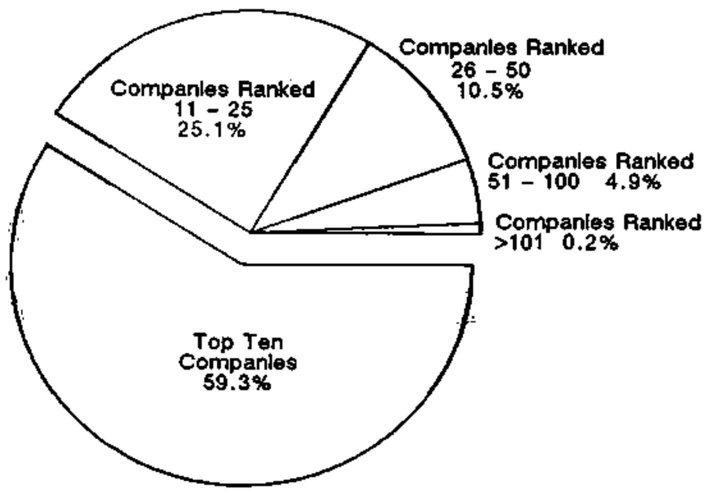
Market Concentration

In 1988, the top 10 companies accounted for well over half of total worldwide semiconductor market revenue. The top 25 companies together accounted for 84 percent of the market. The remaining companies (ranked 26 through 112) accounted for only 16 percent of the worldwide market. Figure 3 shows the revenue concentration percentages.

Figure 3

1988 Worldwide Semiconductor Market Share—Concentration of Revenue



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Source: Dataquest
January 1989

PRODUCT MARKETS

The products driving 1988's strong market growth were memories—especially DRAMs and SRAMs—and microdevices. Table 2 shows worldwide industry growth by product for the 112 companies surveyed. MOS ASIC revenue also showed very strong growth of 37.0 percent. In a total market that grew 32.9 percent, MOS memory grew 91.1 percent and MOS microdevices grew 42.8 percent. If MOS memory were removed from the picture, total industry growth would have been only 21.8 percent. The removal of both MOS memory and MOS microdevices would leave a total market growth of only 17.6 percent. The importance of memory and micros is shown graphically in Figure 4.

Table 2

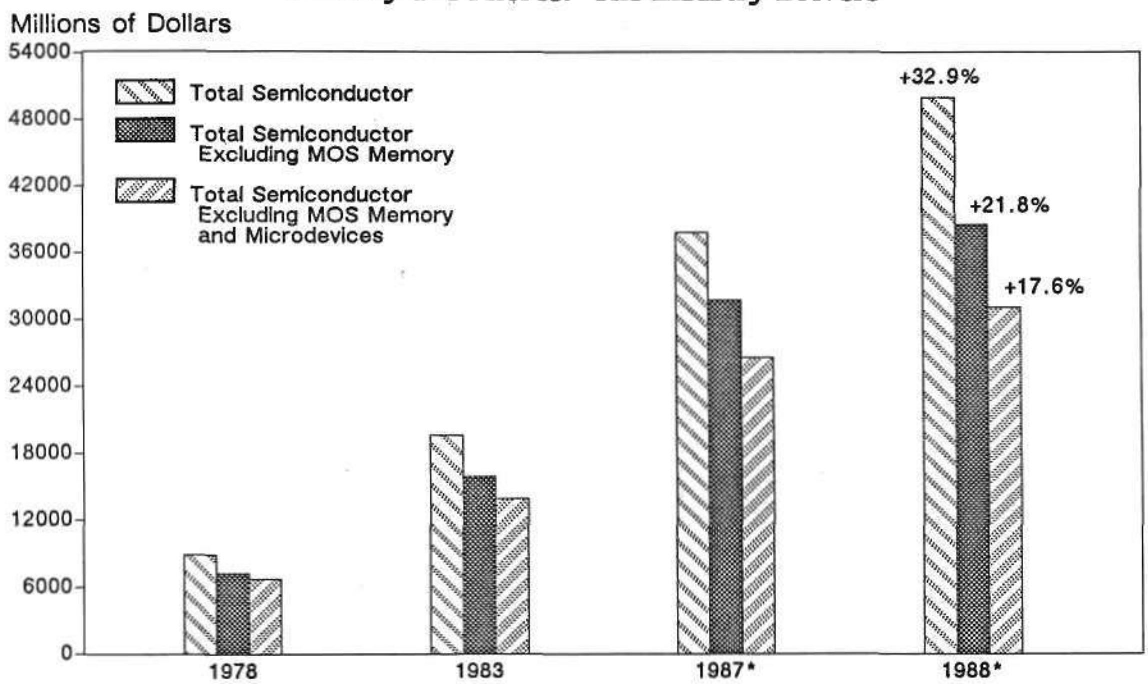
**Worldwide Semiconductor Market
Revenue Base of Top 112 Companies
(Millions of Dollars)**

	1987	1988	Percent Change
Total Semiconductor	37,759	50,167	32.9%
Total Integrated Circuit	29,568	40,689	37.6%
Bipolar Digital	4,730	5,162	9.1%
Bipolar Memory	620	669	7.9%
Bipolar Logic	4,110	4,493	9.3%
ASIC	1,671	1,855	11.0%
Standard Logic	2,243	2,398	6.9%
Other Logic	196	240	22.4%
MOS Digital	17,465	26,964	54.4%
MOS Memory	6,047	11,555	91.1%
MOS Microdevice	5,204	7,429	42.8%
MOS Logic	6,214	7,980	28.4%
ASIC	4,189	5,741	37.0%
Standard Logic	1,105	1,265	14.5%
Other Logic	920	974	5.9%
Analog	7,373	8,563	16.1%
Monolithic	6,443	7,474	16.0%
Hybrid	930	1,089	17.1%
Discrete	6,557	7,449	13.6%
Optoelectronic	1,634	2,029	24.2%

Source: Dataquest
January 1989

Figure 4

Memory and Micros: The Industry Drivers



* "Other" companies are not included in 1987 and 1988 numbers.

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Source: Dataquest January 1989

Tables 3 through 9 rank the top 20 manufacturers in the categories of total integrated circuit, total bipolar digital, total MOS digital, MOS memory, analog ICs, discrete, and optoelectronic.

In the MOS digital category, the phenomenal growth experienced by Mitsubishi, Samsung, Sharp, and Micron Technology was due to high demand for DRAMs. The extremely high growth experienced by Western Digital (WD) was caused largely by internal demand for microperipherals from the computer storage companies that WD acquired during 1987 and 1988.

In MOS memory, changes in ranking occurred among the top 10 companies, although NEC remained number one. Samsung and Micron Technology both jumped two places. Advanced Micro Devices, number 10 in 1987, dropped to number 15 because of its lack of participation in the DRAM market.

Table 3

1988 World Semiconductor Market Share Ranking
Total Integrated Circuit
(Millions of Dollars)

1988 Rank	1987 Rank	Company	1987 Revenue	1988 Revenue	Percent Change
1	1	NEC	2,795	3,875	38.6%
2	2	Toshiba	2,194	3,223	46.9%
3	4	Hitachi	1,946	2,729	40.2%
4	3	Texas Instruments	2,024	2,637	30.3%
5	7	Intel	1,491	2,350	57.6%
6	5	Motorola	1,755	2,259	28.7%
7	6	Fujitsu	1,660	2,166	30.5%
8	9	Mitsubishi	1,239	1,940	56.6%
9	8	National Semiconductor	1,431	1,625	13.6%
10	11	Matsushita	994	1,335	34.3%
11	10	Philips	1,186	1,302	9.8%
12	12	Advanced Micro Devices	986	1,106	12.2%
13	14	Oki	619	902	45.7%
14	22	Samsung	291	850	192.1%
15	13	SGS-Thomson	646	829	28.3%
16	16	Sanyo	556	813	46.2%
17	17	Sharp	367	752	104.9%
18	15	AT&T	595	688	15.6%
19	18	Sony	364	595	63.5%
20	20	Siemens	354	480	35.6%
		U.S. Companies	12,455	16,323	31.1%
		ROW Companies	500	1,230	146.0%
		Japan Companies	13,795	19,702	42.8%
		Europe Companies	2,818	3,434	21.9%
		Total World Companies	29,568	40,689	37.6%

Source: Dataquest
January 1989

Table 4

1988 World Semiconductor Market Share Ranking
Total Bipolar Digital
(Millions of Dollars)

1988 Rank	1987 Rank	Company	1987 Revenue	1988 Revenue	Percent Change
1	1	Texas Instruments	854	940	10.1%
2	2	National Semiconductor	521	575	10.4%
3	3	Advanced Micro Devices	500	562	12.4%
4	4	Fujitsu	495	561	13.3%
5	5	Hitachi	463	501	8.2%
6	7	Philips	405	442	9.1%
7	6	Motorola	429	435	1.4%
8	8	NEC	247	292	18.2%
9	10	Mitsubishi	122	128	4.9%
10	9	Toshiba	125	108	(13.6%)
11	12	Plessey	68	95	39.7%
12	17	Harris	30	62	106.7%
13	11	AT&T	79	61	(22.8%)
14	14	Raytheon	51	55	7.8%
15	18	Sanyo	29	41	41.4%
16	16	Oki	32	38	18.8%
17	22	Gold Star	21	32	52.4%
18	13	Siemens	63	31	(50.8%)
19	21	Chips & Technologies	25	30	20.0%
20	20	Matsushita	26	30	15.4%
		U.S. Companies	2,583	2,806	8.6%
		ROW Companies	21	32	52.4%
		Japan Companies	1,540	1,700	10.4%
		Europe Companies	586	624	6.5%
		Total World Companies	4,730	5,162	9.1%

Source: Dataquest
January 1989

Table 5

1988 World Semiconductor Market Share Ranking
Total MOS Digital
(Millions of Dollars)

1988 Rank	1987 Rank	Company	1987 Revenue	1988 Revenue	Percent Change
1	1	NEC	2,006	3,114	55.2%
2	2	Toshiba	1,593	2,546	59.8%
3	3	Intel	1,473	2,328	58.0%
4	4	Hitachi	1,173	1,885	60.7%
5	5	Fujitsu	1,014	1,437	41.7%
6	7	Mitsubishi	812	1,408	73.4%
7	6	Motorola	987	1,399	41.7%
8	8	Texas Instruments	784	1,271	62.1%
9	9	Matsushita	592	882	49.0%
10	10	Oki	566	841	48.6%
11	18	Samsung	242	765	216.1%
12	15	Sharp	312	683	118.9%
13	11	National Semiconductor	415	500	20.5%
14	12	Advanced Micro Devices	414	483	16.7%
15	13	SGS-Thomson	344	459	33.4%
16	14	Philips	342	404	18.1%
17	21	Western Digital	187	400	113.9%
18	29	Micron Technology	115	382	232.2%
19	16	AT&T	300	380	26.7%
20	17	LSI Logic	262	370	41.2%
		U.S. Companies	6,924	10,088	45.7%
		ROW Companies	383	1,042	172.1%
		Japan Companies	8,924	14,138	58.4%
		Europe Companies	1,234	1,696	37.4%
		Total World Companies	17,465	26,964	54.4%

Source: Dataquest
January 1989

Table 6

1988 World Semiconductor Market Share Ranking
MOS Memory
(Millions of Dollars)

1988 Rank	1987 Rank	Company	1987 Revenue	1988 Revenue	Percent Change
1	1	NEC	838	1,481	76.7%
2	2	Toshiba	679	1,439	111.9%
3	4	Hitachi	576	1,114	93.4%
4	5	Mitsubishi	492	943	91.7%
5	3	Fujitsu	634	932	47.0%
6	6	Texas Instruments	445	834	87.4%
7	9	Samsung	170	650	282.4%
8	7	Intel	326	392	20.2%
9	12	Micron Technology	115	382	232.2%
10	8	Oki	193	353	82.9%
11	11	Sharp	130	345	165.4%
12	16	Motorola	86	236	174.4%
13	13	NMB	104	218	109.6%
14	15	Matsushita	91	216	137.4%
15	10	Advanced Micro Devices	155	209	34.8%
16	14	SGS-Thomson	95	183	92.6%
17	24	Siemens	52	150	188.5%
18	17	IDT	85	140	64.7%
19	18	Microchip Technology	84	138	64.3%
20	19	National Semiconductor	80	135	68.8%
		U.S. Companies	1,698	2,917	71.8%
		ROW Companies	206	812	294.2%
		Japan Companies	3,909	7,347	88.0%
		Europe Companies	234	479	104.7%
		Total World Companies	6,047	11,555	91.1%

Source: Dataquest
January 1989

Table 7

1988 World Semiconductor Market Share Ranking
Total Analog Integrated Circuits
(Millions of Dollars)

1988 Rank	1987 Rank	Company	1987 Revenue	1988 Revenue	Percent Change
1	3	Toshiba	476	569	19.5%
2	2	National Semiconductor	495	550	11.1%
3	6	Sanyo	377	473	25.5%
4	1	NEC	542	469	(13.5%)
5	4	Philips	439	456	3.9%
6	5	Texas Instruments	386	426	10.4%
7	8	Motorola	339	425	25.4%
8	7	Matsushita	376	423	12.5%
9	10	Mitsubishi	305	404	32.5%
10	11	SGS-Thomson	282	350	24.1%
11	14	Sony	217	345	59.0%
12	9	Hitachi	310	343	10.6%
13	12	Analog Devices	280	340	21.4%
14	13	Rohm	235	264	12.3%
15	15	AT&T	216	247	14.4%
16	16	Fujitsu	151	168	11.3%
17	21	Sanken	119	157	31.9%
18	17	Harris	139	146	5.0%
19	19	Burr-Brown	120	143	19.2%
20	20	Siemens	120	125	4.2%
		U.S. Companies	2,948	3,429	16.3%
		ROW Companies	96	156	62.5%
		Japan Companies	3,331	3,864	16.0%
		Europe Companies	998	1,114	11.6%
		Total World Companies	7,373	8,563	16.1%

Source: Dataquest
January 1989

Table 8

1988 World Semiconductor Market Share Ranking
Discrete
(Millions of Dollars)

1988 Rank	1987 Rank	Company	1987 Revenue	1988 Revenue	Percent Change
1	1	Toshiba	703	864	22.9%
2	2	Motorola	652	752	15.3%
3	3	Hitachi	625	707	13.1%
4	4	NEC	518	571	10.2%
5	5	Philips	390	435	11.5%
6	6	Matsushita	318	369	16.0%
7	7	Mitsubishi	227	311	37.0%
8	9	SGS-Thomson	213	254	19.2%
9	13	Rohm	200	242	21.0%
10	11	Fuji Electric	206	227	10.2%
11	10	Sanyo	210	210	0
12	14	Sanken	162	207	27.8%
13	8	Siemens	218	205	(6.0%)
14	16	International Rectifier	151	200	32.5%
15	18	General Instrument	132	164	24.2%
16	12	AT&T	200	161	(19.5%)
17	15	ITT	160	146	(8.8%)
18	17	General Electric	146	145	(0.7%)
19	19	Powerex	106	115	8.5%
20	23	Sony	72	112	55.6%
		U.S. Companies	2,009	2,140	6.5%
		ROW Companies	92	121	31.5%
		Japan Companies	3,338	3,938	18.0%
		Europe Companies	1,118	1,250	11.8%
		Total World Companies	6,557	7,449	13.6%

Source: Dataquest
January 1989

Table 9

1988 World Semiconductor Market Share Ranking
Optoelectronic
(Millions of Dollars)

1988 Rank	1987 Rank	Company	1987 Revenue	1988 Revenue	Percent Change
1	1	Sharp	223	285	27.8%
2	4	Sony	138	217	57.2%
3	5	Toshiba	132	215	62.9%
4	2	Hewlett-Packard	186	213	14.5%
5	3	Matsushita	145	182	25.5%
6	10	Rohm	70	114	62.9%
7	9	Fujitsu	71	111	56.3%
8	7	Siemens	85	99	16.5%
9	11	NEC	55	88	60.0%
10	8	Telefunken Electronic	77	82	6.5%
11	12	Hitachi	47	70	48.9%
12	6	Sanyo	85	62	(27.1%)
13	14	Texas Instruments	39	41	5.1%
14	19	Oki	25	36	44.0%
15	15	Honeywell	30	30	0
16	17	Mitsubishi	26	27	3.8%
17	18	Philips	26	27	3.8%
18	20	Motorola	24	24	0
19	21	Plessey	17	22	29.4%
20	22	General Electric	16	21	31.3%
		U.S. Companies	373	339	(9.1%)
		ROW Companies	0	0	N/A
		Japan Companies	1,046	1,449	38.5%
		Europe Companies	215	241	12.1%
		Total World Companies	1,634	2,029	24.2%

N/A = Not Applicable

Source: Dataquest
January 1989

DATAQUEST CONCLUSIONS

The Japanese companies have grown from 28.4 percent of the worldwide semiconductor market in 1978 to 50 percent in 1988. Intel reaped the rewards of its sole-sourcing policy on the 80386, which was the microprocessor to have in 1988. Dataquest believes that the tremendous growth of the ROW companies in 1988 was due to the decisions by Hyundai and Samsung to concentrate on DRAMs and SRAMs.

In our opinion, the message from 1988 is clear: those companies that participated in strong growth product areas generally gained market share; among those products, proprietary products gained market share. Although products that experience dynamic growth spurts are also more vulnerable to downturns, we believe that market share gains will continue to be made in the long run.

Patricia S. Cox

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HITACHI AND TI SHARE THE RISK: THE 16Mb DRAM AGREEMENT

SUMMARY

On December 22, Texas Instruments (TI) and Hitachi Ltd. announced that they had entered into an agreement to jointly develop DRAMs. Under the terms of the agreement, the two companies will create a common 16Mb DRAM technology. Implementation of the agreement will allow each company to have access to the other's DRAM technology as it relates to the development of the 16Mb device.

AN INDUSTRY FIRST

The Hitachi/TI agreement marks the first time that leading U.S. and Japanese semiconductor companies have come together to develop a future-generation memory product. The Motorola/Toshiba agreement, although equally significant, involves joint manufacturing and technology exchange related to existing products. In this sense, then, the Hitachi/TI deal has its counterpart more in the "MegaProject" agreement between Philips and Siemens, in which the two European chip manufacturers shared the development costs and technology in producing the 4Mb DRAM (Siemens) and 1Mb fast SRAM (Philips).

The semiconductor industry is certainly familiar with technology exchange as the raison d'etre of alliances. To understand the Hitachi/TI agreement, however, one must also appreciate the risks associated with the increasing capital intensiveness of leading-edge memory development. These risks are probably as great, if not greater, a factor in bringing the two companies together as is any mutual benefit to be obtained through technology swapping.

RISK SHARING

The issue of risk concerning the 16Mb DRAM has to do with cost and timing. From the standpoint of cost, future participants in the high-density memory business face incredible investments in development and production. Equipment and clean room technology required to produce devices based on 0.5-micron linewidths is enormously expensive. At a recent meeting of a semiconductor task force hosted by the American Electronics Association (AEA), a representative of one major U.S. semiconductor manufacturer introduced a cost model that estimated a $250 million capital investment to build a 0.8-micron, 1Mb DRAM factory with throughput capability of 5,000 6-inch wafers a week. This is probably a conservative estimate to begin with.

To Dataquest's knowledge, construction of a prototype 16Mb fab will be started by NEC in Sagamihara, Japan, in the third quarter of 1989. This facility, with a probable capacity of about 5,000 6-inch wafers per four-week period, alone will cost an estimated $160 million. Eventually, companies will have to consider building the next-generation factory--a 0.8- to 0.5-micron, 8-inch wafer fab--that can produce 4Mb as well as 16Mb DRAMs. The cost of such fabs is currently estimated to be about $400 million.

Whatever reductions in development costs their agreement may achieve, both Hitachi and TI will have to build expensive fabs. By working together, however, the two companies have a better chance of coming up with a winning formula for product manufacture and, thereby, overcoming the other demon of DRAM development: timing. Any company that plans to participate in the 16Mb market, which Dataquest believes will reach approximately 2 million units in 1992, must make massive capacity investments during an industry cycle that we have forecast to be weak. If a company stumbles badly in bringing up its 16Mb DRAM production, the penalties will be serious. From this standpoint, then, the Hitachi/TI deal is not so much about sharing costs as it is about sharing expertise and resources and about minimizing individual exposure. Given the stakes in entering the 16Mb DRAM market, failure could be disastrous.

WHAT TI GETS

While risk sharing can be seen as the most powerful common denominator of the alliance, each company has some unique advantages to gain from its partner. In the case of TI, the advantages seem obvious. Hitachi is an acknowledged leader in memory technology, was the first company to introduce the 256K DRAM, and was in the top two in 1Mb DRAM introductions. Furthermore, Dataquest believes that Hitachi is a major contender, along with Toshiba, for the lead in 4Mb DRAMs. As a result of its agreement with Hitachi, TI—the seventh largest producer of 1Mb DRAMs (in units) in 1987—could be one of the leaders in the future DRAM market.

Hitachi is also a leader in BICMOS, which is a critical process for fast SRAMs as well as high-speed DRAMs. In 1987, Hitachi presented a paper at the ISSCC (International Solid State Circuit Conference) on a 35-nanosecond 1Mb DRAM utilizing BICMOS. Dataquest expects to see samples of such a device in 1989, and we further believe that this technology will be a very important process at the 16Mb DRAM density.

In addition to its expertise in memory technology, Hitachi now manufactures in TI's backyard. Hitachi has just finished equipping its Irving, Texas, fab, which is capable of producing 1.3-micron SRAMs. Future production is planned for ASIC devices and microprocessors. Although the Hitachi/TI agreement does not entail joint manufacturing, as is the case with the Motorola/Toshiba alliance, the proximity of the companies' manufacturing sites would at least make such an arrangement logistically convenient.

WHAT HITACHI GETS

With Hitachi's leading position in DRAMs, substantial capital resources, and existing manufacturing presence in the United States, the Hitachi/TI agreement raises the logical question, "What's in it for Hitachi?" Once again, the issue of risk sharing is paramount; but aside from this factor, some other possible motives are worth speculation. These include the following:

- TI's hold on fundamental DRAM patents may be a factor in the joint development effort—Hitachi was one of the Japanese memory manufacturers sued by TI in 1986 over DRAM patent violations. The companies settled out of court in 1987.

- Although the press release from the companies mentions product development beyond DRAMs, a technology swap involving TI DSP (digital signal processing) circuits could certainly be attractive to Hitachi in view of DSP's relevance to the high-definition TV market and Hitachi's growing emphasis on microdevices.

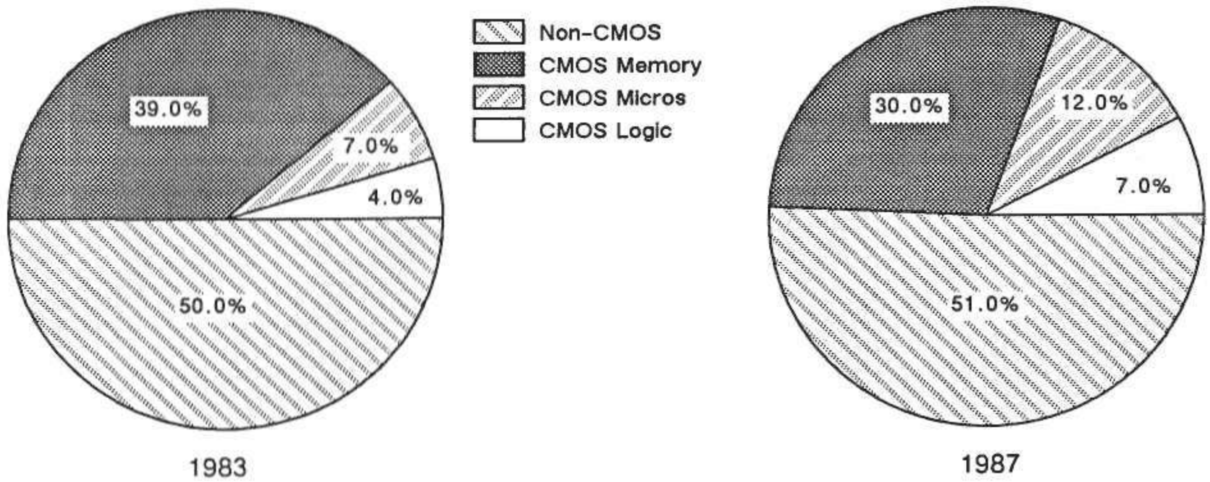
- Not knowing which way the "trade winds" will blow in the future, having a U.S. partner as well as a domestic manufacturing presence certainly cannot hurt Hitachi from a political standpoint.

HITACHI IN TRANSITION

From a more strategic point of view, the agreement with TI is further evidence of Hitachi's broadening market presence. According to Dataquest's Tokyo office, Hitachi's single most important project at this time is the TRON microprocessor—a reflection of Hitachi's focus on logic and micros. Figure 1 shows just how Hitachi's semiconductor product mix has changed in the past five years. While Hitachi's memory business has diminished as a percentage of its total semiconductor revenue, the percentages for logic and microdevices have nearly doubled.

Figure 1

Hitachi CMOS Logic Function Revenue
As a Percentage of Total Semiconductor Revenue
1983 versus 1987
(Based on Millions of Dollars)



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Source: Dataquest
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Contrasted with NEC, one senses the path Hitachi must follow. In 1987, combined microdevice and logic revenue accounted for approximately 19 percent of Hitachi's semiconductor business, compared to 35 percent for NEC. Obviously, Hitachi has no plans to abdicate the memory market. Nevertheless, it will be increasingly difficult for Hitachi to continue along its present path in logic and micros while committing ever greater resources to the MOS memory side of its business.

DATAQUEST CONCLUSIONS

Dataquest has long maintained that the complexities of product mix and the escalating costs of development and manufacture at the leading edge will make it difficult for even the largest broad-based semiconductor suppliers to afford a "go it alone" attitude. Certainly, the Hitachi/TI agreement underscores this point of view. Given the costs and risks of participating in the commodity memory business of the future, it is hard to believe that this agreement will be unique.

For the U.S. electronics systems industry, the Hitachi/TI deal should send a message that the U.S. semiconductor industry is committed to the DRAM market for the long term. While the merits of having a domestic (i.e., United States-owned) supplier base may be debated, it must certainly be reassuring to U.S. computer manufacturers to know that at least one DRAM vendor is not a systems-level competitor.

One issue that may confront the Hitachi/TI agreement is TI's involvement with Sematech, the U.S. manufacturing consortium. There is likely to be some concern about Hitachi's possible access to Sematech-related technology. Inasmuch as the consortium is a beneficiary of its members' intellectual capital as well as a benefactor, it is possible that the technologies developed through the Hitachi/TI agreement could make a positive contribution to the U.S. semiconductor industry as a whole.

As evidenced by the deliberations of U.S. semiconductor companies over reentering the DRAM business, such a commitment cannot be made on the basis of short-term opportunism. Participation in the DRAM market must be a fundamental part of a semiconductor company's long-term strategy. Although the benefits of developing a 0.5-micron manufacturing capability will accrue to other areas of chipmaking beyond the DRAM business, investments in DRAMs cannot preclude the development of other key component areas.

As the cost of capital investment continues to rise, participation in both leading-edge commodity products and higher-margin businesses such as microdevices and ASICs will be more difficult to support. A major reason for this is that these product development paths are becoming increasingly divergent—while future DRAM generations will depend on trench and other 3-D technologies, ASICs will continue to stress CAD technology and multiple metal deposition. In spite of their differing demands, companies will have to have their feet in both worlds if they intend to be major suppliers to the data processing arena. The Hitachi/TI agreement suggests one way of meeting this challenge; and, as such, it follows a direction already indicated by the Motorola/Toshiba alliance.

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BLOCKING INFRINGEMENT AT THE BORDER: THE OMNIBUS TRADE BILL AND THE ITC

SUMMARY

In late November 1988, Intel Corporation announced that the International Trade Commission (ITC) had issued an Initial Determination in Intel's favor regarding its EPROM infringement complaint against All-American Semiconductor Inc., Atmel Corp., Cypress Electronics Inc. (a distributor), General Instrument Corp., Hyundai Electronics Industries Co. Ltd., Microchip Technology Inc., and Pacesetter Electronics Inc. In addition to lodging its complaint with the ITC, Intel had filed a lawsuit over the EPROM issue through the Federal District Court in San Jose, California. Both of these events occurred in September 1987. This newsletter looks at recent actions by the ITC on behalf of U.S. semiconductor suppliers in order to illustrate the power of trade policy in the enforcement of intellectual property law. In addition, this newsletter discusses changes in the scope of that enforcement resulting from the passage of the Omnibus Trade Bill.

THE INTEL EPROM RULING

Although Intel's civil case against Hyundai and the other above-named companies has yet to be tried in court, the ITC in its Initial Determination has already reacted to Intel's allegations with a decision that, if upheld, would result in an exclusion order preventing the future importation of EPROMs that infringe on Intel's patents. Coincidentally, the ITC Initial Determination was made by Janet Saxon, the same judge who had earlier issued an exclusion order against Samsung in Texas Instruments' DRAM patent infringement suit against the Korean supplier.

The ITC will issue its Final Determination in Intel's EPROM case on March 16. In its final ruling, the ITC might either rubber-stamp the Initial Determination, request a further review of the issues, or remand Judge Saxon's initial ruling altogether. If the Initial Determination is upheld, however, Hyundai, as an offshore manufacturer, will be forced to post a bond in order to export infringing EPROMs to the United States. At that point, only a presidential decision could prevent the exclusion order from remaining in effect—or a settlement on Intel's terms involving significant royalty payments.

THE POWER OF THE ITC

The Fast Track to Patent Enforcement

The outcome of the ITC ruling certainly has immediate significance to both Intel and Hyundai. The power of an ITC exclusion order was clearly demonstrated in the DRAM patent suits brought by Texas Instruments (TI). As a result of the ITC's ruling, TI was able to expedite out-of-court settlements with both Samsung, which was immediately affected by the exclusion order, and NEC, which probably saw itself as the next likely target. As the last two companies to settle in TI's sweeping DRAM suit, both Samsung and NEC had initially appeared willing to "go to the mat" on the patent infringement suit. As it was, the ITC offered them a very powerful incentive to soften their positions. In addition, TI was able to claim more than $190 million in royalty revenue in fiscal 1987 as a result of its lawsuit settlements.

Aside from its obvious clout, the ITC offers U.S. patent holders a more expedient avenue of legal recourse than the Federal District Court when dealing with an offshore infringer. Once a complaint is filed with the ITC, the commission has 18 months in which to come up with an Initial Determination. After this ruling has been made, the ITC then has another two months to review the determination and issue a final decision. Compare this process with the many years it has taken to produce a decision through the district court in the Intel/NEC copyright case.

Limitations

Although the legal recourse offered by the ITC looks attractive from the standpoints of expediency and muscle, it has had historical limitations not encountered through the Federal District Courts. Chief among these limitations has been the requirement that a company prove damage to its business as a result of patent infringement by a foreign competitor—and underlying this, the requirement that a company be an active participant in the market associated with the infringed-upon patent. In the case of Intel, this meant that although the company could legitimately file an action through the ITC regarding EPROMs, it was prevented from filing a similar complaint regarding DRAM patent infringement because Intel no longer competes in the DRAM market as a producer of these devices.

THE IMPACT OF THE OMNIBUS TRADE BILL

Enter the Omnibus Trade Bill. This trade bill amends Section 337 of the Tariff Act of 1930 by removing the proof-of-injury requirement noted above. In fact, the amendment minimizes the requirement that a petitioner show investments in R&D, plants and equipment, or employment as evidence of its participation in a market. Also removed is the requirement that the aggrieved company be efficiently and economically operated. Had these amendments been in force when Intel filed its original DRAM patent infringement lawsuit against Hyundai, Intel could have filed an action with the ITC in that case as well. The door is now open for Intel to do just that—in which case, the ITC's Initial Determination regarding Hyundai's violation of Intel's EPROM patents may have been the first shoe to drop.

The larger issue here is not just whether or not Intel succeeds in collecting additional royalties for its earlier memory technology, or even whether Hyundai's competitiveness in DRAMs or EPROMs is compromised by the payment of royalties to an aggrieved U.S. company. The issue is also the impact that Asian memory suppliers may ultimately have on a U.S. end-user market traumatized by the 1988 DRAM shortages. Although DRAM purchasers in U.S. OEM electronics companies could console themselves that the Koreans may soon rescue them from the current supply/price squeeze that their U.S. and Japanese vendors have put them in, it may be too soon to become complacent. Where and how memory technology was obtained may become a key question that users will want answered as they contemplate relationships with Asian suppliers, as any one of a number of former U.S. memory participants may be carefully dusting off its stack of patents in the wake of the Omnibus Trade Bill's passage.

DATAQUEST CONCLUSIONS

The Omnibus Trade Bill raises the level of importance assigned to the source of intellectual property, in effect, since technology is often the bargaining chip in foundry and distribution deals between U.S. start-ups and Asian semiconductor companies. If Goldstar, Hyundai, Samsung, Yamaha, or any other offshore semiconductor competitors plan to "buy" access to a product market through technology swaps with smaller U.S. companies, they will want to be sure that they know the full price up front. The final bill may not be in the hands of a Start-Up Inc., but rather in the hands of an AMD, Intel, or National Semiconductor.

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UNDERSTANDING THE NEC/INTEL DECISION

". . . the more the court is led into the intricacies of dramatic craftsmanship, the less likely it is to stand upon the firmer, if more naive, ground of its considered impressions upon its own perusal." (Judge Learned Hand, Nichols v. Universal Pictures Corp., 1930)

SUMMARY

The above reference, quoted by United States District Judge William P. Gray in reference to an earlier intellectual property lawsuit, says much about the nature of the decision reached last week regarding the microcode copyright trial between NEC Corporation and Intel Corporation. In his decision, which came as the latest development in a dispute that has gone on in one form or another since 1982, Judge Gray declared the following:

- Intel's microcodes for its 8086 and 8088 microprocessors "were proper subjects for protection under United States copyright laws."

- Although its microcode copyright claims were valid, Intel forfeited its copyrights because "more than a relatively small number of copies of product . . . did not contain the copyright notice," and because "Intel failed to make a reasonable effort to cause such notice to be added to those copies after the omission had been discovered."

- NEC's microcode for its V20, V30, V40, and V50 microprocessors did not infringe on Intel's copyrights for its 8086/88 microcodes.

- NEC's V20 and V30 microprocessors could not be considered as "improvements" upon its earlier uPD 8086 and uPD 8088 devices, which were licensed by Intel.

The outcome of the NEC/Intel trial has been long anticipated as a landmark decision on semiconductor intellectual property. This case has rightly been characterized as having implications that go far beyond its impact on the litigants. As a result, this question is often asked: "What effect does the outcome have on NEC/Intel?" Just as often asked is this question: "Does the decision provide any clear guidelines to the industry regarding copyright?"

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The answer to this last question, Dataquest believes, is an emphatic "yes." Judge Gray's decision sends a clear message to the industry regarding the extension of copyright to that form of intellectual property known as microcode; it represents a thorough, well-reasoned consideration of issues that many had considered beyond the competent grasp of a lay jurist. Because of the complexity of the issues involved, which encompass legal, technical, and market share considerations, this newsletter will confine itself to a summary of Judge Gray's decision, with an emphasis on those aspects of the judgment that offer the most insight on the industry's protection of intellectual property.

THE COPYRIGHTABILITY OF MICROCODE

The first part of Judge Gray's decision constitutes what Intel has called "a precedent for our large investments in new products" and "a broad landmark decision for the industry." To begin with, as in the previous decision by Judge William Ingram (which was vacated when the judge disqualified himself from the case due to ownership of a small number of shares of Intel stock), Judge Gray maintains that microcode fits the definition of a computer program as contained in the Copyright Act of 1980. This act defines microcode as "a set of statements or instructions to be used directly or indirectly in a computer in order to bring about a certain result."

The Originality of Microcode

In reaching this decision regarding the copyrightability of microcode, Judge Gray was unconvinced by NEC's arguments that Intel's microcode should not be subject to copyright because many sequences consist of "only a few obvious steps and thus lack the originality required for copyright protection," and that Intel's microcode is in fact "a defining element of the computer itself." To these arguments, Judge Gray replied that "any copyrighted work . . . can be chopped into parts that could be said to have very few creative steps." He further replied that the copyrightability of a work requires only its independent creation by an author and that it contain "a modicum of originality." In the judge's opinion, Intel's microcode meets both of these conditions.

The Relationship of Microcode to Computer

Noting that Intel's microcode falls within the statutory definition of a computer program, Judge Gray used the following quote from a 1983 case involving Apple Computer and Formula Intern, Inc.: "There is nothing in any of the statutory terms which suggest a different result (concerning copyrightability) for different types of computer programs based upon the function they serve within the machine."

The "Merger Doctrine"

The most profound test of the copyrightability of microcode resulting from the NEC/Intel suit, in terms of defining the limits of copyright's domain, has to do with the "merger doctrine." This concept, which on an abstract level seems pointlessly pedantic, is a critical issue from the standpoint of applying copyright to anything that is functional in nature. Since 1879, the courts have allowed that the expression of an idea, not the idea itself, is copyrightable. NEC's chief argument against applying copyright to microcode is that it represents the "merger" of expression and idea.

In the context of the technology being considered, the "merger doctrine" holds that the characteristics of microcode (an expression) cannot be separated from the constraints imposed upon it by the implementation of a macroinstruction set (the idea) in a specific microprocessor architecture. Quoting from a precedent case in 1971, NEC's argument was stated by Judge Gray as follows: "When the 'idea' and its 'expression' are thus inseparable . . . protecting the 'expression' would confer a monopoly of the 'idea' upon the copyright owner free of the conditions and limitations imposed by the patent law." As can be imagined, this is an issue that would inspire a federal circuit judge to rigorous deliberation--and on the outcome of this deliberation, one can trace the trajectory of the final decision.

Judge Gray's answer to the "merger doctrine" is that, while it is "an axiom of copyright law," it should "not be considered on the issue of copyrightability, but . . . be deferred to the discussion of the infringement. Therefore, "the burden of showing such constraints should be left to the alleged infringer." In this manner, the stage was set for NEC to argue technical constraint as the cause of any similarities between its microcode and Intel's, rather than use the merger doctrine as a "preemptive strike" against the copyrightability of microcode itself.

INTEL'S COPYRIGHT FORFEITURE

Judge Gray's ruling on the forfeiture by Intel of its microcode copyright serves as a cautionary tale to the industry and a further clarification of the Copyright Act. The act states that the failure to affix a notice of copyright on distributed copies of a work invalidates the copyright, unless the omission involves "no more than a relatively small number of copies." Otherwise, the copyright owner is expected to make a "reasonable effort" to add notices to all copies that have been distributed or to show that the notices were omitted "in violation of an express requirement in writing that . . . the . . . copies . . . bear the prescribed notice."

Intel has estimated that out of 28,000,000 copies of microcode distributed between May 1978 and May 1986, approximately 10.6 percent did not contain the required copyright notice. Judge Gray first of all noted that nearly 3,000,000 copies of anything, in an absolute sense, seem like more than a "relatively small number." Assuming that this interpretation is based on a relationship between the number of copies without proper notification and the total distributed, Judge Gray examined 20 federal court cases that had considered the same issue. He concluded that, regardless of the absolute numbers involved, none of these cases had considered 10.6 percent to be a "relatively small number."

Concerning Intel's subsequent efforts to correct the omission of copyright notice by its licensees, Judge Gray noted that, "There appears to be no precise authoritative definition as to what constitutes 'a reasonable' effort." More than seven pages of Judge Gray's decision are devoted to a consideration of Intel's efforts to monitor and enforce the affixing of copyright notices on its 8086/88 microprocessors, as well as the adequacy of those efforts. One of Judge Gray's remarks seems to summarize his assessment of Intel's follow-up: "I recognize that Intel's failure to include the requirement of copyright notice does not constitute abandonment of its copyright . . . (however) such an oversight certainly is relevant evidence that protection of its copyright was not high on Intel's list of priorities when the licenses were issued."

THE NONINFRINGEMENT BY NEC'S MICROCODE

Determining infringement in a copyright case boils down to two things: establishing that the accused infringer had "access" to the the original work, and showing that there is "substantial similarity" between the accused work and the original. In regard to the NEC/Intel case, access was a foregone conclusion because NEC had licenses to the 8086/88 microprocessors. The issue of "substantial similarity" was fought concerning about 50 lines of microcode that Intel claimed showed clear evidence of being copied.

Judge Gray stated an important "philosophical" position in approaching this issue. Quoting a UCLA law review article on copyright protection for computer programs, he declared that the court should "not allow the accused work to be dissected into pieces, and the pieces isolated, as if each stood alone." From this perspective, Judge Gray ruled that "the NEC microcode (Rev. 2), when considered as a whole, is not substantially similar to the Intel microcode within the meaning of the copyright laws."

Although this declaration would seem to end the argument, Judge Gray's judgment enumerates the key issues raised by Intel. These issues support the accusation of copying, citing an obligation voiced by a federal judge in another intellectual property case to "make a qualitative, not quantitative, judgment about the character of the work as a whole and the importance of the substantially similar portions of the work." It is to these considerations and their relationship to the final decision that the semiconductor industry should pay close attention, for they reveal much about the application of copyright to situations involving "technical constraint."

To fully appreciate the issues of "similarity" in the NEC/Intel suit, it helps to compare patent and copyright law. With its more rigorous standards of uniqueness and nonobviousness, patent law has no tolerance for similarity. Similarity, in fact, is tantamount to infringement. The intent of copyright, however, is to protect and encourage a multiplicity of expression. Similarity, particularly if it involves expressions related to a common idea, is not in itself proof of plagiarism. What matters is the degree of similarity, which obviously varies with the amount of constraint placed on one's choice of expression.

The crux of Intel's arguments concerning evidence of copying in NEC's microcode revolve around the contention that NEC could have created a microprocessor compatible with Intel's 8086/88 by using "different hardware, different architecture, different specifications, and a different microinstruction format." Thus, from Intel's point of view, because other options were available, any similarity would be the result of copying. To this argument, Judge Gray noted that, because Intel issued a license to NEC to duplicate the 8086/88 hardware, "Intel is in no position to challenge NEC's right to use the aspects of Intel's microcode that are mandated by such hardware."

Enter the "merger doctrine" as a litmus test of whether similarity implies infringement. Having acknowledged NEC's right to duplicate the 8086/88 hardware—not to mention the company's unfettered access to the macroinstruction set (never a matter of contention in the trial)—Judge Gray commented that "if . . . underlying ideas are capable of only a limited range of expression, they "may be protected only against virtually identical copying." He further noted, "NEC properly used the underlying ideas, without virtually identically copying their limited expression."

THE V20/30 ARE NOT "IMPROVEMENTS" ON THE uPD 8086/88

Given the significance of the above decision, the final point in Judge Gray's ruling seems somewhat anticlimactic. As one part of a multiperimeter defense, NEC noted that the license it acquired from Intel in 1983 authorized the copying of Intel's 8086/88 microcode in NEC's uPD 8086 and uPD 8088 microprocessors, as well as in "improvements thereon developed by NEC." NEC argued that, because its V20 and V30 devices were "improvements" upon the uPD 8086 and uPD 8088, they were therefore covered by its existing license from Intel. In reviewing the testimony of NEC's principal license negotiator, Judge Gray observed that NEC's officers never considered the V20 and V30 to be simply "improvements" over the 8088/86, and he concluded that "NEC's contention of 'improvement' was conceived after this litigation began, and it is rejected."

DATAQUEST CONCLUSIONS

In September 1986, Judge William Ingram made his initial decision on the copyrightability of microcode. Then, as now, much was made of the significance of this ruling. In a Research Bulletin written at the time, Dataquest noted the following points:

> "Any major victory celebrations are premature on the part of either Intel or the industry. While the court has decided that microcode does indeed fall within the domain of copyright law, just how effectively it can be protected is difficult to assess until Judge Ingram decides on the infringement issue.
>
> If the infringement criterion is rigidly interpreted to mean literal copying, successfully proving infringement will be very difficult for any copyright holder. With regard to the NEC/Intel trial, similarities between NEC's V-Series microcode and Intel's 8088/8086 code could be judged the result of 'functional constraint' rather than copying. In this case, NEC would very likely be found innocent of infringement."

In reaching his decision, Judge Gray appears to have labored hard to uphold the nature of copyright law in a case that tests its application in a very challenging way. The NEC/Intel trial has at last provided a means by which the industry can assess how the legal system will determine the copyright infringement of microcode. In the aftermath of his decision, however, the industry must now reflect on where it stands.

Michael J. Boss

Dataquest
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Research Newsletter

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RIDING THE MICROCOMMUNICATIONS WAVE: A CLOSER LOOK AT THE AT&T/INTEL AGREEMENT

SUMMARY

Alliances can be seen as concessions to market forces when, for example, companies enter second-source manufacturing relationships in the face of increasing demand or the need to penetrate new regions. Agreements can also create new market forces, as was seen in 1988 with the proliferation of RISC microprocessor agreements. In this sense, then, alliances can at times catch waves and at times create them. Sometimes, as in the case of the recently signed agreement between AT&T Microelectronics and Intel Corporation, they can attempt to do both.

AT&T Microelectronics and Intel have banded together under a five-year agreement to provide original equipment manufacturers (OEMs) with what the two companies have described as "the broadest array of products supporting ISDN (Integrated Services Digital Network) and LANs (Local Area Networks) available from a common source." The agreement will combine Intel's expertise in silicon and marketing with AT&T's understanding of the data transmission and communications market. In what AT&T describes as a "true alliance," the companies will second-source each other on an initial 10 components supporting twisted-pair Ethernet (TPE) LANs and ISDN, jointly develop future ISDN and LAN products, and work together to promote communications standards.

The keys to the ultimate success of this agreement have to do with the following:

- The types of products offered by the two companies and their impact on a market force that Intel refers to as "microcommunications"
- The efforts of AT&T and Intel to both influence and target developing industry standards
- The ability of the two partners to blend their respective strengths through this alliance

This newsletter describes each of these factors and evaluates the importance of this alliance to the strategic horizons of both AT&T Microelectronics and Intel.

TERMS OF ENDEARMENT

In reviewing the AT&T/Intel agreement, analysts in Dataquest's Semiconductor Industry Service (SIS) have noted the following:

- Product and technology exchange does not extend to joint process development. Future products will be created using design rules that have been "developed so that the products will run in both companies' fabs."

- No proprietary packaging technology is involved in the products affected by the agreement, so no packaging information will be exchanged.

- Both companies will sell each other's products through a "private label agreement" (purchase/resale program). No specific comments have been made by either company concerning royalty arrangements.

- The agreement establishes "definite trigger points" that will determine when the purchasing party may become a true second source (i.e., manufacturer) for the other's products. Neither company has disclosed the nature of these triggers.

- With the exception of two AT&T components that will be available late in the first quarter of 1989, the purchase and resale agreement covers products that currently are shipping. The first jointly developed products are not expected to appear this year.

THE PRODUCTS

The cross-reference guide for the 10 ICs to be jointly marketed by AT&T and Intel reveals 4 different LAN products and 6 ISDN products. In the LAN category, each company is contributing 2 existing devices. Intel is the originator of a 16-bit Ethernet LAN controller for high-performance applications (82586) and a CMOS 16-bit LAN controller, introduced in July 1988, which is aimed at lower-cost Ethernet applications (82592). AT&T will contribute a CMOS device that interfaces LAN controllers to twisted-pair Ethernet line drivers and receivers (T 7210) and a VLSI device designed for use in TPE repeater designs.

Among the ISDN devices to be exchanged, AT&T is the originator of 5 out of 6 components. These are a two-chip, 2B1Q (2 "B" channel, 1 "D" channel) "U" transceiver (T 7262/7263); two separate "S" transceiver components (T 7250A, T 7252A); and a single-channel HDLC with 64-byte FIFO register (T 7121). Intel's ISDN contribution is an "S/T" transceiver designed to connect between serial devices, microprocessors, and the ISDN "S/T" interface (29C53).

PROMOTING STANDARDS

AT&T and Intel are throwing their combined weight behind two industry standards that already have some impetus propelling them. In the LAN market, the two companies are supporting current efforts by the IEEE 802.3 committee to develop a new standard that will merge the low-cost benefits of StarLAN with the high-performance features of Ethernet. This new standard, referred to as 10BASE-T, will permit Ethernet data transmission at a rate of 10 Mbps over low-cost, unshielded twisted-pair wires (phone wires). Commonly called Twisted Pair Ethernet (TPE), 10BASE-T is based on the star topology popularized by StarLAN.

In ISDN, AT&T and Intel will support standards promulgated globally by the CCITT. The previously mentioned AT&T "U" interface chips, which will be sampled by the two companies in the second quarter of this year, are designed to meet the 2B1Q standard adopted by ANSI. In addition to participating in the development efforts of existing standards committees, AT&T and Intel also are working toward a common bus structure for all ISDN products (known as the Concentration Highway) and a common software platform that they hope will facilitate the creation of applications for, and by, component end users.

A SHARED VISION

Perhaps as important to the driving of the "microcommunications" market as is the joint product sharing of AT&T and Intel is their acknowledgment of a shared vision--a vision of the integration of the information age with the communications age. This vision calls for the participation of both companies in the continued transformation of communications technology--a transformation that had its beginnings with the digitization of the interoffice trunk lines in the late 1960s and has continued with the replacement of analog switches by digital switches. Now it focuses on the analog-to-digital conversion of the local loop, the link between user and network. It is this final phase of the transformation that is at the heart of ISDN. It is an evolutionary step for communications networks, but it is a revolutionary one for users from the standpoint of moving voice, data, and images through a standard interface and into a single network that already serves them.

Both companies concede that ISDN has not permeated the network as rapidly as initially projected and believe that the lack of network standards, the cost of equipment, and the lack of IC solutions have held back the expansion of ISDN. It is in the digitization of the local loop that AT&T and Intel hope to have a catalytic impact on the ISDN market, hence the significance of their joint offering of "U" interface products in compliance with developing ANSI standards. The companies see the acceptance of these components as laying the silicon foundation for cost-effective provision of basic rate ISDN service.

THE MARKET IMPACT

The AT&T/Intel agreement views the future of ISDN and LANs as being intertwined. As more ISDN lines are installed, greater pressure will be exerted to develop applications that exploit the digital capabilities of these lines. Growth of ISDN is likely to parallel the growth of LANs by networking the networks: linking a variety of equipment and functions together (via local area networks) and giving them a common communications interface. ISDN field tests have allowed companies to consolidate telephone voice services, computers, printers, facsimile machines, and other equipment on one network. As a result, network users get access to multiple computer systems, send facsimile, and share services like electronic directory, voice mail, and conference calling, to name a few.

With a 60 percent share of the LAN market in 1987, Ethernet's origins are in the technical and engineering environments. The high costs associated with the technology and the lack of perceived need for high-speed data transfer within the office environment initially worked against Ethernet applications in the general-business/ PC-oriented segment of the LAN market. Higher-performance microprocessors have changed that environment, driving the need to transfer data at higher-speeds and making a lower-cost Ethernet solution a quest that Intel has decided is well worth undertaking.

AT&T and Intel believe that the trend toward using Ethernet for PC networks could become a wave with the availability of 10-Mbps systems running on less costly twisted-pair cabling. Therefore, both companies are interested in shaping IEEE standards for TPE (10BASE-T) and in jointly developing leading-edge products that conform to those standards.

THE COMPANIES

AT&T Microelectronics: Toward the Merchant Market

The impact on the developing ISDN and LAN markets by two companies of AT&T's and Intel's significance cannot be overlooked as a factor favoring their success. As a communications systems company, AT&T's 1987 equipment revenue included approximately $3.7 billion in public network equipment, giving AT&T 50 percent of the U.S. market. AT&T's customer premises equipment, including LANs, accounted for approximately $2.6 billion in revenue, for a U.S. market share of 25 percent. In addition to its obvious strengths as a telecommunications powerhouse, AT&T has made a corporate commitment to become a more significant factor in the merchant semiconductor industry.

Located in Berkeley Heights, New Jersey, AT&T's chip-producing arm, AT&T Microelectronics, employs 18,900 people and achieved $1.9 billion in 1988 revenue. Dataquest estimates that the merchant portion of AT&T Microelectronics' semiconductor revenue has grown from 1 percent of sales in 1985 to 6 percent in 1987—a compound annual growth rate (CAGR) of 200 percent! Dataquest believes that AT&T Microelectronics' 1988 merchant semiconductor revenue will be in the $100 million range. The company has stated a goal of realizing 50 percent of its semiconductor revenue from merchant sales by 1993. Table 1 shows the company's semiconductor consumption and production for both its captive and merchant operations.

To achieve its goals of greater merchant participation, AT&T has taken several steps. To begin with, as Table 1 indicates, it has increasingly exposed its captive semiconductor operations to competition with merchant suppliers. In order to more closely parallel the decentralized P&L organizations of its competitors, AT&T Microelectronics recently reorganized its component operations into five strategic business units: MOS, lightwave, high-performance, power (such as transformers, power supplies, batteries), and interconnects. Finally, AT&T has pursued strategic agreements that have ranged from obtaining 32-bit microprocessor technology from Sun Microsystems to an alliance with Western Digital that encompasses technology transfer; design support; and fab, assembly, and test of semiconductors. Dataquest believes that AT&T has a goal of establishing partnership arrangements with a total of 25 to 50 OEM companies as a part of its merchant market strategy.

Table 1

AT&T's Estimated Semiconductor Consumption and Production by Captive and Merchant Operations

	1985		1986		1987		CAGR
Semiconductors	$M	%	$M	%	$M	%	1985-1987
Total Consumption	$1,405		$1,188		$1,224		(7%)
Captive Source	1,095	78%	968	81%	757	62%	(17%)
Merchant Source	310	22%	220	19%	467	38%	23%
Total Production	$1,100		$ 983		$ 802		(15%)
Captive Use	1,095	99%	968	98%	757	94%	(17%)
Merchant Sales	5	1%	15	2%	45	6%	200%

Source: Dataquest
March 1989

Intel: Not Just a One-Trick Pony

Intel is certainly no stranger to the communications market, nor is that market ultimately of less strategic importance to a company that has influenced today's data processing market as have few others. Among the significant events in Intel's history of "microcommunications" developments are the following:

- In 1977, Intel introduced the world's first commercially integrated codec chip.
- In 1980, Intel codeveloped Ethernet as a wiring standard for LANs.
- In 1982, Intel announced a high-performance coprocessor for Ethernet LAN control, the 82586.
- In 1984, Intel participated in the move to develop StarLAN as a low-cost PC network and developed the 82588 as a controller for StarLAN.

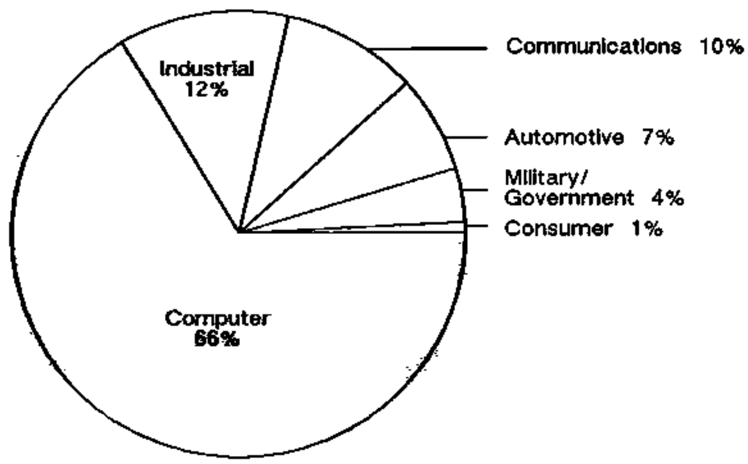
- In 1986, Intel announced its first ISDN chips, development tools, and software.

- In 1988, Intel announced its 82590 family of LAN products for the PC office environment.

Increasing its participation in the communications market is important for Intel if it is to maintain its current position in the pantheon of world-class semiconductor manufacturers. Its current ranking as the seventh largest semiconductor manufacturer in the world is largely owing to the success of its high-end, MS-DOS microprocessor products. As Figure 1 illustrates, Intel depends very heavily on its OEM sales to the computer market.

Figure 1

Intel's Percentage of OEM Sales by Market Segment



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Source: Dataquest March 1989

The past vagaries of the personal computer market aside, Intel cannot allow itself to depend so heavily on a market that is rapidly changing, both in terms of microprocessor platform standards and in terms of operating systems, as the worlds of *he microcomputer and minicomputer converge. Expanding its presence in the communications market, which currently accounts for 10 percent of its OEM sales, provides Intel with an avenue for strategic repositioning, just as when the company rolled out its embedded controller strategy in 1988.

DATAQUEST CONCLUSIONS

Both AT&T and Intel sense a level of critical mass in the microcommunications market. With ISDN standards developing for subscriber loops and the installed base of LANs growing from 333,000 nodes in 1983 to nearly 8 million in 1988, the two companies are looking for a synergy from their strategic alliance that will help them catch the wave. Furthermore, they are in a position to influence the wave's shape. A factor in exerting this influence, as both companies acknowledge, is the formation of strategic alliances between vendors of ISDN and LAN products.

AT&T and Intel are alone in this assessment. The maturing of the ISDN market is a phenomenon that will evolve over the next decade. In spite of its long-term nature, would-be participants must make investments in this market today. Sharing this investment, as well as areas of expertise, has been the impetus for earlier agreements such as the original Ethernet alliance between Xerox, Intel, and Digital Equipment Corporation, along with the Digital/Compaq and Digital/Apple Ethernet alliances.

More recently, systems and components suppliers have come together in such notable alliances as the AMD/Siemens ISDN product agreement and National Semiconductor's alliance with SGS-Thomson. While the above agreements definitely create significant spheres of influence in the European market, the positions held by AT&T and Intel in the U.S. market would seem to give the two companies a powerful domestic edge. In all cases, however, any participants in this market will have to be able to satisfy some deep pocket requirements in order to reap future market growth.

If the AT&T/Intel agreement succeeds in providing OEMs (and, ultimately, the users of telecommunications services) with the solutions that they need, the alliance will have accomplished much for the two companies. Intel will have gained a further inroad into a highly strategic market, while AT&T will have further ensured the invigoration of its merchant semiconductor operations, as well as served the proprietary needs of its systems businesses.

Michael J. Boss

Dataquest
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TRADE ISSUE DEBATED AT DATAQUEST CONFERENCE AS SUPER 301 APPROACHES

OVERVIEW

Super 301 is a provision of the 1988 Omnibus Trade Act passed by the U.S. Congress. According to this provision, the U.S. Trade Representative (USTR) must identify "priority countries" and "priority practices" that inhibit U.S. trade in world markets and then take actions against those countries and practices. The USTR must report on priority practices and countries by May 30, 1989. The Semiconductor Industry Association (SIA) has stated that Japan has not made any progress in opening its markets to foreign suppliers of semiconductor components in the last 10 years. The SIA believes that it is very likely that Japan will be placed on the Super 301 list.

Japan's Ministry of International Trade and Industry (MITI) counters the American claim with an assertion that foreign market share has increased since 1986. MITI further contends that continued low levels of foreign purchases reflect product mismatches, not trade barriers. On April 17, 1989, MITI assembled approximately 160 Japanese companies in Tokyo and instructed them to submit action plans concerning how they would increase semiconductor purchases from foreign suppliers. MITI also introduced an 11-point, step-by-step plan to solve the U.S. complaint of closed markets. Dataquest believes that both sides have a common goal to increase the use of foreign products in Japan; however, the methodology and the time frame for reaching the goal are where the two sides clash.

Both sides of the rapidly intensifying trade dispute between Japan and the United States were presented to a audience of some 350 semiconductor industry managers at Dataquest's Japanese Semiconductor Industry Conference held in Tokyo on April 20 and 21, 1989. Yukio Honda, director of the Industrial Electronics Division of MITI, presented MITI's 11-point plan for improving trade relations. Andrew Procassini, president of the SIA, presented his organization's view that the Japanese markets still remain essentially closed to foreign suppliers.

MITI'S PROPOSAL

MITI's 11-point proposal to encourage expansion of market access for foreign semiconductors as revealed at the Dataquest meeting is as follows:

- Point 1—MITI will encourage major semiconductor users, including Electronic Industry Association of Japan (EIAJ) user's committee members and Japan Auto Parts Industries Association (JAPIAS) members, to adopt market access plans. MITI also will encourage biannual updating of all market access programs and establishment of a special internal committee to increase procurement of products from foreign suppliers as part of their market access programs.

- Point 2—MITI will encourage expansion of efforts to design-in foreign semiconductors.

- Point 3—MITI will encourage automotive parts manufacturers to make qualification and test criteria available to foreign semiconductor suppliers from the early stage of new product development to expedite qualification of foreign semiconductors for current automotive electronics parts production and to commercialize existing joint R&D efforts between Japanese automotive electronics parts manufacturers and foreign semiconductor suppliers.

- Point 4—MITI will encourage Japanese high-definition television (HDTV) manufacturers to hold symposia and/or seminars to provide information about the development of the system and the market and to establish a contact window to facilitate foreign producers' access to the HDTV system producers.

- Point 5—MITI will encourage Japanese manufacturers of consumer electronics to do joint developments with foreign semiconductor suppliers, the objective of which is to increase the foreign semiconductor content in consumer electronics.

- Point 6—MITI will encourage ISDN (Integrated Services Digital Network) equipment makers to aim programs at design-ins of foreign semiconductors.

- Point 7—MITI will encourage Japanese users to make further efforts to expand their qualifications of foreign products.

- Point 8—MITI will encourage Japanese users to engage in long-term relationships with foreign suppliers.

- Point 9—MITI will encourage frequent and timely meetings between EIAJ members and foreign suppliers for the purpose of building relationships and solving problems.

- Point 10—MITI will encourage EIAJ members to hold seminars for foreign semiconductor suppliers to introduce their new products.

- Point 11—MITI will encourage foreign semiconductor suppliers and EIAJ member companies to develop and implement engineering exchange programs.

MITI'S ACTIONS

In order to enforce the proposed 11 points, Mr. Honda stated that MITI will take the following actions:

- MITI will encourage semiconductor user companies to make action plans and to update them biannually. MITI will follow up on their implementations.
- MITI will conduct periodic surveys regarding procurement of foreign semiconductors and will publicize the results in statistical form.
- MITI will survey, when appropriate, the implementation of design-ins and the establishment of long-term relationships.

Mr. Honda's presentation was followed by a spirited question-and-answer session. Surprisingly, all of the questions were from Japanese semiconductor company representatives; the considerable number of American and European representatives remained silent. Most responses were not questions but rather "minispeeches" that expressed the speaker's own view on the trade issue and MITI's approach. Mr. Honda stated that MITI could not make guarantees for the industry and stressed the fact that MITI could only encourage the enactment of the suggested 11 points, not having the power of absolute enforcement.

SIA'S POSITION

MITI's proposal was followed immediately by the presentation by Andrew Procassini, president of the Semiconductor Industry Association. Mr. Procassini quickly recognized Japan as having the world's strongest economy. He suggested, however, that Japan is not recognized as the world's financial leader, and he stressed that the financial leader of the world must be prepared to take on additional responsibilities. Sourcing R.T. Murphy in the March-April 1989 edition of Harvard Business Review, Mr. Procassini listed the following five essential characteristics of a world economic and financial leader:

- Maintains its currency as a store of value
- Allows its currency to function as a global reserve currency
- Acts as an international lender of "last resort"
- Ensures that its domestic and international financial institutions are sound and innovative
- Keeps the trading systems open even at domestic political cost

The United States was the world economic and financial leader for many years. However, with this leadership in question, much of the world is looking to Japan to assume the leadership. Mr. Procassini advised the audience that, in the view of the SIA, Japan at present cannot be counted on for assumption of world economic and financial leadership because of an "adversarial trade mentality." He then presented a series of statistical tables supporting his position.

According to Mr. Procassini, a measure of openness is the "import penetration ratio," which is the ratio of imports to consumption (see Table 1).

Table 1

Import Penetration Rates in All Manufacturing
(Imports as a Percentage of Consumption)

	Importing Country					
	United States		Germany		Japan	
Imports From	1975	1986	1975	1986	1975	1986
World	7.0	13.8	24.3	37.2	4.9	4.4
OECD Countries	4.9	9.3	20.5	30.6	2.9	2.6
Developing Countries	2.1	4.2	2.6	4.4	1.8	1.8

Source: ACTN Report

Mr. Procassini argues that, based upon these statistics, Japan's imports have declined since 1975 while the United States and Germany (a nation similar to Japan in the sense of having very few natural resources) have experienced increases of 197 percent and 153 percent, respectively, in their imports. In the total electronics marketplace, Mr. Procassini suggests that Japan's imports are not on par with the United States and Europe (see Table 2).

Table 2

Total 1987 Electronics
Production, Export, and Import Ratios

Regions	Production as % of World's Production	Exports as % of Region Production	Imports as % of Region Consumption
Europe	24	18	29
United States	38	20	21
Japan	26	36	6

Source: EIC
SIA

Finally, as illustrated by Table 3, Mr. Procassini compared selected segments of electronic production such as hard disk drives and personal computers. He stressed to the audience that, even though Japan is a minority market-share producer of these products, it nevertheless exports 57 percent and 55 percent, respectively, of its production and imports but 1 percent of its hard disk drives and 17 percent of its personal computers.

Table 3

Electronics—Selected Segments
1987
Production, Foreign Sales, and Foreign Penetration Ratios for U.S. and Japanese Producers and Consumers

	Producers				Consumers	
	Production as a % of World Production		Foreign Sales as a % of Production		Foreign Penetration as a % of Consumption	
Segment	U.S.	Japan	U.S.	Japan	U.S.	Japan
Hard Disks (5-1/4")	63	28	25	57	22	1
Personal Computers	69	18	25	55	13	17
Semiconductors	41	45	39	25	19	10

Source: SIA
Dataquest
May 1989

Mr. Procassini concluded by noting that the American semiconductor industry (SIA) and the Japanese semiconductor industry (EIAJ) are "working very hard" to improve the openness of the Japanese market, but that it was "not an easy task and extraordinary efforts" would be required on both sides.

DATAQUEST ANALYSIS

Taking the SIA's statistics at face value, it is understandable to conclude that Japan has made no progress in opening its semiconductor user markets to foreign suppliers. A fairly thorough sampling of the opinions of Japanese executives regarding the SIA talk produced the following comments:

- No one disputed the statistics presented or construed them to be presented for the purpose of "Japan bashing."

- Virtually all agreed that a problem existed in one degree or another and that Japan must improve its market access to foreigners.

- Many commented that Japan still cannot produce enough foodstuffs to feed its people from independent means. A strong export balance is one way to ensure that Japan will always be able to obtain essential agricultural products.

Dataquest believes that Japan is sincerely concerned about the trade issues. The major Japanese companies and MITI genuinely believe that they are taking the hard steps that will ultimately lead to markets more open to foreign suppliers of semiconductor components, and evidence indicates that this is true. Mr. Procassini praised the five largest Japanese semiconductor consumers for increasing their purchases of semiconductors to 17 percent of total supply from foreign suppliers. We note, however, that the other Japanese companies procure only about 7 to 8 percent of their semiconductor needs from foreign sources.

Nevertheless, key Japanese semiconductor leaders are sensitized to the need for open markets. NEC Electronic Devices executive, Dr. Tsugio Makimoto, stated that "Japanese managers are aware that they may be producing too much, that the share may be too big." He went on to say, "The Japanese industry should realize its important role in the worldwide industry, because a small erroneous decision could result in a serious problem in terms of international economic conflicts." Dataquest agrees. The semiconductor industry has become totally global in nature, with the Japanese being the memory suppliers and the Americans the microcomputer and microprocessor suppliers. The worldwide semiconductor industry will not achieve its intrinsic potential if the two largest participants continue their adversarial trade relationship. It is Dataquest's observation that the two sides are not in substantial disagreement as to the goal. Rather, the contest is over the methods of achieving the goal. The U.S. semiconductor producers have seen their market share eroded more each year and are drawing the line and demanding action now. The Japanese culture dictates change through a step-by-step, albeit slow, methodology. The matter is as much an issue of culture and fundamental approach to life as it is a world-class economic dispute. Japan and the United States must coexist on this planet, which, by virtue of the formidable technology the two nations have created, grows smaller each year. Much of the solution lies in achieving a mutual understanding of the basic differences between the countries and in making concessions to those differences that run deep on both sides. The Japanese have displayed a passion, rarely seen in prior history, for producing goods destined for export. Changing a national agenda so intrinsic to Japan's way of life simply will not occur overnight. On the other hand, the U.S. semiconductor industry executives who are insisting that Japan's markets be opened expeditiously and that Japan take upon the responsibilities commensurate to a world economic leader are of a superior fiber to those who watched with seeming disinterest as America's basic industries moved offshore. These individuals have a deep commitment to and a firm belief in the essentials of strong American participation in the global semiconductor industry. They are resolved in their determination to gain access to Japan's markets.

In Dataquest's opinion, both the MITI 11-point proposal and the EIAJ/SIA commitment to make the electronics marketplace a model for other key industries potentially represent the right solution to this most arduous problem.

David Angel

Dataquest

Conference Schedule

1989

Semiconductor User/ Semiconductor Application Markets	February 27–28	Le Meridien Hotel San Francisco, California
Japanese Components	April 20–21	Tokyo Bay Hilton International Tokyo, Japan
Computer Storage	April 26–28	The Doubletree Hotel Santa Clara, California
Document Processing	May 16–18	Monterey Sheraton Hotel Monterey, California
Copiers	May 16–17	
Printers	May 16–17	
Electronic Publishing	May 18	
Imaging Supplies	May 18	
Color	May 18	
SEMICON/West Seminar	May 24	The Dunfey Hotel San Mateo, California
Telecommunications	June 5–7	Silverado Country Club Napa, California
European Components	June 7–9	Park Hilton Munich, West Germany
Asian Semiconductor and Electronics Technology Seminar	June 28	Radisson Hotel San Jose, California
Financial Services	August 22–23	The Doubletree Hotel Santa Clara, California
Technical Computing and Applications	September 11–13	The Doubletree Hotel Santa Clara, California
European Copying and Duplicating	September 18–19	Majestic Hotel Cannes, France
Western European Printer	September 20–22	Majestic Hotel Cannes, France
Taiwan Conference	September 25–26	Grand Hotel Taipei, Taiwan
Distributed Processing	September 26–28	The Doubletree Hotel Santa Clara, California
SIA/Dataquest Joint Conference	September 27	Santa Clara Marriott Santa Clara, California
Information Systems	October 2–6	Tokyo American Club Tokyo, Japan
Semiconductor	October 16–18	Monterey Sheraton Hotel Monterey, California
Asian Semiconductor and Electronics Technology	November 2–3	Kunlun Hotel Beijing, China
European Telecommunications	November 8–10	Grand Hotel Paris, France
European Personal Computer	December 6–8	Athens, Greece

Dataquest

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May 16, 1989

Dear SIS Client:

Recently, you received a Semiconductor Industry Service newsletter entitled "Trade Issue Debated at Dataquest Conference as Super 301 Approaches." A quotation referenced to NEC Corporation appears on Page 6 of the newsletter. We incorrectly attributed the statement to Dr. Tsugio Makimoto. The statement was made by Mr. Tomihiro Matsumura, Executive Vice President of NEC Corporation. Dr. Makimoto is a representative of Hitachi, Ltd. Dataquest regrets this error and apologizes to both Mr. Matsumura and Dr. Makimoto.

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Research Newsletter

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1989: THE YEAR OF FORECASTING DANGEROUSLY

SUMMARY

The year 1989 will be a pivotal one for the semiconductor industry—a year that will test the roller coaster curve of industry cyclicality, and challenge or confirm its notorious volatility. If one were to adhere to a strict "past-as-prologue" interpretation of the industry's four-year swings in revenue, a recession would certainly be called for by 1990.

Dataquest's most recent semiconductor industry forecast does, in fact, call for negative quarterly growth for the worldwide market beginning in the third quarter of this year, and continuing through the first quarter of 1990. In the face of continued evidence of the industry's enduring vitality, however, even the mild slowdown predicted by Dataquest may seem unduly pessimistic.

Behind the recent headlines of record bookings and billings in the U.S. semiconductor market, however, the forces of the next recession are in evidence. These forces are:

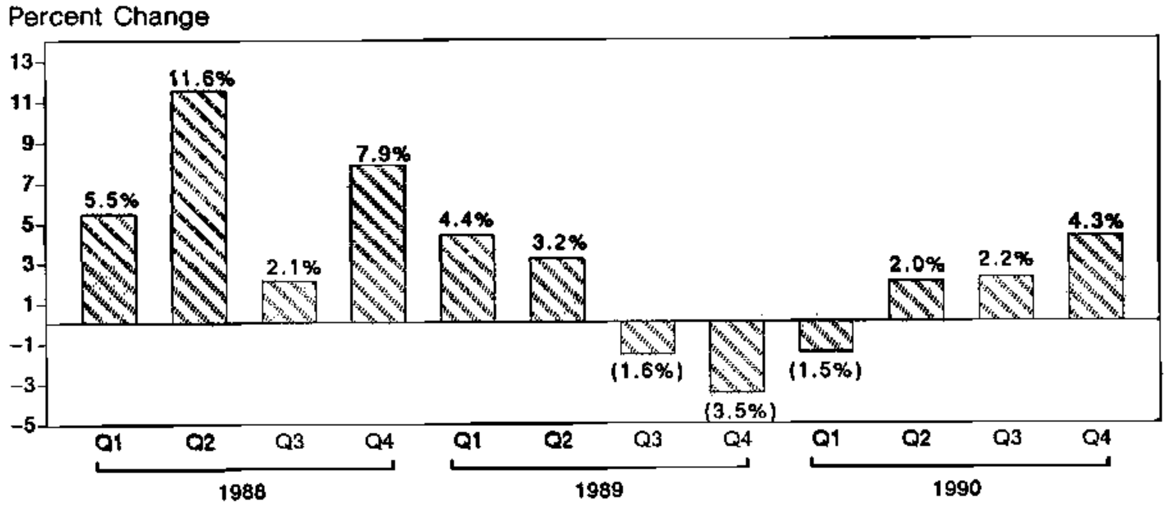
- Slower growth in electronics equipment markets, leading to lessened unit demand for semiconductors.
- The skewing of perceived industry growth caused by strong DRAM pricing.
- Tighter control of inventory by semiconductor end users as a result of a more cautious business outlook and a greater confidence in component availability.
- A decrease in the average selling prices (ASPs) for components, led primarily by lower DRAM pricing as supply surpasses demand later this year.
- The likelihood that macroeconomic influences will negatively affect electronics equipment shipments as the year progresses.

A LESS VOLATILE SEMICONDUCTOR INDUSTRY?

In seeming defiance of history, Dataquest has suggested that the semiconductor market is becoming less volatile, and that following a 15 percent rate of growth in 1989, worldwide negative growth of less than 1 percent will distinguish the industry's next recession in 1990, as shown in Figure 1. Compared with the last major downturn in 1985, during which worldwide revenue declined nearly 15 percent from the previous year, 1990 will be a mere catching of breath before the three years of successively higher double-digit growth that Dataquest has forecast from 1991 through 1993.

Figure 1

Worldwide Semiconductor Consumption
Quarter-to-Quarter Growth Rates
(Percent of Dollars)



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Source: Dataquest May 1989

POSITIVE SIGNS

Not long ago, a presentation of Dataquest's "bust-free" forecast to a group of financial clients was met with some scepticism—and, in fact, our assessment of first quarter 1989 shows a decided slowdown in the U.S. market from the final quarter of 1988. In spite of this, however, the industry is showing a stamina that may cause some to wonder if our present forecast is too conservative. Consider the following indicators:

- On a three-month average basis, semiconductor orders and shipments for the U.S. market reached an all-time industry high for the month of March. Orders booked grew nearly 18 percent over March of last year.

- The World Semiconductor Trade Statistics (WSTS) group noted in April that preliminary 1989 billings for the U.S. market are running 27.1 percent ahead of first quarter 1988, while bookings have grown 8.2 percent over the same period.

- On the whole, U.S. semiconductor companies are reporting positive sales and profits for first quarter 1989. Companies addressing higher margin segments of the memory and logic market, such as Chips & Technologies, Cypress Semiconductor, and LSI Logic, are seeing 60 to 70 percent increases in both revenue and net income compared to 1988.

- Analysts in Dataquest's offshore offices are reporting positive performance in their regional markets. January's "Flash Report" from Japan's Ministry of International Trade and Industry (MITI) showed that, although shipments to the Japanese market had declined approximately 6 percent from December 1988, they had grown 37 percent over December 1987. While production and consumption of semiconductors have been rising fairly steadily since 1987, inventory levels have been declining. The European market has posted several consecutive months of positive book-to-bill ratios, with the March figure at 1.07, and the Asian electronics market has been growing steadily because of the increasing availability of components that were in short supply last year.

In the face of so many signs of vitality, Dataquest's forecast of negative growth occurring in the third quarter of this year and continuing through the first quarter of 1990 may seem unduly pessimistic—particularly in light of the fact that we have forecast that U.S. market recovery in 1990 will lag other world regions by an extra quarter.

This dour outlook, however, is by no means unique to Dataquest. Even the historically optimistic WSTS has noted that "the future outlook for the market is clouded by recent weaknesses in orders from key end markets." Addressing a recent Texas Instruments' shareholders meeting, chairman, president, and CEO Jerry R. Junkins commented that, "The world semiconductor market increased 38 percent in 1988 with about half of this growth coming from unit price increases and movements in exchange rates. The industry growth rate is continuing to moderate from the unsustainably high levels of 1988, and is more closely aligning itself with the growth of end-equipment markets."

DRAMs: THE FORCE BEHIND THE GROWTH

In 1988, removal of MOS memory revenue from the industry's performance would have resulted in market growth of less than 22 percent, in contrast to the nearly 32 percent growth in dollars recorded by Dataquest. The "fulcrum factor" of memories in deciding the current swing of the market is apparent in the observations of Dataquest's most recent forecast newsletter, which showed that if MOS memories were excluded from first quarter revenues, worldwide industry growth would have been only 1 percent. Although we expect the dollar value of the 1989 MOS memory market to grow approximately 47 percent over last year, actual unit growth will be a more modest 10 percent. In this environment, the direction that pricing takes will have a major impact on the overall market. Although first quarter MOS memory pricing has so far stayed firm compared with fourth quarter 1988, Dataquest expects that by the third quarter prices will be much lower. This slowdown will result from lower unit demand, increased supply, and tighter inventory management.

LOWER DEMAND

According to our most recently analyzed Department of Commerce (DOC) data, shipments and bookings growth rates in the computer and office equipment market have flattened on an annualized basis, with February orders slowing to slightly more than 8.0 percent over the previous 12-month period. Quarterly figures, however, are more disturbing: for the three-month period ended February, DOC data shows shipments weakening to a 5.2 percent rate of growth over the same period last year, compared with an 8 percent growth rate noted in January. Quarterly bookings are running at only 2.8 percent ahead of last year, down from a 9.1 percent figure the month before.

The production of PCs still remains critical to the health of the U.S. semiconductor industry. The PC's role in sustaining the current industry expansion is easily realized when one considers that PCs alone account for approximately 11.0 percent of North American semiconductor consumption. Dataquest believes that unit shipments of PCs for the U.S. market will slow to 9.8 percent growth from last year's 13.0 percent annual growth rate. By contrast, unit shipments of PCs in 1987 exceeded those of the previous year by nearly 28 percent. Dataquest expects unit shipments of PCs to further slow in 1990 to less than 9.0 percent over 1989.

TIGHTER INVENTORY CONTROL

While the North American electronic equipment market as a whole decelerates from 8.5 percent growth in 1988 to less than 8.0 percent growth in 1989, availability of last year's shortage components is no longer perceived as a problem. At present, overall component lead times have declined to less than eight weeks for the first time since Dataquest began its monthly poll of original equipment manufacturer (OEM) procurement plans, with half of the companies surveyed noting no difficulty in obtaining semiconductors.

Increasing component availability has had a definite effect on the mentality of end users, who have on average lowered their target inventory levels for the past three months in a row. At the same time that target levels have declined, however, computer OEMs in particular have seen an increase in actual inventory levels. As a result, the difference between target and actual levels has risen to nearly 15 days from the less than 10-day difference noted in March's semiconductor procurement survey.

On the distribution side, the National Electronics Distributors Association (NEDA) reports a recent rebound in distributor orders following the inventory corrections of late 1988, and has forecast distribution business to grow 3 percent in 1989. In a recent market newsletter, however, the NEDA concluded that current order strength "is not enough to evidence aggressive inventory replenishment."

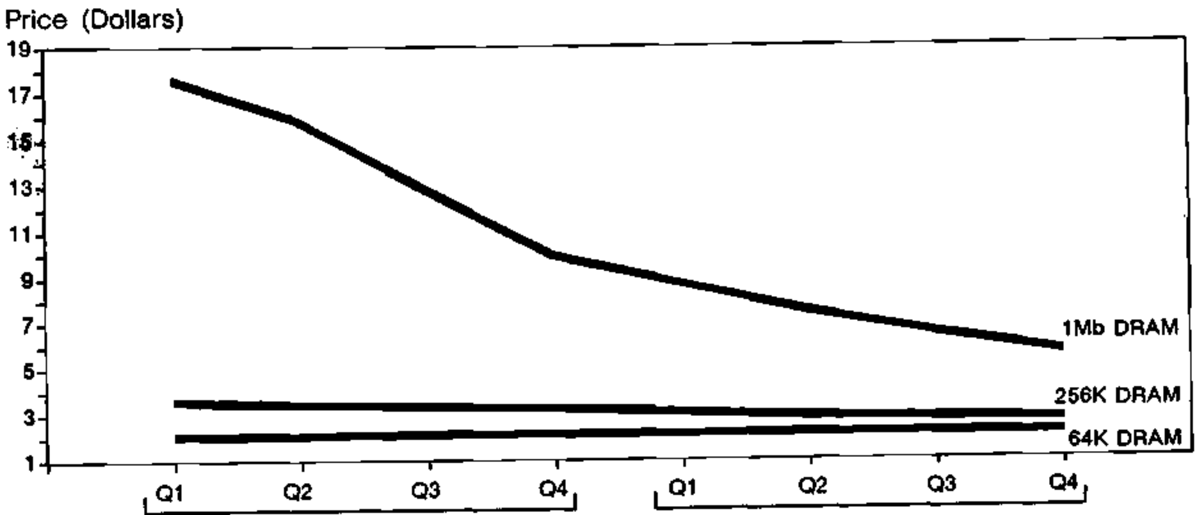
DECLINING ASPs

Analysts in Dataquest's Semiconductor Users Information Service group (SUIS) have noted that if one were to exclude those portions of inventory accounted for by memories and work-in-progress, there would be little difference between target and actual inventory levels. For the moment, then, the prescription for managing inventory is: curtail DRAM orders. This approach is bound to have a downward effect on both price and demand.

Looking ahead at DRAM unit pricing, Figure 2 illustrates the sharp decline that is anticipated for 1Mb DRAMs through the remainder of this year and 1990. From a current volume contract average of $16.75/unit in the U.S. ($14.59/unit in Japan), the cost of 1Mb DRAMs is expected to be at less than $7.00 by the end of 1990.

Figure 2

DRAM Price Trends



Source: Dataquest
May 1989

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The capacity allocated to the manufacturing of DRAMs has had a definite effect on pricing for other memory devices, most notably slow SRAMs, video RAMs, and x4 DRAMs. Suppliers of such devices have had little incentive to increase production at the expense of DRAMs given the volumes and pricing involved in DRAM manufacture. Slow SRAM lead times are expected to remain long and pricing firm during the second quarter of 1989. By the third quarter, however, users can expect an increase in the supply of slow 8Kx8 and 32Kx8 SRAMs.

Declines in ASP are by no means unique to the memory market. Based on procurement surveys by Dataquest's Semiconductor Users Information Service, the following pricing trends emerge in other component sectors:

- Standard logic prices, especially in the more mature product families, have declined since mid-1988 and are expected to continue declining through the first quarter of 1989, even though demand will remain steady because of the increased availability of DRAMs.

- Microprocessor price trends show a softening in the slower 8- and 16-bit devices as the personal computer markets show signs of a leveling of growth. The demand for high-end, 32-bit devices is becoming moderate, but prices remain firm and in line with projected 5-percent-per-quarter price declines. The acceptance of the Intel 80386SX, Motorola 68020, and 80286-16 have caused some price erosion in the 10- and 12-MHz 80286 market, as these new products compete for market share.

- In the ASIC market, gate arrays are declining both in terms of price per gate and nonrecurring engineering (NRE) costs, with the trend most apparent in the 1.5-micron segments. Dataquest notes greater price competition in the CMOS PLD market as well.

As 1989 progresses, lower order rates from end users should continue to cause a decline in both unit and ASP growth for semiconductors. A survey of average bookings by systems manufacturers in the United States has shown a glut of orders occurring in January of this year—perhaps nearly equal to the total of orders in the last quarter of 1988! Since then, each month has shown successive declines in the average, with April orders at a level about half that of January.

MACROECONOMIC INFLUENCES

At present, the semiconductor user mentality is probably as much affected by lessening lead times and price declines as by anticipation of slower business conditions. In an April market newsletter, NEDA noted that distribution inventory continues to be well-managed. Inventories, which peaked during the summer of 1988, have declined in four out of five months since September, and as of February had returned to first quarter 1988 levels. By the second half of this year, however, it is likely that general economic conditions will be the major factor behind dampened demand.

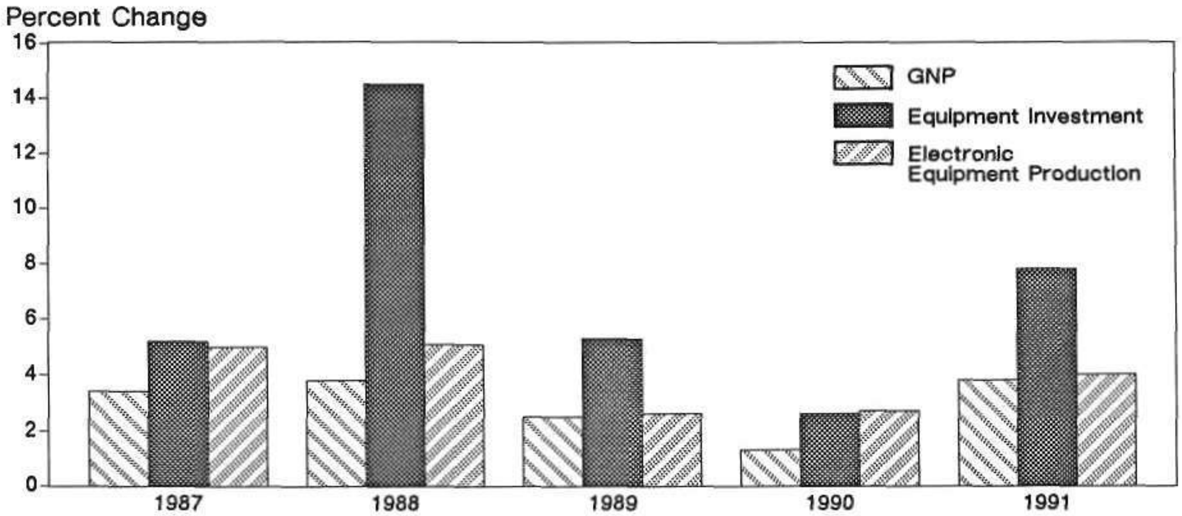
The U.S. economy grew 3.8 percent in terms of real GNP in 1988. Although economic growth was not as strong in 1988 as it was in 1987, real growth in equipment investment for the year was an impressive 14.5 percent compared with 5.2 percent in 1987. This growth in capital spending fueled an increase in 1988 North American electronic equipment production of 5.1 percent over 1987.

A combination of higher short-term interest rates, restrained government spending, and minimal improvement in the trade balance all point to slower economic growth and lower capital equipment spending in the year ahead. Figure 3 shows Dataquest's outlook for GNP, capital spending, and electronic equipment production, based on data from our parent company, Dun & Bradstreet.

Exports were a critical factor in 1988 economic growth. Nevertheless, export activity declined as the year progressed, with real exports at 17 percent annual growth in the first half of 1988, slowing to 11 percent in the second half, and falling to an 8 percent annualized growth rate in the final quarter. In March of this year a survey by the National Association of Purchasing Managers revealed that of the 69 percent of respondents that export, only 22 percent indicated export increases over the previous year. In the previous year's survey, 40 percent of the companies surveyed saw increased exports. While this may be good news on the inflation front, with near-record capacity utilization and low unemployment threatening further interest rate increases by the Federal Reserve Bank, it nonetheless spells lower industrial output and capital investment.

Figure 3

Economic Outlook—Real Growth
Percentage Change 1987–1991



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Source: Dataquest May 1989

NO CLIFF IN SIGHT

The latest Blue Chip Economic Indicator survey of 54 economists reveals that only 35 percent expect a recession this year, with 30 percent predicting one in 1990, and another 30 percent in 1991. An impressive 80 percent of the economists surveyed, however, believe that whenever the recession does hit, it will not be severe. The Blue Chip Economic Indicator forecast for industrial output growth is a modest 1.7 percent for 1989, with business investment up 1.8 percent.

The good news for the electronics industry, however, is that nearly 50 percent of equipment investment will be for information processing equipment. This outlook is consistent with Dataquest's expectation that the data processing industry will set the pace among the semiconductor application markets with 11.3 percent growth this year—a modest slowdown from the 13.4 percent growth rate achieved by this market in 1988.

Within the semiconductor industry itself, a number of signs indicate that the impending slowdown will not turn into a crashing halt:

- In the distribution business, the average industry inventory turnover rate has improved to nearly 4X—the best rate NEDA has recorded since it began keeping monthly statistics in 1986.
- End-user control of semiconductor inventories promises to soften the transition to slower electronics equipment growth for semiconductor suppliers.
- Industry constraint in capital spending has not led to a situation of overcapacity such as was experienced in 1985 and 1986.

- So far Dataquest does not see any price-cutting catalyst that would drastically affect MOS memories. As Mr. Junkins of Texas Instruments recently expressed it, "Because of the high cost of investment, and the increasing complexity of each new generation of products, there are fewer companies with the resources to participate in the DRAM market. Therefore, we expect price reductions to be more moderate than in the past, with the industry taking into account the need for profitability to sustain investments for the future, as well as passing along cost reductions."

DATAQUEST CONCLUSIONS

The recent spate of positive indicators for the semiconductor industry should be tempered by the knowledge that the industry has a history of comparatively strong second quarters. Dataquest's overall outlook for slower end-equipment growth calls for weakening demand, and more carefully managed inventories. Given the recent impact that memory ASPs have had on industry growth, Dataquest expects their resulting decline to contribute to negative quarterly growth in the latter part of this year. Should the U.S. economy perform more vigorously than our 2.5 percent GNP assumption suggests, of course, the industry could see a higher-than-predicted demand.

Mr. Junkins' remarks on the changed climate of DRAM manufacturing touches on a wild-card factor in the Dataquest forecast: with the regional dominance that now exists in the semiconductor memory business, the action of market forces may no longer play as significant a role in determining the trajectory of ASP declines. The extent to which this new reality is a factor in 1989 may have profound implications for memory manufacturers, end users, and, perhaps, for the future direction of U.S. trade policy.

Michael J. Boss

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Research Bulletin

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ACER AND TI "PUT THE EYES ON THE DRAGON"

In a traditional Chinese ceremony, Acer Incorporated of Taiwan and Texas Instruments (TI) affixed two 4Mb DRAM chips to the eyes of a mock dragon, symbolizing the creation of a jointly owned memory manufacturing plant that will produce 1Mb and 4Mb DRAMs in Taiwan. Aside from its ritual significance, the ceremony, which included the presentation of a 4Mb DRAM wafer slice to Taiwan's president Lee Deng Huei, proved a fitting allegory for his country's DRAM market in 1988. In the face of last year's memory shortages, Taiwan's electronics industry "dragon" was indeed running blind: Dataquest believes that DRAM shortages in 1988 were responsible for a 25 percent reduction in Taiwanese PC shipments.

With as much as one-half of the production from the Acer/TI joint fab available to satisfy Acer's internal requirements, the decision to expand capacity in Taiwan underscores the growing demand from the Pacific Rim for MOS memory devices. Figure 1 shows the incredible growth in consumption of MOS memories forecast by Dataquest for the Rest of World (ROW) segment (largely Asia/Pacific) as the newly industrialized countries of Asia increase their production of electronic equipment.

The agreement between Acer and TI will create Texas Instruments-Acer Semiconductor Ltd., a jointly owned wafer manufacturing plant. Construction of the facility, which will be located in the Hsinchu Science Park development just outside of Taipei, Taiwan, is scheduled to begin in September of this year, with initial wafer production expected in mid-1991. Details of the agreement, as released by Acer and TI, are as follows:

- Acer will hold a 74 percent equity position in the joint venture, with TI owning 26 percent. TI's share could, however, be increased to 51 percent within five years.

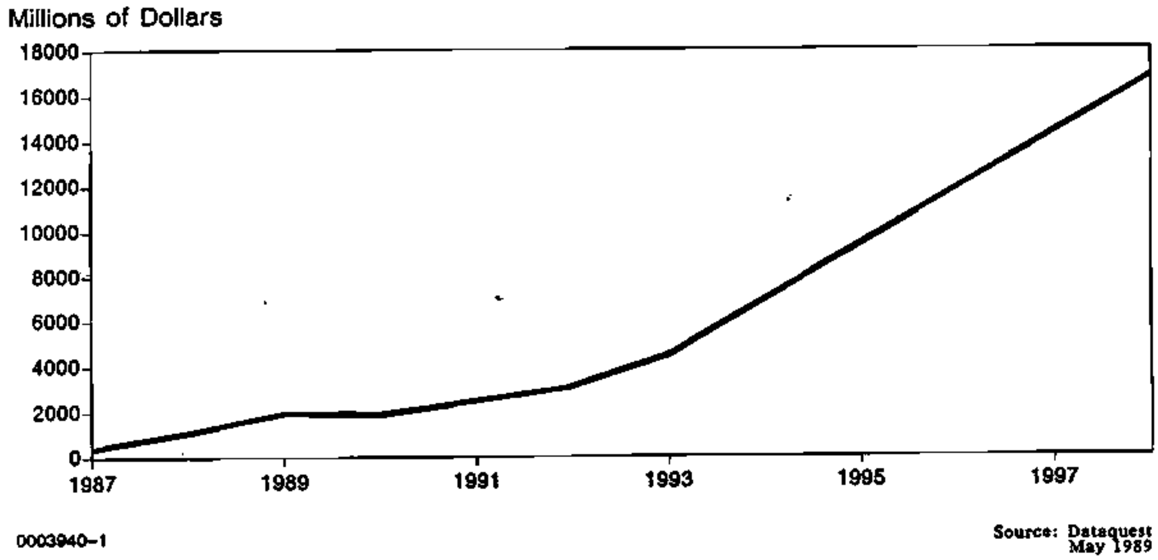
- The cost of the facility is estimated at $250 million to $300 million, with Acer providing most of the required cash.

- TI will provide the joint venture with its 1Mb and 4Mb submicron CMOS technology. The process will be run using 6-inch wafers, with shipment of qualifying samples available as early as the fourth quarter of 1990.

- All production will be sold to TI. Acer will have the option to obtain up to 50 percent of the plant's total output.

Figure 1

Estimated MOS Memory Consumption by ROW Countries



Collaborations between Acer and TI are nothing new. In November 1987, for example, the two companies signed an agreement under which TI's Instruments Data Systems Group in Austin, Texas, would manufacture, assemble, and test all Acer PC AT-compatible computers for distribution in the United States and Canada.

This latest venture with Acer provides TI with its first memory production capacity in the Asia/Pacific region, outside of Japan. With the addition of a plant now under construction in Averzano, Italy, TI's MOS memory fabrication capabilities now will encompass the four major world markets of Asia, Europe, Japan, and the United States. The joint venture with Acer allows TI to expand its memory production capability into the Pacific Rim while limiting the financial burden of this investment. For Acer's part, the joint venture offers an assured source of DRAMs for its personal computer, peripherals, and communications products. As the largest computer company in Taiwan, Acer's consolidated annual sales in 1988 exceeded $500 million.

In addition to DRAMs, TI has stated that its Taiwan plant may eventually manufacture ASICs, and that the facility will incorporate TI's "living fab" philosophy. The plant will be constructed and equipped so that it can produce advanced logic and other integrated circuits in the future.

While the agreement between Acer and TI points to the future, it also marks the 20-year anniversary of TI's presence in the Taiwanese market. As pointed out by the president of TI's Semiconductor Group, Pat Weber, "This dragon eye ceremony is important . . . as a symbol of the beginning of our next 20 years."

Michael J. Boss

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Research Newsletter

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TAIWAN'S AMAZING SCIENCE-BASED INDUSTRIAL PARK

OVERVIEW

According to the Stanford Research Institute, Taiwan has required only 30 years to achieve an economic success comparable with what it took the West 100 years to establish. Agriculture, which contributed 29 percent of Taiwan's GNP in 1960, has been taken over by manufacturing. Today, much of that manufacturing is in the high-technology sector. The Science-Based Industrial Park (SIP), located in Hsinchu, is the Republic of China's high-tech center. Founded in 1980, the SIP had grown to almost 100 companies by the end of 1988, with revenue approaching US$2 billion. Approximately 60 of the SIP companies are locally owned, and of the 40 that are foreign based, 75 percent are U.S. companies. Computer manufacturing represents the majority of the SIP activity; however, production of integrated circuits is the fastest-growing business. Dataquest believes that Taiwan's IC industry is rapidly approaching a capability wherein it is positioned to be a major factor in the worldwide semiconductor industry.

CREATION OF THE SIP

In 1980, the Republic of China (ROC) made a decision to embark upon a course of high technology by establishing an industrial park devoted entirely to high-technology industries. The SIP is the result of this visionary commitment to high technology in Taiwan. By fostering investment and development in high-profile industries, the ROC believes that it will be able to upgrade its industrial structure and stay competitive in the constantly changing worldwide economic environment.

Among the driving elements for the creation of the SIP were:

- The need to establish an infrastructure for creating and attracting high value-added industries in the private sector to Taiwan

- A desire to provide a vehicle that would offer attractive, rewarding employment to expatriates who went abroad for education but wished to return home

- A plan to establish state-of-the-art research and development capabilities by recruiting top-level personnel in the areas of science and technology

- The need to solve common technical problems for local industry, improve the standard of living, and increase industrial productivity

The Science-Based Industrial Park is located in Hsinchu, a rapidly growing city about 50 miles southwest of Taipei. The master plan for the SIP anticipated essentially all future needs. As a result, the SIP currently includes approximately 750 acres (300 hectares) of developed land including industrial, research, manufacturing, and utility zones, as well as residential and educational areas. Single-family dwellings, duplexes, apartments, and dormitory-style accommodations are available. Modern 1,500-square-foot townhouses rent for US$300 a month, apartment rentals range from US$100 to US$250, and dorms rent for less than US$50 per month. The SIP will eventually occupy 5,200 acres (2,100 hectares). One of the distinctive advantages of the Hsinchu location is the number of educational facilities nearby. These include the National Tsinghua University, the National Chiaotung University, and the Industrial Technology Research Institute (ITRI).

FACILITIES, COSTS, AND CAPITAL

Ready-built, multipurpose factory sites are available for companies (start-up or established) that wish to expedite their operations. The rental rate for standard 5,500- to 6,000-square-foot buildings is US$0.19 per square foot per month. Construction cost for new, custom-designed buildings is around US$25 per square foot. Building and land taxes are included in the rental fees or paid by the SIP for custom-built facilities; however, an administration fee of 0.25 percent of annual sales is paid to SIP Administration for management services. Taiwan has a rapidly growing venture capital and investment community that maintains a favorable attitude toward new ventures that are considering operations in the SIP. These investors include the China Development Corporation, ITRI, Multiventure Investment, Inc., Taiwan Cement Corp, Ching Fong Investment Co., China Securities, Kwang Hua Securities, and Hambrecht & Quist (H&Q) Taiwan. Government sources include the Development Fund of the Executive Yuan and the Bank of Communication. Assistance to new entities includes:

- Tax holidays; duty-free import of critical equipment, raw materials, and semifinished goods; and exemption from commodity and business taxes for exported goods

- Government joint venture options (up to 49 percent of the total paid-in capital)

- Low interest (currently 5.25 percent) and R&D matching funds

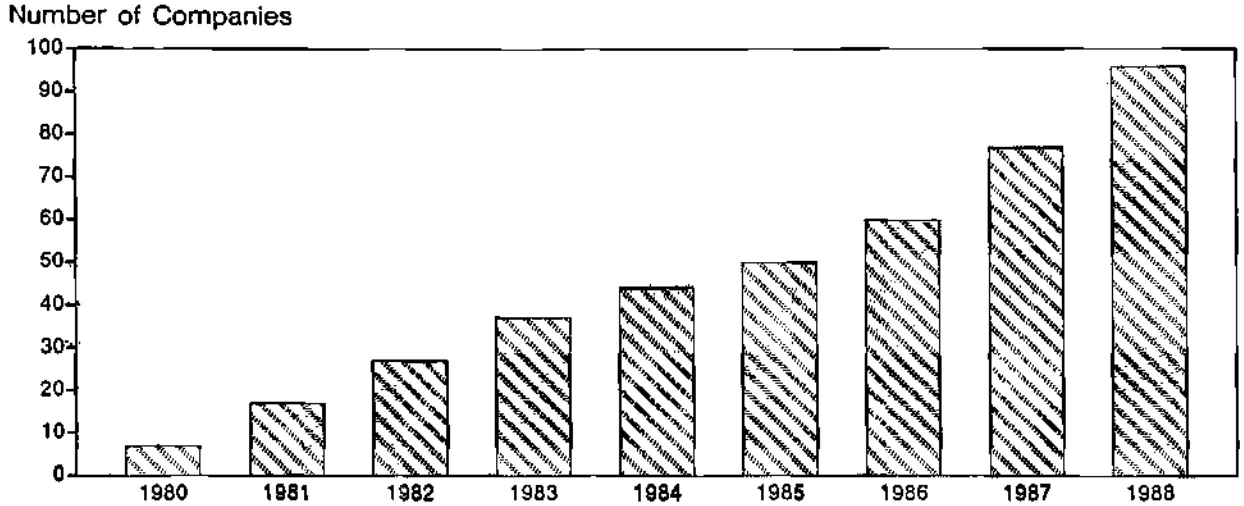
- Technology in trade for equity

SUCCESS AS MEASURED BY THE RESULTS

By virtually any measure, the SIP appears to have achieved a success beyond that realized by any other regional effort. Commencing with 7 companies in 1980, the SIP had grown steadily to 96 companies at the end of 1988. The growth during this period is shown graphically in Figure 1.

Figure 1

Growth in Number of Companies
Hsinchu Science-Based Industrial Park



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Source: SIP
Dataquest
June 1989

Business Types

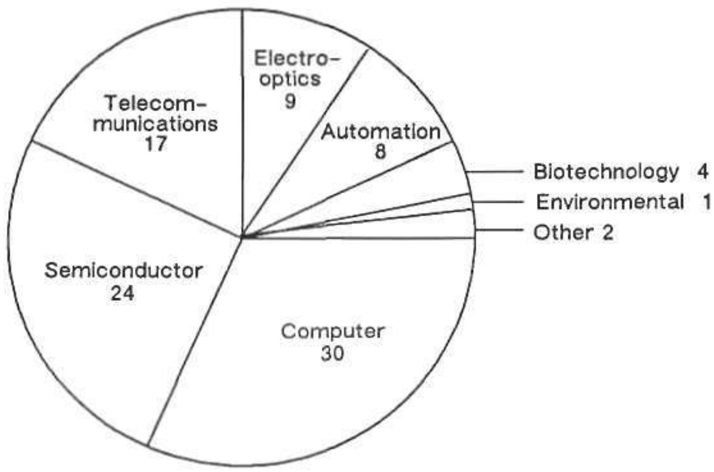
Computers, semiconductors, and telecommunications represent approximately 75 percent of the 96 companies currently in business in the SIP. As indicated in Figure 2, however, there is a reasonable representation of other technologies, including biotechnology, automation, environmental, and optical.

Employment

A central purpose of the regional technology parks based throughout the world is to create employment. SIP's achievement in this area is noteworthy. Starting from a base of 1,200 employees in 1982, employment in the park had grown to more than 16,000 by the end of 1988, a compound annual growth rate (CAGR) of approximately 55 percent (see Figure 3).

Figure 2

SIP Types of Companies by Technology



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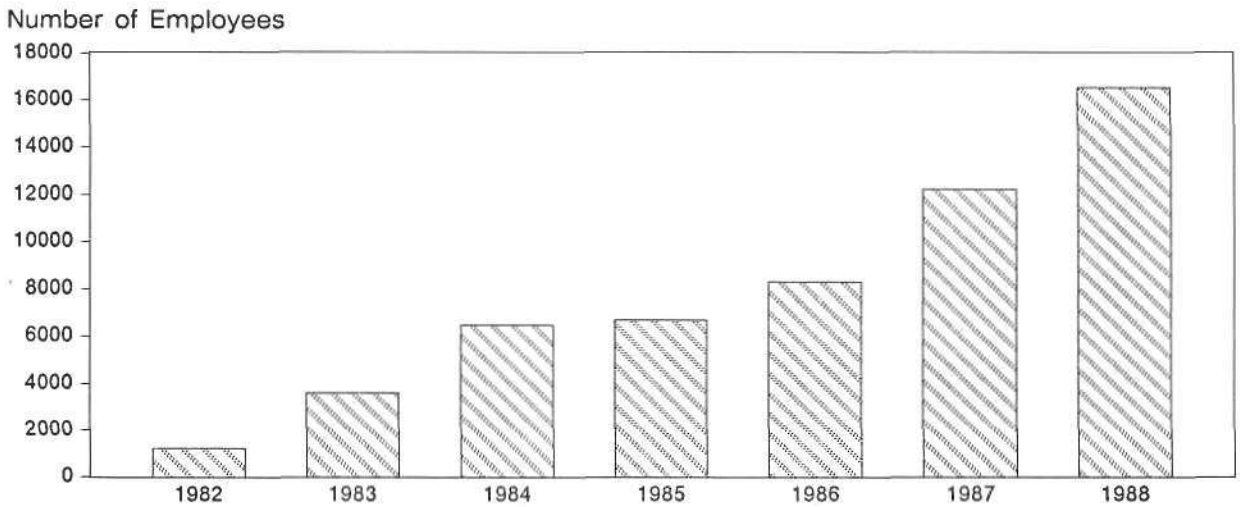
Source: SIP
Dataquest
June 1989

Figure 3

Growth in Number of Employees
Hsinchu Science-Based Industrial Park



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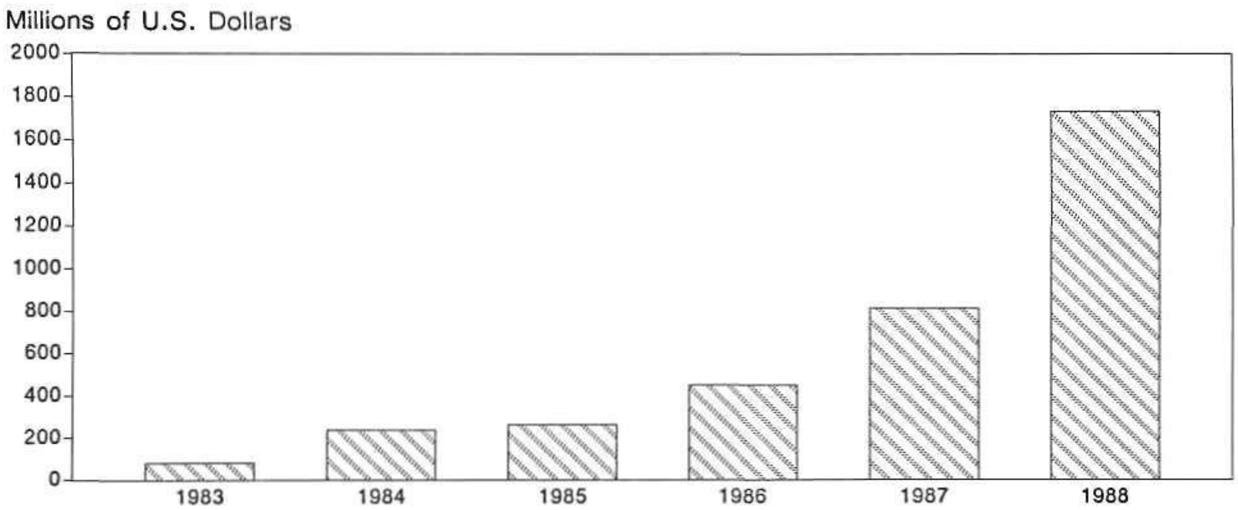
Source: SIP
Dataquest
June 1989

Revenue

The most critical measurement parameter of a regional endeavor such as SIP is its commercial success. Technology acquisition, employment, and a local supply of essential products are all important elements. However, to be competitive on a worldwide basis, the venture must demonstrate its ability to compete on an economic standard. Sales of products produced in the Taiwan's Science-Based Industrial Park have grown from approximately US$82 million in 1983 to more than US$1.7 billion in 1988 (see Figure 4). This is an astounding 85 percent CAGR for the period from 1983 through 1988.

Figure 4

Sales of SIP Companies
1983–1988



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Source: SIP
Dataquest
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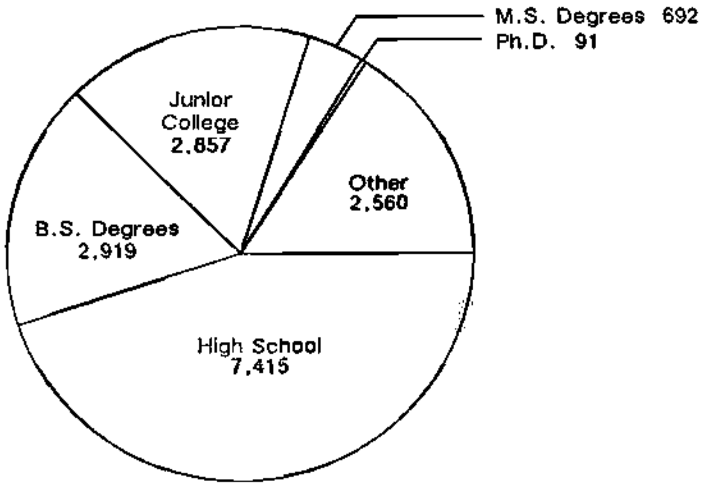
Education

Taiwan is a nation of limited natural resources that might logically be associated with a relatively small island. However, the ROC possesses great strength in the form of its people. Family oriented and hard working, the Taiwanese revere education. This fact is borne out by the SIP employees' educational backgrounds. Approximately 85 percent of the employees working in the SIP have at least high school educations, while nearly 40 percent have junior college or greater educations. Figure 5 provides a breakdown of the educational levels achieved by SIP employees.

Figure 5

Distribution of SIP Employees' Educational Background



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Source: SIP
Dataquest
June 1989

THE SIP SEMICONDUCTOR INDUSTRY

The fastest-growing segment of the SIP appears to be its semiconductor industry. Using the Electronics Research and Service Organization (ERSO) division of ITRI as a nucleus, there are currently six major semiconductor companies operating in the park. The recent announcement of the Acer/Texas Instruments joint venture will create a seventh major entity by the end of 1990. The partnership will occupy 15 acres of land in the SIP and expects to ship sample quantities of DRAMs in the fourth quarter of 1990. All of the six operating companies have construction under way or have plans for major wafer fabrication capacity expansion in 1989 and/or 1990. Dataquest believes that the ROC will consume approximately US$4 billion of MOS memories in 1993 and more than US$16 billion by 1997. Virtually all of the semiconductor companies in the SIP are moving quickly to incorporate SRAMs, EPROMs, and other MOS memory devices into their product portfolios.

DATAQUEST ANALYSIS

In a few short years, the Hsinchu Science-Based Industrial Park has been able to establish the ROC as a world-class player in the electronic equipment industry. In five years, SIP company revenue has grown to nearly US$ 2 billion. By way of comparison, it took the Japanese semiconductor industry ten years to increase revenue from approximately US$100 million to US$1.7 billion.

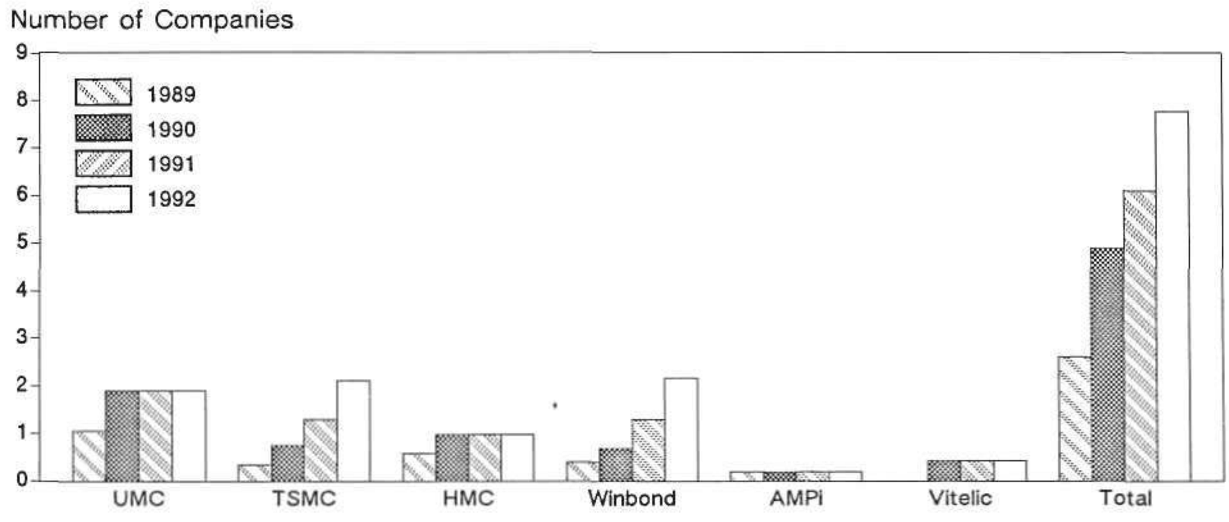
Dataquest believes that in the next few years, the SIP semiconductor industry will emerge as the leading growth and revenue entity in the park. All six of the semiconductor companies in the park are currently operating at full capacity. All are planning or are in the process of completing significant capacity expansions.

Dataquest has an extensive data base that closely correlates square inches of silicon started (not including test wafers) to revenue produced throughout the worldwide semiconductor industry. In 1988, these data were $48 per square inch of silicon fabricated for U.S. IC producers, $40 for Japanese producers, $36 for European producers, and $22 for ROW producers. Dataquest believes that given the recent increase in product value added, the revenue produced per square inch of silicon started in the SIP in the 1989 to 1992 time frame will be in the $25 to $30 range.

On this basis, an estimate of the revenue potential of the SIP IC companies can be calculated. Figure 6 compares the silicon start capacity in millions of square inches per month of the six major IC companies in the SIP on the basis of installed and forecast capacity for the years 1989, 1990, 1991, and 1992. (An apparent leveling of capacity by some companies simply reflects that that company did not provide a firm forecast for capacity expansion beyond the year(s) in which leveling occurs.)

Figure 6

SIP Wafer Start Capacity
(Millions of Square Inches per Month)



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Source: SIP

In 1989, the six companies have a potential annual revenue of approximately US$772 million on the basis of the installed capacity. This figure rises to US$1.6 billion in 1990, US$2.2 billion in 1991, and US$3.1 billion in 1992. Table 1 shows Dataquest's forecast for the total value of semiconductors produced in the ROW for the period 1989 to 1992.

Table 1

Estimated Value of ROW-Produced Semiconductors
(Billions of U.S. Dollars)

	1989	1990	1991	1992
Value	$5.8	$7.3	$8.6	$8.9

Source: Dataquest
June 1989

Considering all of the above information, we suggest that the companies in the SIP are at least positioned, on the basis of installed capacity, to capture 13 to 35 percent of the forecast ROW semiconductor production during the period from 1989 to 1992. This simple analysis does not take into account the value of the products produced from the Acer/TI partnership, nor does it assume that capacity beyond that forecast will be added during the subject period. Hence, the model is conservative and may further understate the significant capability that is now forming in the SIP.

A conclusion that one can draw is that Taiwan's semiconductor industry is rapidly becoming a world-class player. With submicron technology and large-volume capacity virtually in place by the end of 1989, combined with product offerings that include SRAMs, EPROMs, and soon DRAMs, Dataquest believes that the SIP-based IC suppliers will soon begin to compete aggressively in the Pacific Rim. The SIP administration seems to agree with the potential of the SIP IC industry. On May 18, 1989, the Hsinchu Science-Based Industrial Park announced that it has decided to offer integrated circuits producers first priority on the remaining land in the park.

David Angel

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Research Newsletter

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INTERNATIONAL SEMICONDUCTOR TRADE ISSUES—DOMINANCE, DEPENDENCE, AND FUTURE STRATEGIES

OVERVIEW

Trade issues have been a major concern throughout the world thus far in 1989. The Japanese semiconductor manufacturers have achieved dominance of the worldwide DRAM market, while U.S. manufacturers still hold a comfortable lead in high-end microprocessors. The European semiconductor producers, particularly in view of the forthcoming 1992 combined-market scenario, have pledged that they will be in a position to supply Europe's semiconductor needs. Finally, substantial growth is being seen throughout the Asia/Pacific region as Taiwan, Korea, and Singapore rapidly expand their semiconductor production base.

Dataquest forecasts a global semiconductor industry taking shape by the mid-1990s, with a more balanced distribution of products and technologies than we witnessed in the 1970s and 1980s. However, with the trade press burgeoning with weekly—if not daily—statistics regarding export balances, threats of protectionism, and national agendas for critical electronic components, it is difficult to sort out the true current situation in the worldwide market. Dataquest has taken an alternate perspective on current worldwide production/consumption of semiconductor components and has classified each region as to whether it consumes more ICs than it produces or has a sufficiency for export after satisfying domestic needs. This net difference for each region, presented by major product category, is a measure of the self-sufficiency profile for each region. By understanding the net consumer or net producer profile of each region, we can anticipate strategic moves that the IC producers in these regions may make in the international marketplace.

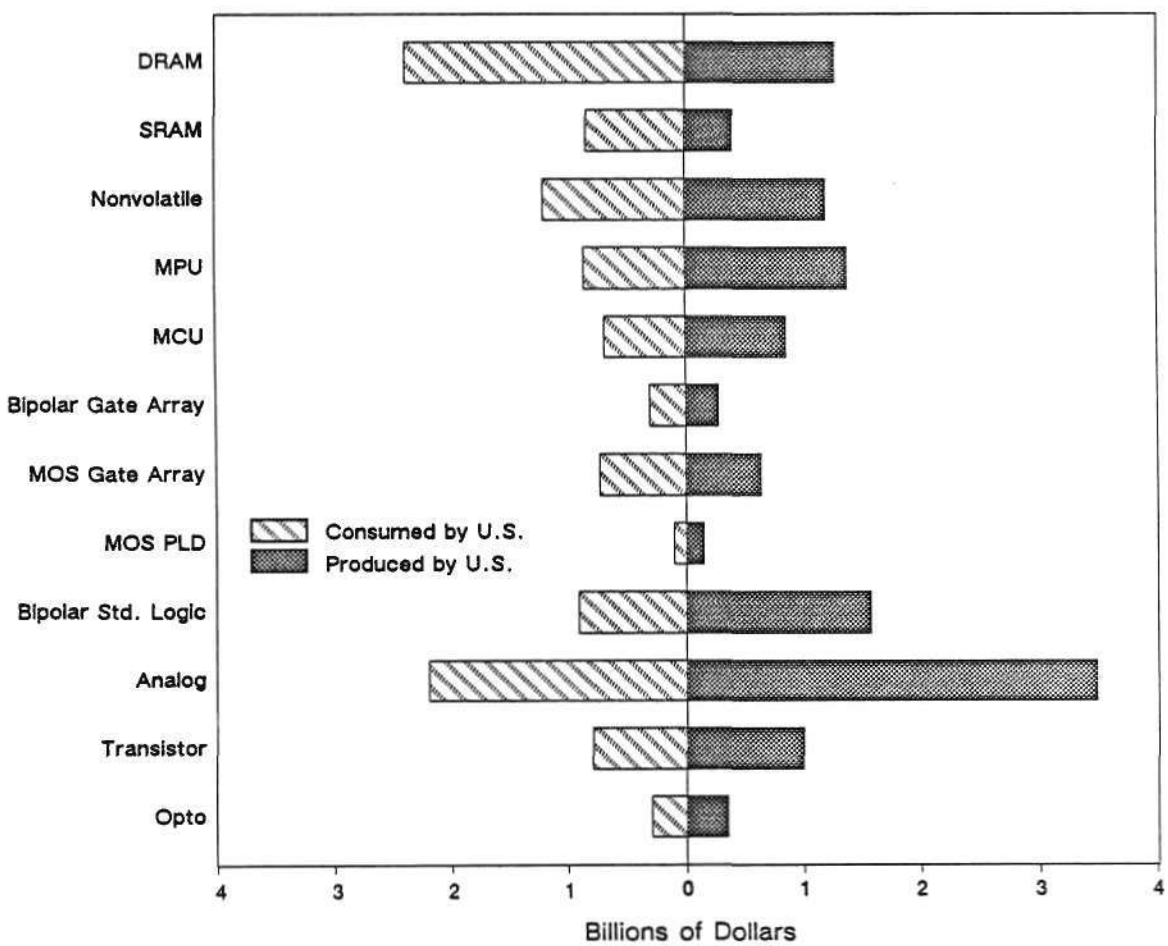
PROFILES BY REGION

U.S. Companies

We begin our analysis of worldwide production and consumption of ICs with a look at the U.S. semiconductor consumption/production profile. Figure 1 illustrates that the United States has a relatively symmetrical consumption/production profile, except for DRAMs and analog ICs. Figure 2 presents a better picture of the United States' position as a net consumer or net producer of ICs. From it, we can see that the United States is a net producer of both microprocessors and microcontrollers of bipolar standard logic, analog ICs, and discrete transistors. However, as expected, the United States also is a net consumer of DRAMs, a net consumer of SRAMs, and, surprisingly, a net consumer of both bipolar and MOS gate arrays.

Figure 1

Semiconductor Consumption/Production Profile
United States



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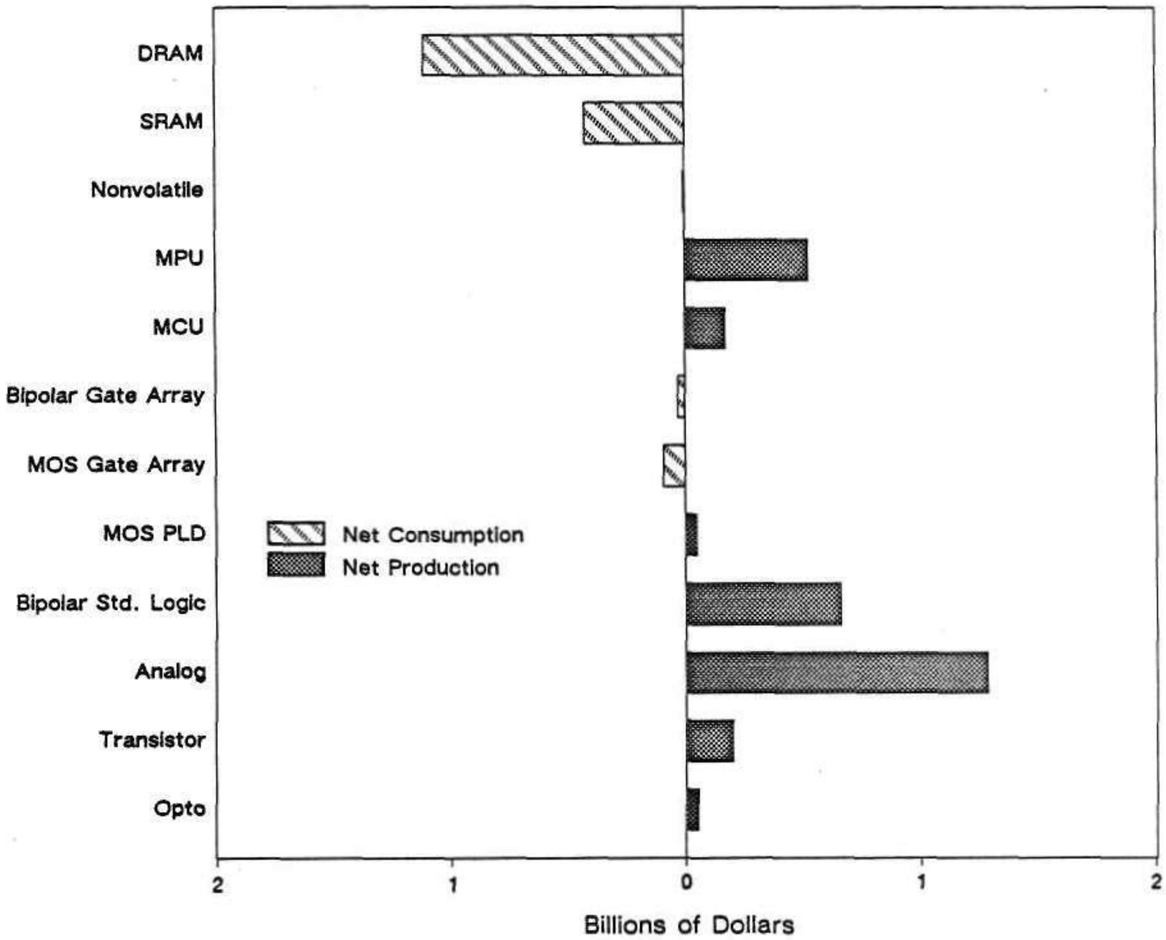
Source: Dataquest
June 1989

Figure 2

Difference between Semiconductor Consumption and Production
United States



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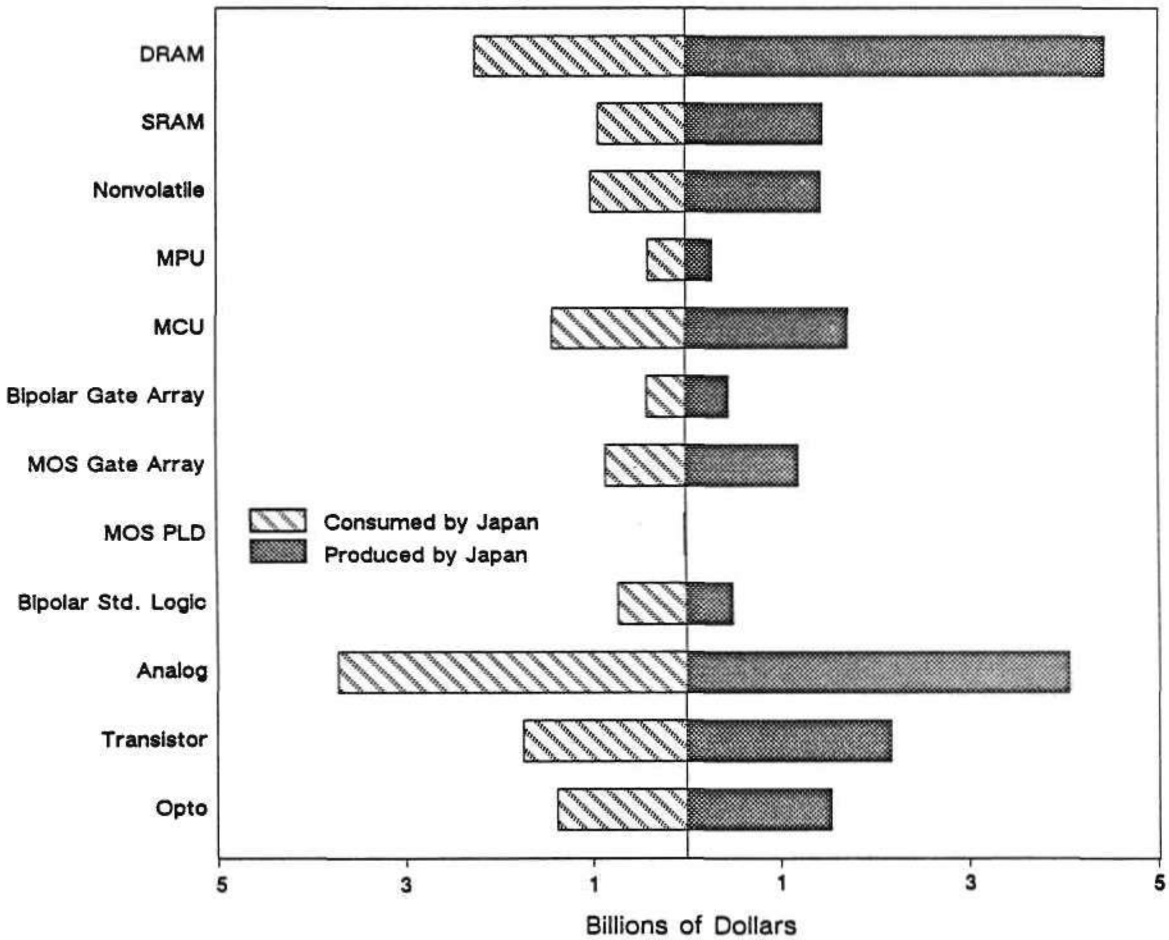
Source: Dataquest
June 1989

Japanese Companies

Figure 3 presents the overlay of Japanese semiconductor consumption, and Figure 4 presents the net consumption/production chart as it relates to Japan. These figures illustrate that Japan is overwhelmingly a net producer of ICs and that it consumes only microprocessor units, MOS PLDs, and bipolar standard logic from foreign sources.

Figure 3

Semiconductor Consumption/Production Profile Japan



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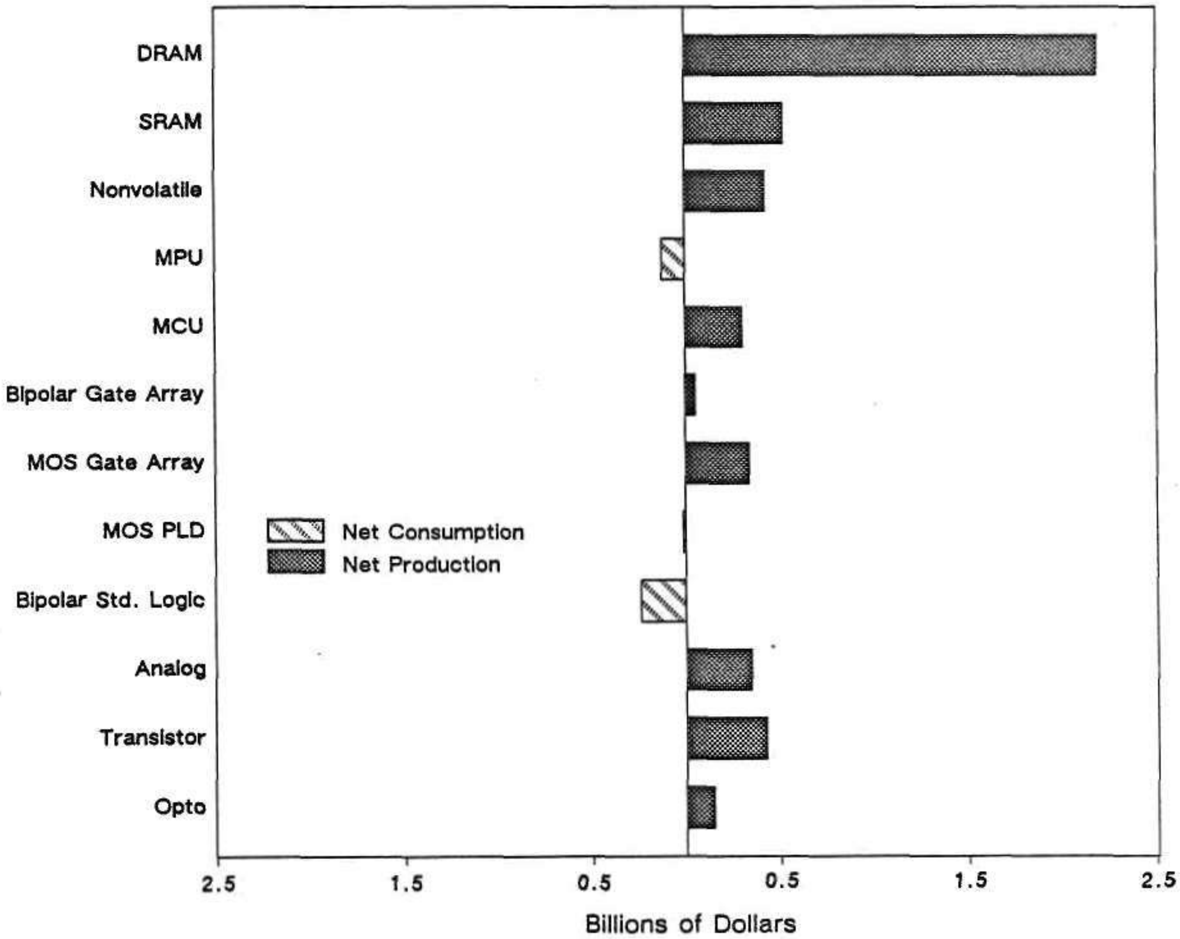
Source: Dataquest June 1989

Figure 4

Difference between Semiconductor Consumption and Production
Japan



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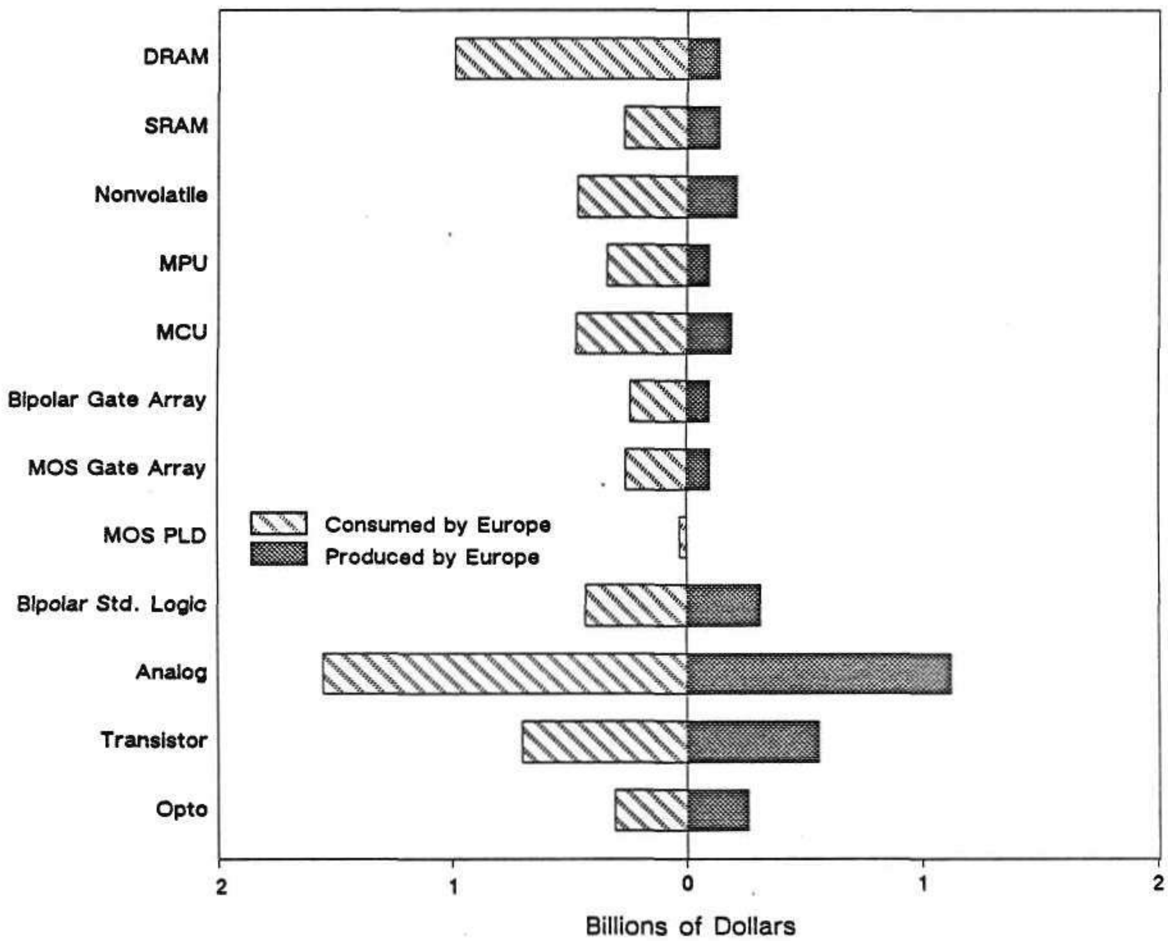
Source: Dataquest
June 1989

European Companies

Figures 5 and 6 depict the consumption/production scenario for Europe. As seen in Figure 6, Europe is a net consumer of foreign semiconductors in all categories.

Figure 5

Semiconductor Consumption/Production Profile Europe



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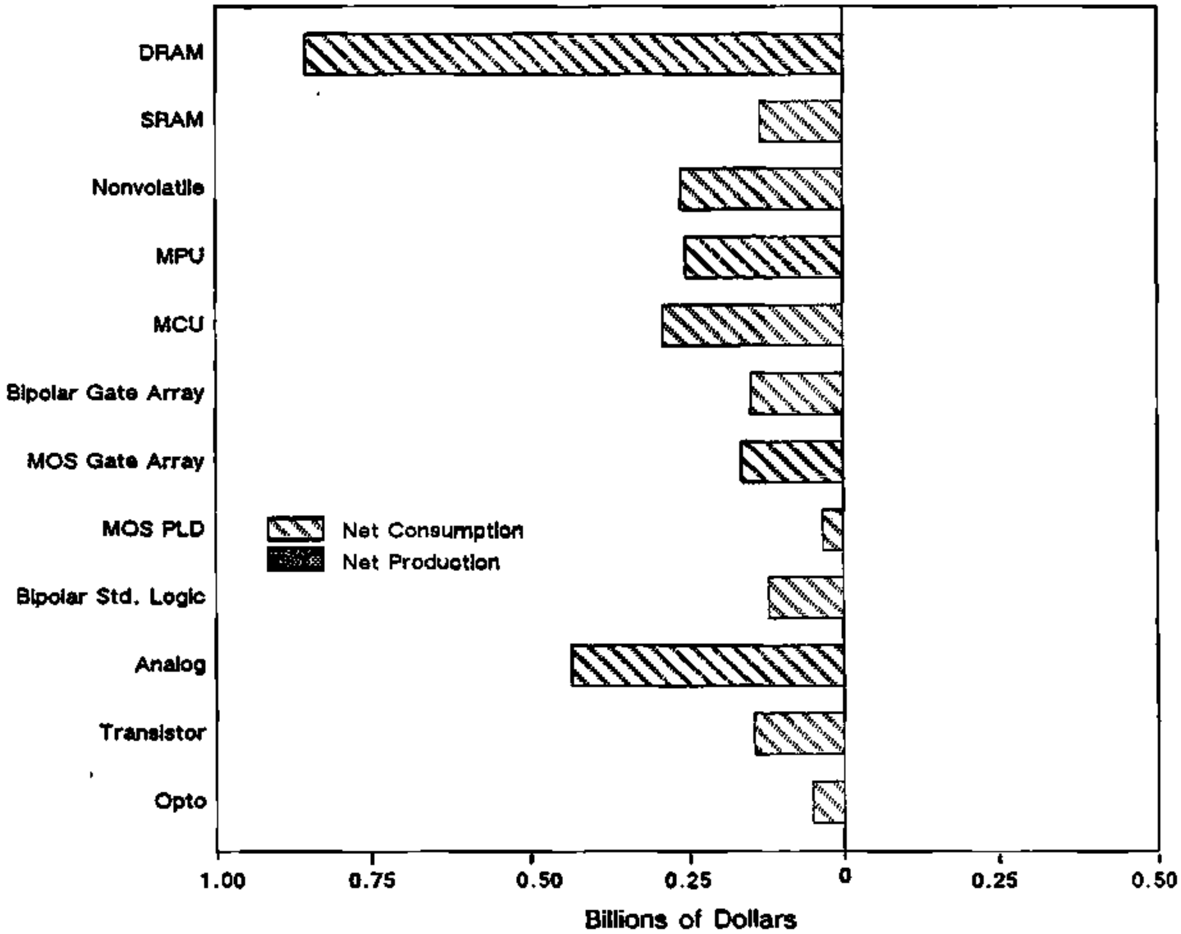
Source: Dataquest June 1989

Figure 6

Difference between Semiconductor Consumption and Production
Europe



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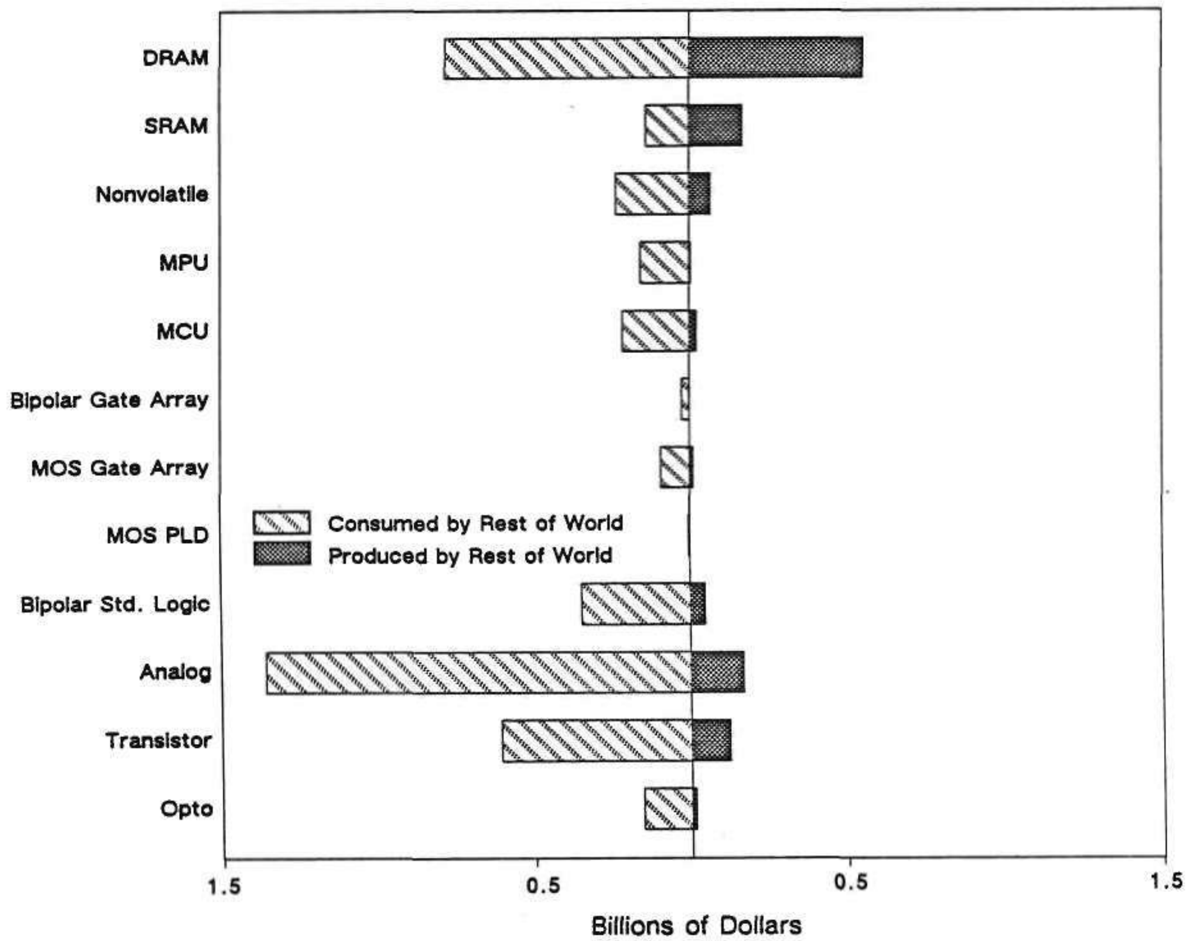
Source: Dataquest
June 1989

Asia/Pacific and ROW Companies

Figures 7 and 8 depict the consumption/production profile for the rest of the world, which is essentially Asia/Pacific. As seen in these figures, ROW is a net consumer of foreign ICs, with the exception of SRAMs.

Figure 7

Semiconductor Consumption/Production Profile
Rest of World



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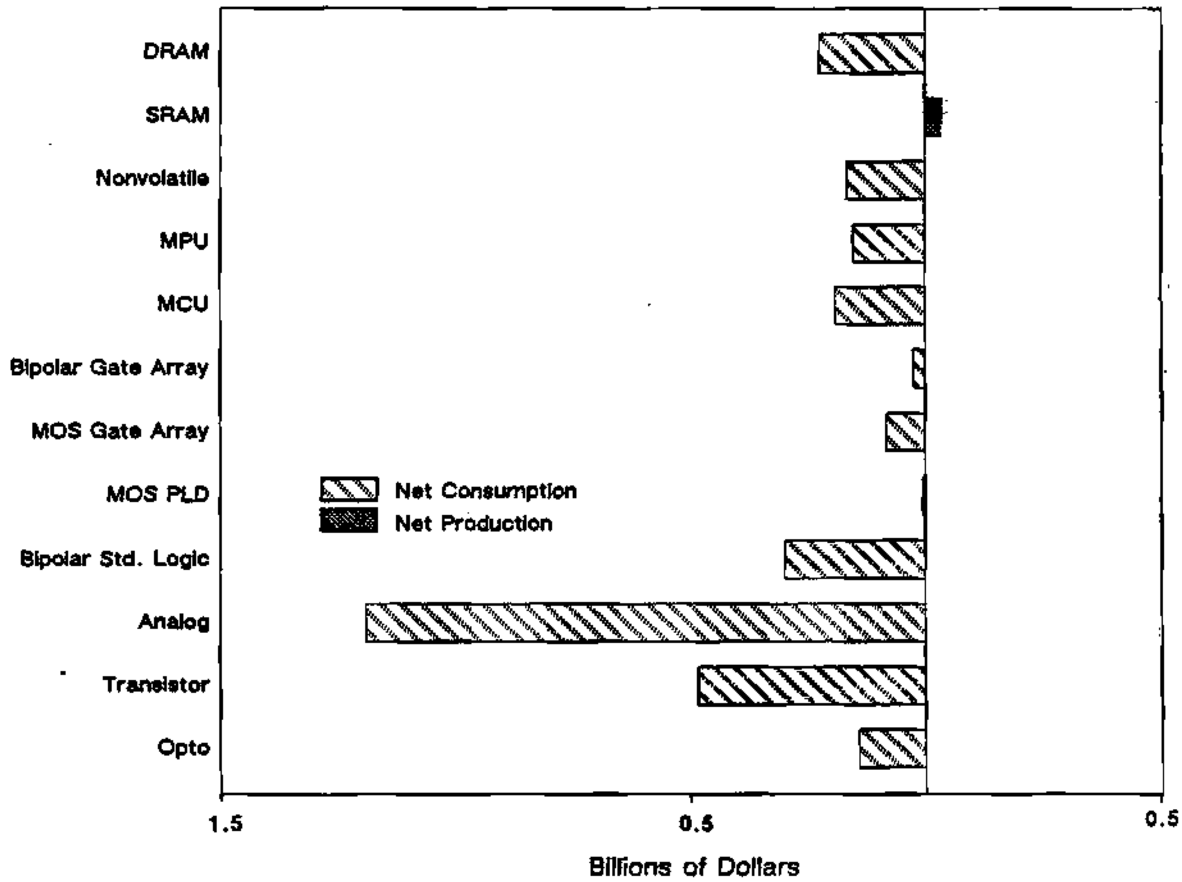
Source: Dataquest June 1989

Figure 8

Difference between Semiconductor Consumption and Production
Rest of World



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Source: Dataquest June 1989

DATAQUEST ANALYSIS

Viewing the information in the net consumer/producer format allows one to quickly assess the characteristics of a certain region and also allows one to anticipate strategic moves that the semiconductor producers and system manufacturers in the region may make to defend markets or to obtain a better balance between consumption and production. Viewing the U.S. consumption/production profile, Dataquest believes that the United States will become a larger producer of both DRAMs and SRAMs and may become a net exporter of SRAMs in the next four to five years. Most of the semiconductor start-up companies that have begun operations in the United States in the last four years have some plans in place to produce SRAMs and specialty memories. Therefore, we believe that the United States will take a stronger position in SRAMs in the 1990s.

Dataquest believes that U.S. producers will continue to exercise dominance in microprocessors, given their superiority in complex design and software expertise; however, we also believe that the United States will become a net consumer of microcontrollers as Japanese companies gain expertise in this technology. This is particularly true for the less complex microcontrollers, which are embedded into a vast array of consumer electronic products and office equipment.

The U.S. companies' position in gate arrays, both bipolar and MOS, is surprising. Already, in this relatively young market, the United States does not produce enough to satisfy its own needs, suggesting underinvestment in this important and growing market. Unless dramatic changes occur, and occur very soon, we believe that non-U.S. suppliers will gain dominance in MOS gate arrays and that the U.S. electronics industry will continue to consume more gate arrays than it produces in the 1990s. Finally, although the U.S. IC producers appear to have a strong position in analog ICs, we believe that this strength will diminish somewhat in the 1990s, resulting from the lack of an indigenous consumer electronics industry.

To no one's surprise, the Japanese IC suppliers are the world's leaders in DRAMs. Dataquest believes that the Japanese companies will continue in their dominance of these markets and will be substantial net producers of DRAMs in the 1990s. Numerous Japanese companies are well positioned in 4Mb DRAMs already and are beginning to focus their attention on the 16 and 64Mb DRAMs. With this much inertial energy, we believe that it will be difficult for anyone to dislodge the Japanese IC producers from this number one status. We believe that the Japanese semiconductor producers will continue to strengthen their position in gate arrays and soon will begin to focus their energies on the MOS programmable logic device (PLD) area. Although it is purely speculation at this point, we believe that in the light of increasing trade friction, the Japanese suppliers may pursue microprocessor devices with less intensity and that the Japanese electronics industry will continue to be a net importer of MPUs, particularly 32- and 64-bit MPUs.

The European region forecast is less clear. The European electronics industry, at this time, is substantially dependent upon non-European sources for its critical semiconductor devices. We will have to wait to see if the "1992 Effect" and the recent consolidation of several European IC manufacturers will have a positive impact upon this profile as we head into the 1990s.

Dataquest believes that the area wherein the greatest change in profile could occur will be ROW—principally, Taiwan, Korea, Singapore, and Malaysia. Taiwanese and Korean companies are making substantial increases in semiconductor manufacturing capacity. In the last year alone, Taiwan has witnessed several new IC start-ups focused on the SRAM market as well as incorporation of SRAMs into the product profiles of many of the existing Taiwanese companies. Korean companies are well positioned to gain a major role in DRAMs. Singapore, Malaysia, and Taiwan, to some extent, have large amounts of installed foundry capacity. Dataquest believes that several of these foundries may begin to run SRAM-type products as technology drivers and as capacity balancers, further enhancing the region's image as a net producer of SRAM-type products. We also believe that there will be increased activity in both microprocessor- and microcontroller-type products, especially in Taiwan and Korea, as these regions' technical competency increases in high-end personal computers and workstations.

Dataquest anticipates an era of greater interdependence among geographic regions, beginning in the early 1990s. We believe that this will be especially true among the electronic IC companies of the United States, Japan, and Asia/Pacific, as all of these regions attempt to arrive at an amenable trade balance. We further believe that European industry will first focus on meeting a greater share of its own internal needs in the early 1990s and then join the other regions of the world in the mid- to late 1990s as the electronics industry becomes truly global in nature, with virtually no geographical boundaries.

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Mel Thomsen

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WAFER FAB IN THE 1990s: ASIA COMES ON STRONG

SUMMARY

The worldwide semiconductor industry recently has undergone one of its cyclical conjunctions of high demand and limited capacity--at least where leading-edge products are concerned. The recent effects of this coincidence are only too evident to procurement managers at U.S. electronics companies. As the industry heads for a downturn, however, Dataquest maintains that the severity of the coming recession will be mitigated by the overall constraint shown by U.S. and Japanese semiconductor companies in constructing new fab facilities--particularly when compared with the halcyon capital spending period between 1983 and 1985. Nevertheless, based on the current wafer fab trends that Dataquest analysts are observing in Asia, the industry may face another serious overcapacity situation by 1994.

This newsletter provides a look at Asian fab trends by drawing on the recent and extensive fab data base work done by analysts in Dataquest's Semiconductor Equipment and Materials Service (SEMS) and Asian Semiconductor and Electronics Technology Service (ASETS). Dataquest believes that the massive investments in capacity now being undertaken by the newly industrialized countries (NICs) of Asia, combined with major shifts in Japan's fab strategy, could lead to tremendous competitive pressures in the next five years--not only in commodity memories, but in the microcomponent and ASIC markets as well.

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ENTERING THE ASIAN AGE

At the beginning of this year, Dataquest's ASETS analysts observed that the rapid growth in personal computer, office automation, and consumer electronics production was resulting in the construction of 39 new semiconductor plants in Asia (see Table 1). Although most of this activity is centered in South Korea and Taiwan, the countries of Australia, China, Hong Kong, Malaysia, Singapore, and Thailand also are seeing fast growth. Some of the regional factors behind the rush of new semiconductor investment in Asia include the following:

- Dynamic growth in Taiwan's PC clone, consumer, and industrial electronics sectors has resulted in the opening of 40 ASIC design centers. These factors have prompted government interest in expanded semiconductor production capacity—particularly in memory ICs.

- South Korean conglomerates are investing heavily in new semiconductor plants to achieve self-sufficiency and to respond to the huge demand for memory chips. The capital spending levels of both Samsung and Hyundai, for example, have reached parity with Toshiba, which will spend in excess of $600 million this year.

- Foreign companies are opening plants in the People's Republic of China to take advantage of the growing demand there for semiconductors.

- The Singapore government pays 100 percent of new plant investments and, by doing so, has attracted Chartered Semiconductor, Hewlett-Packard, and NEC assembly plants.

- Thailand is experiencing massive investments by Japanese companies. Japan's Ministry of International Trade and Industry (MITI) estimates that 277 Japanese companies in all sectors opened their doors in Thailand in 1987, and 670 opened in the first nine months of 1988 alone.

- Malaysia has 16 U.S. semiconductor companies and offers tax breaks and duty-free imports of equipment, materials, and technologies.

Table 1 summarizes all semiconductor facility plans for Asia known to Dataquest as of the beginning of this year.

Table 1

Asian Semiconductor Facilities
Known Plans for 1988–1996
(Exchange Rates: US$1 = ¥120, W680, Y3.73)

Company	Location	Cost (US$M)	Start Mfg.	Plant Type*	Initial Products	Wafer Size	Wafers/ Month**
			South Korea				
Daewoo	Guro	N/A	Q3/88	Fab	Zymos chip sets	4"	10,000
Goldstar #1	Woomyun	135.0	1988	Fab	CMOS memory	6"	18,000
Goldstar #2	Chongju	2,200#	Q4/90	Fab	1Mb DRAM,256K SRAM	6"	45,000
Goldstar #3	Chongju	above	1993	Fab	4Mb DRAM,1Mb SRAM	6"/8"	90,000
Goldstar #4	Chongju	above	1996	Fab	16Mb DRAM,4Mb SRAM	6"/8"	135,000
Hanil	N/A	7.0	1989	Fab	GaAs laser diodes	N/A	N/A
Hyundai #4	Ichon	N/A	Q1/90	Fab	1Mb DRAM	6"	40,000
Hyundai #5	Ichon	450.0	Q4/90	Fab	4Mb DRAM	6"	20,000
Sammi	N/A	7.0	1989	Fab	GaAs laser diodes	N/A	N/A
Samsung #3	Suwan	N/A	Q1/88	Fab	1Mb DRAM	6"	22,400
Samsung #4	Kiheung	N/A	Q1/89	Fab	1Mb DRAM	6"	18,000
Samsung #5	Kiheung	514.7	Q4/89	Fab	4Mb DRAM	6"	30,000
			Taiwan				
AMPI	Hsinchu	5.3	Q3/88	Fab	Power & consumer ICs	4"	8,000
Diodes Inc.	Taipei	N/A	1989	Fab	Diodes	N/A	N/A
HMC	N/A	N/A	Q4/89	Fab	Memory,telecom ICs	5"	30,000
Hualon	Hsinchu	200.0	Q3/88	Fab	Memory, consumer	5"	25,000
TSMC(ERSO)	Hsinchu	32.5	Q2/88	Fab	Memory, telecom ICs	6"	10,000
TSMC	Hsinchu	220.0	Q4/89	Fab	CMOS foundry	6"/8"	30,000
UMC(Phase I)	Hsinchu	140.0	Q1/89	Fab	Memory,MCU, graphics	6"	30,000
Vitelic	Hsinchu	80.0	Q3/90	Fab	Memory	6"	10,000
Winbond	Hsinchu	50.0	Q4/88	Fab	SRAM, ASIC, consumer, telecom	5"	20,000
			China				
Wuxi	Wuxi	N/A	1991	Fab	Integrated circuits	N/A	100MU/yr##
Motorola	Tianjin	N/A	1990	Fab	Discrete, ICs	6"	N/A
Philips	Shanghai	N/A	Q4/89	Fab	TV/VCR ICs	N/A	70MU/yr
Shanghai #17	Shanghai	N/A	Q3/88	Fab	Consumer	N/A	N/A
			Hong Kong				
Motorola	Hong Kong	50.0	Q3/89	A/T	Analog, memory, MPR, ASIC	N/A	N/A

(Continued)

Table 1 (Continued)

New Semiconductor Plants Planned for Asia, 1988–1996
(Exchange Rates: US$1 = ¥120, W 680, Y 3.73)

Company	Location	Cost (US$M)	Start Mfg.	Plant Type*	Initial Products	Wafer Size	Wafers/ Month**
			Singapore				
Chartered	Singapore	50.0	Q2/89	Fab	CMOS ASICs	6"	5,000
HP	Singapore	N/A	N/A	Fab	GaAs	N/A	N/A
Matsushita	Singapore	N/A	1988	A/T	N/A	N/A	N/A
NEC	Singapore	12.5	1989	A	256K/1Mb DRAM	N/A	1.5MU
					Linear	N/A	500KU##
			Malaysia				
Fujitsu	Kuala Lumpur	25.8	Q1/89	A/T	CMOS memory, logic and linear ICs	N/A	N/A
Hitachi	N/A	N/A	Q3/87	A	1Mb DRAM	N/A	10KU
Motorola	Seremban	48.0	Q3/88	Fab	Small signal trans.	N/A	N/A
			Thailand				
Shindengen	N/A	N/A	Q3/89	A/T	Car electronics	N/A	N/A
Sony	AMD Thai.	N/A	1989	Fab	Bipolar	N/A	3.0MU
Sony	Bangkok	21.7	Q3/90	Fab	Bipolar	N/A	10.0MU
			Australia				
AWA Ltd.	Sydney	52.0	Q1/89	Fab	CMOS ASIC	6"	N/A
Ramax	Melbourne	45.0	1989	Fab	Ferroelectric ICs	N/A	N/A
University of Adelaide	Adelaide	N/A	1988	R&D	GaAs	N/A	N/A

*Type of plant: Fab = fabrication, A = assembly, T = testing
**Total available capacity, not current capacity utilization
#$2.2 billion Goldstar investment will cover three new plants
##MU = million device units per month; KU = thousand device units per month
N/A = Not Available

Source: Dataquest
July 1989

JAPAN'S CONSISTENT CAPACITY EXPANSIONS

Compared with the United States, Japan has been very consistent about its additions of semiconductor fab capacity. Japan has brought up new production and pilot-based silicon fab lines at a rate of approximately 12 per year since 1984—and we believe that this rate will continue, at least through 1990. By comparison, U.S. fab additions fluctuated between 8 and 21 per year during the same time period. Dataquest believes that most new Japanese fabs that have or will come on-line during industry downturns begin production with a small fraction of the equipment that they will ultimately contain. The companies that own these fabs therefore are well-positioned to handle the next upturn by quickly adding equipment to their partially utilized floor space.

JAPANESE VERSUS U.S. FABS

The fab data base currently maintained by Dataquest's SEMS analysts reveals that the United States boasts 216 silicon-based wafer fabs compared with 168 in Japan. On the average, however, Japanese fabs are larger and newer. Although the average maximum wafer start capacity for U.S. companies is 16,000 wafers per month for production facilities and 4,000 per month for pilot lines, the comparable figures for Japan are 23,000 and 8,000, respectively. The average age for Japanese fabs is four years, compared with six years for U.S. fabs. On the average, Japanese fabs are running 5-inch wafers, while the average wafer size for U.S. fabs is 4 inches.

Japanese and U.S. fab capacities also differ in terms of both product and micron mix, as shown in Table 2.

Table 2

Comparison of U.S. and Japanese Fabs

	Differences in Product Mix				
Country	Memory	MPU	Logic	ASIC	Other
Japan	39%	7%	6%	14%	34%
United States	25%	14%	8%	26%	27%

	Differences in Micron Mix					
	≤1u	≤1.1-1.5u	≤1.6-2u	≤2.1-2.5u	≤2.6-3u	≥3u
Japan	22%	30%	28%	0	14%	5%
United States	17%	31%	19%	3%	13%	19%

Source: Dataquest
July 1989

Looking more closely at the Japanese fab data base, SEMS data show that 13 production and pilot-based silicon fabs went into operation in Japan during 1988. In 1989, 14 will go into production, and 12 more are expected to come on-line in 1990. Eight other gallium arsenide and R&D lines should come on-line between 1988 and 1990. Dataquest also knows of 13 more fab lines that are scheduled to go into production after 1990. Out of this activity, the following details emerge:

- Nine of the 13 production and pilot-based silicon fabs that began operations during 1988 produce advanced DRAMs and SRAMs.
- Ten of the 14 fabs begun during 1989 and 9 of the 12 during 1990 are also expected to produce advanced DRAMs and SRAMs.
- Approximately 75 percent of these new fabs will produce advanced 1Mb or 4Mb DRAMs and, with few exceptions, all will process linewidths at 1 micron or less on 6-inch or 8-inch wafers.
- The average wafer-start capacity for future DRAM production-based lines is 21,133 wafers per four-week period, while the average wafer-start capacity for future DRAM pilot lines is 8,500 wafers per four-week period.

JAPAN'S SHIFTING FAB STRATEGY

As interesting as these comparisons may be, SEMS analysts have uncovered a far more profound competitive trend in Japanese wafer fab production. Historically, an advanced fab in Japan has produced two generations of DRAMs. It has been logical to try to produce as many generations of a DRAM as possible from the same fab because DRAMs have represented the clear majority of Japanese production. Traditionally, these fabs have upgraded or replaced some of the installed equipment in order to produce the second DRAM generation through its die shrink. Dataquest now believes that more of Japan's new and future DRAM fabs will produce one, or perhaps one and a half, DRAM generations. Rather than retool existing fabs for next-generation DRAMs, we believe that Japanese suppliers will shift production down the "product food chain" in the following sequence: DRAMs/SRAMs—>gate arrays—>CBICs—>MCUs/MPUs—>opto devices—>standard logic—>analog—>power ICs—>discretes.

Dataquest already has observed the beginning of this movement toward single-generation DRAM fabs, with some companies bringing up dedicated 1Mb fab lines that are not expected to be upgraded to 4Mb DRAM production. Although 4Mb DRAMs have been sampled out of these 1Mb fabs, Dataquest has noted that, so far, all Japanese manufacturers have plans to do volume production in new, dedicated 4Mb lines. Factors that may influence this move toward a single-generation DRAM fab concept, with subsequent production of other types of products, include the following:

- The implementation of common "core" manufacturing processes for all product divisions—Under ideal conditions, this would require that only the mask set be changed for manufacturing a different product while using the same "core" process recipe.

- Conversion to 8-inch wafers for volume production of next-generation DRAMs—Most of the companies that do not adopt 8-inch production during the 4Mb generation will do so at the 16Mb level.

- Required purity improvements in DI water and gas-handling systems for next-generation DRAM manufacturing—The move to 4Mb production appears to require new fabs and support facilities as opposed to upgrading existing fabs. In turn, there is a chance that 16Mb production will be better addressed with new fabs and support facilities instead of upgraded 4Mb lines.

- The reduction of process capability overlap for semiconductor processing equipment when moving from one DRAM generation to the next—This is particularly true in regard to lithography limits.

  - New 4Mb fabs brought up on high numerical aperture g-line steppers could, at best, make the final die shrink of the 4Mb DRAM.

  - For new 4Mb fabs brought up on i-line steppers, this shift will mark the beginning of a rather short transition phase in Japan, most likely beginning and ending with the 4Mb DRAM.

FUTURE SHOCK

Not coincidentally, the trend toward shifting fab production down the product food chain comes at a time when Japan is making gains in ASICs, microcomponents, and other ICs for consumer, computer, and automotive applications. If Japan rapidly adopts the single-generation DRAM fab strategy, a large bubble of advanced and low-cost capacity would begin to move into ASIC and microcomponent production. The first such capacity bubble would begin to come in after the 1Mb production peak during 1992, and the second capacity bubble would begin to come in after the 4Mb production peak during 1995.

By 1992, Japanese companies should be enjoying the fruits of their current ASIC and microcomponent efforts that include many technology exchange agreements and joint development projects being conducted on- and offshore. At the same time, DRAM capacity that is very low in cost and advanced will become available to the Japanese. This equipment will be close to being written off the books and should already have provided a minimum of three good years of DRAM profits.

DATAQUEST CONCLUSIONS

At present, Dataquest foresees worldwide semiconductor capacity utilization levels remaining at or above 80 percent through 1993. However, there are some ominous signs that the industry could face an overcapacity situation in 1994. These signs include the following:

- Rest of World (ROW) markets are making enormous investments in semiconductor wafer fab facilities. Korean companies Goldstar, Hyundai, and Samsung all are adding 4Mb DRAM lines between 1989 and 1992 and expect to sample 16Mb DRAMs in 1993.

- In addition to the more visible "Four Tigers" of Asia (Hong Kong, Korea, Singapore, and Taiwan), the Southeast Asian nations of Indonesia, Malaysia, the Philippines, and Thailand are poised to be the next major wave of electronics producers. China and India may not be far behind.

- The forces of trade and end-user demand are requiring semiconductor companies to invest more heavily in producing where they do business. Regarding Japan, companies that would have been content to supply their world markets from Japan-based factories are announcing that they will expand capacity in other regions--particularly in Europe and the United States.

- In response to stronger competition from Korea and the United States in the memory market, it appears that Japan's changing fab strategy will shift future production capacity into nonmemory markets such as ASICs and microcomponents.

A final, although more speculative, caution comes in the form of past industry cycles. If the past serves as prologue, the industry's 10-year cycle of major booms and busts indicates that a serious recession might be due in 1994--just in time for much of the capacity additions that we foresee in the early 1990s to come up to full production. Like it or not, participation in the semiconductor industry has become an imperative for almost every world economy that seeks to be globally competitive in the 21st century. Before the economies of China, India, and Southeast Asia learn firsthand about industry cyclicality, the semiconductor market may yet be in for some heavy weather.

Michael J. Boss
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Research Newsletter

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0004375

MOTOROLA AFFIRMS ITS COMMITMENT TO BROAD-BASED SUPPLY

INTRODUCTION

The year 1988 marked Motorola's sixtieth anniversary. Founded in September 1928 as the Galvin Manufacturing Corporation to produce battery eliminators, the company barely survived the stock market crash in 1929. Today, the company is an approximately $8 billion supplier of electronic equipment, systems, and components.

In an era of increasing specialization and niche-market-oriented companies, Motorola represents an unusual breed of U.S. semiconductor manufacturers. Motorola, the largest U.S. chipmaker, continues to be one of the few remaining broad-based semiconductor suppliers in the nation. The company considers its wide breadth of products to be critical to its semiconductor strategy and has charted a course that provides an extensive rather than an intensive product portfolio. This newsletter focuses on Motorola's broad-based supplier strategy, the challenges of maintaining this position in the future, and, more specifically, how the company's semiconductor operations are changing to meet these challenges.

MOTOROLA—THE COMPANY

In 1947, the company name was changed from Galvin Manufacturing Corporation to Motorola, the name of a car radio produced by Galvin Manufacturing. Corporate headquarters are located in Schaumburg, Illinois. Figure 1 details the company's organizational structure, and Table 1 shows Motorola's revenue by sector since 1980. It is interesting to see how consistent a percentage share of revenue has been represented by Motorola's two largest sectors, Communications and Semiconductors. The composition of Motorola's business generally can be characterized as balanced. Each business segment has experienced either strong or exceptional growth over the past five years, with the exception of the Information Systems business, where Motorola has apparently met with little success.

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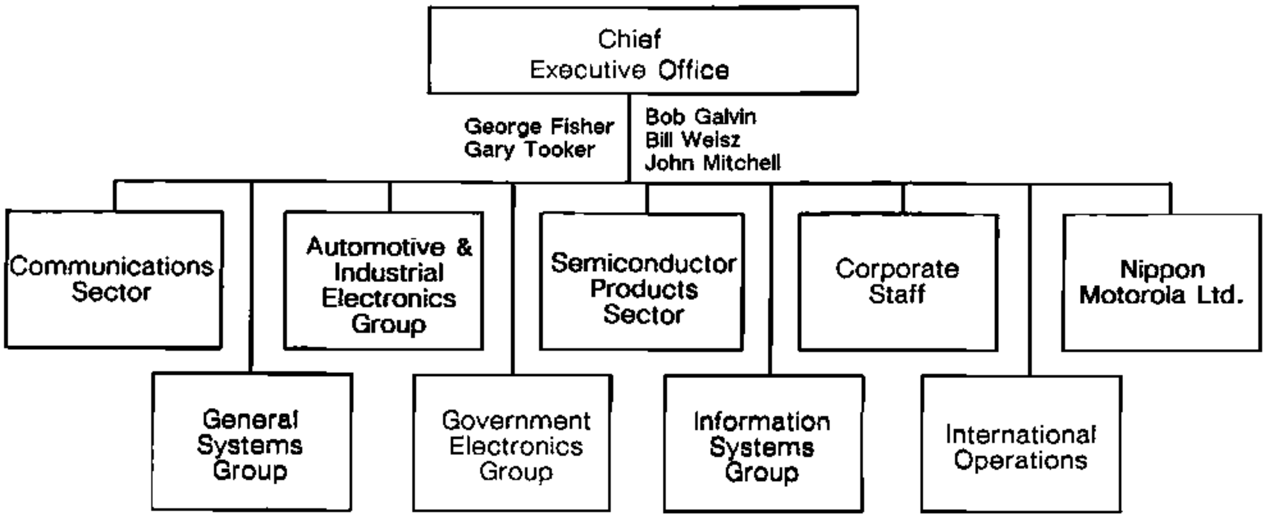
Figure 1

Motorola's Corporate Structure



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Source: Motorola Inc.

Table 1

Motorola's Revenue by Sector (1980–1988)

	1980	1981	1982	1983	1984
Communications	38.3%	40.4%	40.3%	37.4%	33.7%
Semiconductors	36.8%	35.8%	34.3%	37.2%	40.5%
General Systems	-	-	-	-	-
Information Systems	10.0%	11.5%	12.8%	11.9%	8.7%
Government Electronics	-	-	-	8.5%	8.0%
Other Products	16.9%	14.5%	14.9%	7.5%	12.6%
Adjustments	(2.0%)	(2.3%)	(2.3%)	(2.6%)	(3.4%)
Total Revenue (Millions of $)	$3,283	$3,570	$3,786	$4,328	$5,534

(Continued)

Table 1 (Continued)

Motorola's Revenue by Sector (1980–1988)

	1985	1986	1987	1988
Communications	37.0%	38.1%	36.6%	36.6%
Semiconductors	30.6%	30.7%	32.6%	33.2%
General Systems	-	-	11.9%	13.4%
Information Systems	7.9%	7.9%	7.8%	6.9%
Government Electronics	9.1%	8.9%	8.0%	7.9%
Other Products	18.3%	17.5%	6.2%	5.8%
Adjustments	(2.9%)	(3.1%)	(3.1%)	(3.7%)
Total Revenue (Millions of $)	$5,443	$5,888	$6,727*	$8,250

*1987 restated to show reclassification of products from Communications products to Other Products and General Systems products presented separately from Other Products

Source: Motorola Annual Reports

FINANCIAL PERFORMANCE

One way of attempting to assess Motorola's financial performance in relation to its industry peers is to compare the company's ratios of net income to sales and net income to shareholders' equity with those of its competitors (see Table 2). In the United States, however, from the point of view of size and scope of operations, only one other U.S. company, Texas Instruments (TI), has a profile that approximates Motorola's. In fact, Motorola's international competitors are typically much larger companies, frequently encompassing extensive nonelectronic businesses; therefore, relating these statistics to them is not helpful. However, NEC, although considerably larger than Motorola, is engaged primarily in the electronics businesses and so is included for the purposes of comparison. According to this data, Motorola has evidenced superior financial performance.

Table 2

Ratio of Net Income to Sales and Shareholders' Equity
Motorola, TI, and NEC
(1984–1988)

	1984	1985	1986	1987	1988	Average 1984-1988
Motorola Net Sales ($M)	$5,534	$5,443	$5,888	$6,727	$8,250	
Net Income as Percent of Sales	7.0%	1.3%	3.3%	4.6%	5.4%	4.4%
Net Income as Percent of Shareholders' Equity	17.0%	3.2%	7.0%	10.2%	13.2%	10.3%
TI Net Sales ($M)	$5,742	$4,925	$4,974	$5,595	$6,295	
Net Income as Percent of Sales	5.5%	(2.4%)	0.6%	5.7%	5.8%	3.3%
Net Income as Percent of Shareholders' Equity	20.5%	(8.3%)	1.7%	17.0%	16.3%	10.4%
NEC Net Sales* (¥B)	¥2,258	¥2,335	¥2,450	¥2,715	¥3,083	
Net Income as a Percent of Sales	3.0%	1.2%	0.6%	0.9%	2.1%	1.6%
Net Income as Percent of Shareholders' Equity	14.1%	5.5%	2.9%	4.3%	9.3%	7.2%

*NEC's fiscal year ends in March; therefore, in an effort to approximate the time frame for competitors' data, the 1984 column contains data for fiscal year 1985, the 1985 column contains fiscal year 1986 data, and so on.

Source: Motorola, TI, and NEC Annual Reports

SEMICONDUCTOR PRODUCTS SECTOR

Extensive Product Portfolio

Motorola offers one of the industry's broadest semiconductor product portfolios. A review of Motorola's product portfolio (see Table 3) shows that the company is manifestly strong in the areas of discrete devices, logic, and microcomponent products. It is investing to establish a future position in memory through a strategic alliance with Toshiba. Analog is another area where a strategy is being put in place to enhance the company's position and achieve higher penetration in Japan by targeting integrated services digital network (ISDN) and consumer markets.

Table 3

Motorola's Estimated Semiconductor Revenue
and Ranking by Product Area
(Millions of Dollars)

	1987 Rank	1988 Rank	1988 Revenue	Percent of Semiconductor Revenue	1987-1988 Revenue Percent Change	1987-1988 Industry Percent Change
Total Semiconductor	4	4	$3,035	100.0%	24.8%	31.9%
Integrated Circuits	5	7	$2,259	74.4%	28.7%	36.5%
Bipolar (Technology)	6	6	$ 435	14.3%	1.4%	9.2%
Digital Memory	9	9	$ 7	0.2%	(30.0%)	7.9%
Digital Logic	3	4	$ 428	14.1%	2.1%	9.4%
MOS (Technology)	6	7	$1,399	46.1%	41.7%	53.1%
Memory	16	12	$ 236	7.8%	17.4%	90.1%
Microcomponents	3	3	$ 699	23.0%	34.4%	42.7%
Logic	3	3	$ 464	15.3%	21.8%	28.2%
Analog	8	7	$ 425	14.0%	25.4%	15.3%
Total Discrete	2	2	$ 752	24.8%	15.3%	13.2%
Total Optoelectronic	20	20	$ 24	0.8%	0	25.4%

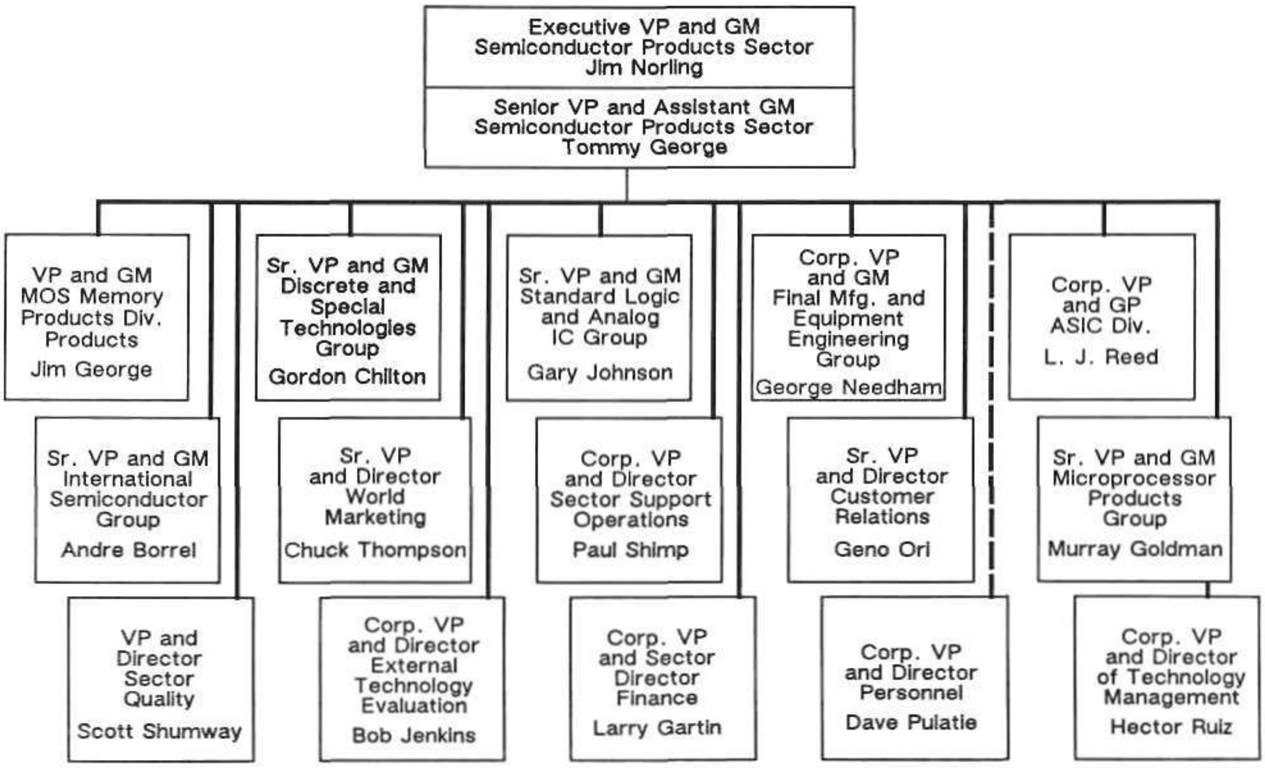
Source: Dataquest
July 1989

Product Operations

Motorola's Semiconductor Products Sector, headquartered in Phoenix, Arizona, is organized as shown in Figure 2.

Figure 2

Motorola's Semiconductor Products Sector



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Source: Motorola Inc.

STRATEGIC GOALS

The cornerstone of Motorola's vision is providing total customer satisfaction. This newsletter focuses on the following areas that Dataquest considers to be essential in Motorola's strategy to achieve its goal of total customer satisfaction within the Semiconductor Products Sector:

- Service strategy
- Increasing end-use focus
- Reentry into the DRAM market
- Microcomponent strategy
- Continuing investment in process and product technology
- Globalization

Service Strategy

In Motorola's terms, customer service is the "third wave" in the semiconductor industry, which has progressed from a technology focus to manufacturing excellence to customer service. Three elements of the company's service strategy bear further inspection:

- Corporate program
- Connectivity
- Marketing structure

Corporate Program

Motorola's corporate program has taken a structured approach to service strategy. Its goal is to achieve economies of scale and share efficiencies with the customer.

In 1987, a task force of eight senior people was assembled for a three-month period of full-time concentration on recommendations for achievement of superior customer service. Based on approximately 40 interviews with customers and input from company employees, more than 50 recommendations were made.

Motorola has achieved substantial progress toward the implementation of these recommendations. Already, much more accurate customer delivery commitments have resulted from some portions of a demand-driven manufacturing system that was subsequently put in place. As Motorola addresses its channels-to-market strategy, just-in-time (JIT) manufacturing is a key element. The implementation of a successful JIT strategy could add as much as 13 to 15 percent to its profits, according to Motorola.

Connectivity

Motorola has invested $6 million to $7 million on new software communications systems to support a worldwide customer network. The following milestones have been reached to date:

- The Electronic Data Interchange program, started in 1978, now processes more than 1.5 million transactions weekly in host-to-host processing of daily orders; the system handles all distributors worldwide, plus 35 U.S. customers and 2 Japanese customers.
- Two years ago, Motorola moved to centralized tracking of its transaction processing through six regional locations, permitting a customer to call a toll-free number to reach his or her account representative, who has worldwide responsibility for the customer's company account at the regional office.

Marketing Structure

As befits the top U.S. semiconductor manufacturer, Motorola derives major strength from its worldwide marketing operations of a wide range of products. Motorola is able to serve its customers on a global basis in response to the changing environment because of the following:

- The company employs approximately 2,000 people in 80 sales offices worldwide, providing both sales and engineering support.

- With customers reducing their vendor bases, Motorola has an advantage in its breadth of product offerings. According to the company, all of its customers buy a range of its products.

- A worldwide distribution network is in place.

- Motorola has local design centers.

- The company's worldwide MIS system allows worldwide order entry and shipment.

Increasing End-Use Focus

With the rapidly evolving pace of technology and accelerating product life cycles, companies are being forced to respond to new markets more quickly. The need for closer customer-vendor relationships becomes more critical as a company plans to introduce products of a higher value-added nature. In this environment, a company can bring application-specific products to market by using better technology. We see this approach manifesting itself through several avenues in Motorola's case. These avenues include the following:

- CAD standards—Motorola will develop an integrated open-architecture CAD system and actively drive industry standards for CAD to accelerate availability.

- Cell-based design methodology—Motorola decided in 1988 not to operate a standard cell group as a standalone unit but rather to disperse this technology throughout the semiconductor sector to enable customers to get customized versions of standard products.

- Application-specific logic products (ASLPs)—One of Motorola's thrusts is to offer application-specific logic products, which are standard products directed at an end-use market. The company is witnessing phenomenal growth in this business, and its strategy depends on being close to the customer and providing a systems solution.

- Standard logic—Motorola proposes to base a standard logic line on its new ECLinPS and design an array that will provide sufficient functionality to form a core of standard logic functions. This approach will speed time to market, and Motorola plans to incorporate a high level of customer involvement in defining the family.

- Vertical integration—Motorola derives considerable synergy between semiconductors, its technology engine, and the other parts of its business in communications, computer, automotive, military, industrial, and consumer products. This gives the company a competitive advantage when providing end-user solutions.

- Marketing—Motorola's worldwide marketing organization is designated by end-use segment as well as by region, which the company believes is advantageous in providing solutions.

Reentry into the DRAM Market

The U.S.-Japan Semiconductor Trade Arrangement provided the necessary framework for Motorola to reconsider entering the memory market. The combination of internal Motorola programs, the Toshiba agreement, and the advent of Sematech will support its reentry into this market. Motorola considers its participation in this market to be of strategic importance. Although tough to operate in, the memory market's value is in driving both technology and manufacturing, as well as addressing a major deficiency in Motorola's product portfolio. Not only is this a difficult market from a competitive viewpoint, but also the sustained investment necessary to pursue a memory strategy is enormous. The risks associated with the increasing capital-intensiveness of leading-edge memory technology development are driving semiconductor manufacturers more and more toward alliances in order to share the costs and the risks involved. The technology road map shown in Table 4 indicates the lengthy lead times involved from commodity development start date to product introduction date.

Motorola/Toshiba Alliance Crucial

Motorola was once a significant participant in the memory market, consistently ranking among the top ten producers worldwide. Although Motorola withdrew from the DRAM market in early 1985, DRAMs remain the company's largest revenue-producing memory product, as Motorola packages and markets DRAM dice manufactured by Toshiba.

If being a major DRAM manufacturer (and making them in Japan) is important to maintain a place in the top echelons of the semiconductor business, Motorola may achieve this through its relationship with Toshiba. Through a joint venture with Toshiba (called Tohoku), Motorola has acquired memory technology to produce 256K, 1Mb, and 4Mb DRAMs and 256K and 1Mb SRAMs. Currently, Motorola is manufacturing 1Mb DRAMs in Japan and East Kilbride, Scotland, and has successfully transferred the process to MOS 6 in Mesa, Arizona. Toshiba, in turn, is to receive 8-, 16- and 32-bit microprocessor technology from Motorola.

Table 4

MOS Memory Technology Road Map

Technology	Commodity Product SRAM	Commodity Product DRAM	Commodity Product Introduction Date	Commodity Development Start Date
1.8u-2.0u	64K	256K	1982-1983	1978
1.2u	256K	1Mb	1985-1986	1980
0.8u	1Mb	4Mb	1988-1989	1983
0.5u	4Mb	16Mb	1991-1992	1986
0.35u	16Mb	64Mb	1994-1995	1989
0.25u	64Mb	256Mb	1997-1998	1992
0.15u	256Mb	1GB	2000-2001	1995

Source: Motorola Inc.

Microcomponents: a Pivotal Strategy

The microcomponents market segment is extremely important for Motorola; the company has consistently ranked as the number three microcomponents supplier worldwide. The need for considerable resources required to maintain a leading position in this segment leads the company to reason that only the strong will survive.

Microprocessors

Companies that base their equipment on a particular microprocessor architecture are concerned about the long-term viability of the supplier and the future availability of hardware and software support and upgrades. The escalating costs for users in maintaining their software investments make the choice of a microprocessor architecture a very strategic one.

The strategic importance of Motorola's microprocessor product line is highlighted by the fact that it is this line that Motorola traded in exchange for Toshiba's DRAM technology. Microprocessors are being targeted by the Japanese, who, rather than be dependent on U.S. technology, are developing their own proprietary microprocessors to support their growing electronics systems' needs. High-end microprocessors represent one of the few remaining strongholds in component technology for U.S. manufacturers. How Motorola manages its relationship with Toshiba without jeopardizing its prominent position in this market will be key to the companies deriving mutual benefit from the agreement.

Today's performance-driven microprocessor market obliges Motorola to continue to introduce enhanced next-generation products that remain upwardly compatible with their microprocessor architecture. It requires large ongoing investment to maintain one's presence at the forefront of this market. Motorola has consistently shown its willingness to do this, as is evidenced by the following:

- A product such as the 68020 is used as a CMOS process driver. Currently, Motorola's production fab in Austin, Texas, MOS 8, is running CMOS at 1-, 1.2-, and 1.5-micron linewidths.

- Currently, the 68020 is offered in speed grades from 12.5 to 33 MHz.

- More integration is on the 68030 microprocessor, which incorporates such functions as a paged memory management unit (MMU), an instruction cache, and data cache on-chip.

- Introduction of the next-generation 68040 is anticipated in late 1989.

- A 50-MHz version of the 68030 has been announced with volume production in the third quarter.

- Upward compatibility saves the customer's investment in software.

Performance: the Driving Factor

The quest for ever-increasing performance has spawned another performance solution in the market: RISC microprocessors. Currently, the RISC market is in its immature phase and is crowded with contenders, many of which are targeting Motorola's traditional area of strength, the workstation market. It is a battle that Motorola cannot afford to lose. The company has responded by doing the following:

- Unveiling its contender in the 32-bit RISC microprocessor market, the 88000, in 1988

- Making an agreement with Data General to create an ECL version of the 88000 microprocessor that the companies claim will achieve 100-mips performance by 1991 and bring mainframe computer power to users at personal computer price/performance levels

- Spending in the neighborhood of $20 million to date in software support alone to launch this architecture

- Promoting the creation of a consortium of computer hardware and software vendors, the 88open Consortium, to drive standards for the 88000 architecture prior to implementation (This is expected to be a more cost-effective approach as vendors share technological innovations and save porting and R&D costs.)

Digital Signal Processing (DSP)

Motorola's DSP device was defined by the company's experience with its communications sector. As people relate more and more to computers, significant benefits derive from the incorporation of advanced DSP devices. The selection of Motorola's 56001 DSP chip in Steve Job's NeXT computer was significant. The NeXT computer system also incorporated Motorola's 25-MHz 68030 and the 68882 floating-point coprocessor. The DSP device was designed directly onto the motherboard to provide sound and speech synthesis, a high-speed modem, facsimile transmission, array processing, voice mail, and numeric processing functions.

Because of the dynamic range of the 56001's 24-bit architecture, the device also is particularly suited to high-end audio applications. The DSP market is an emerging area for Motorola. Its design-win in the NeXT computer could prove significant to the company in establishing a place in a DSP market currently dominated by TI.

Microcontrollers

Microcontrollers claim a larger share of microcomponent revenue than microprocessors. (Microcontrollers accounted for approximately 36 percent of the $7 billion microcomponents market worldwide in 1988.) This market is extremely cost-sensitive, however, and nowhere more so than the automotive and consumer segments, where the company achieves its highest volumes. Motorola has successfully used the lessons it learned from manufacturing in Japan to achieve significant improvement in domestic manufacturing efficiency over the past three years. It is a testimony to Motorola's manufacturing capability and status as a low-cost manufacturer that it competes successfully with its Japanese competitors. Motorola is the leading worldwide supplier of 8-bit microcontrollers. In Japan, the company is expanding aggressively into the automotive and consumer segments. Motorola has announced the industry's first 32-bit microcontroller, the 68332, which is expected to be available in production quantities in the fourth quarter of this year.

A close working relationship with the customer is also called for in this area, and Motorola caters to customers' needs by providing product proliferation geared toward specific applications. In the future, Motorola expects to place more emphasis on ASIC-like microcontrollers, at least for products at the high end of the spectrum. By modularizing its designs, the company will be able to speed up its design turnaround time.

Continuing Investments in Process and Product Technology

Good products and successful marketing, although important to winning in the marketplace, cannot sustain long-lasting success without state-of-the-art technology. But state-of-the-art technology carries a heavy price tag. In spreading its technology investments over a broad product spectrum, Motorola faces significant capital investment costs. Participation in both leading-edge commodity products such as high-density DRAMs and higher-margin businesses such as microcomponents and ASICs will be more difficult to support. For the first time since 1980, Motorola's semiconductor capital spending exceeded the industry average in 1987 and is expected to grow to $490 million in 1989 (exclusive of expenditures on the joint venture with Toshiba). Table 5 provides capital and R&D expenditures as a percentage of semiconductor revenue.

Table 5

Motorola's Capital and R&D Spending
(Millions of Dollars)
(1984–1988)

	1984	1985	1986	1987	1988
Total Semiconductor Revenue	$2,319	$1,830	$2,025	$2,430	$3,035
Semiconductor Capital Spending	$ 412	$ 330	$ 250	$ 350	$ 430
Capital Spending as a Percent of Revenue	17.8%	18.0%	12.3%	14.4%	14.2%
Semiconductor R&D Spending	$ 176	$ 192	$ 199	$ 207	$ 225
R&D as a Percent of Revenue	7.6%	10.5%	9.8%	8.5%	7.4%

Source: Dataquest
July 1989

Process Technology

Motorola divides its process technology development into three major development groups:

- Semiconductor Research and Development Lab (SRDL) focuses on discrete power circuits, non-VLSI analog technology, basic process technology, and packaging.

- Bipolar Technology Center (BTC) focuses on high-performance bipolar, mixed-technology BiCMOS, and process module development.

  - As an evolving technology, BiCMOS can be approached either as uncompromised bipolar technology with CMOS integrated to serve high-performance requirements or as uncompromised CMOS technology integrating bipolar technology to serve high-density needs. In order to eventually merge the two approaches, certain commonality is being built in, such as common layout rules when possible, common lithography, and common metallurgy where possible.

- Advanced Products Research and Development Lab (APRDL) focuses on CMOS and process module development.

Product Technology

Although this newsletter focuses on certain product areas critical to the realization of Motorola's strategic aims, the company has been active in other product segments. Highlights in a number of these segments are summarized in the following paragraphs.

Memory. Increasing priority is being given to the company's fast SRAM family as can be seen from the following:

- In 1987, a family of high-performance CMOS SRAMs was added to Motorola's product line, including 4K, 8K, 16K, and 64K densities with speeds up to 25ns.

- Product announcements expected in the near future will introduce a 16Kx4, 32Kx8, 256Kx1, and 64Kx4 with access times of 20 to 25ns.

- By 1990, Motorola expects to introduce a 1Mb SRAM and bring a 256K SRAM in BiCMOS to market also.

Although current BiCMOS designs are at 1.5 microns over the next 18 months, in terms of production, Motorola hopes to bypass the 1.5-micron level and move directly to production at 1 micron. Motorola plans to use this process technology in product applications such as high-density, fast gate arrays; standard cells; next-generation microprocessors; and custom designs.

Motorola has been withdrawing gradually from the nonvolatile memory market but is expected to preserve EPROM capability to support manufacturing technology and microcomponent and ASIC product offerings.

Discrete. In a market dominated by Japanese companies, Motorola has long been the leading discrete supplier and was dislodged from the number one position only in 1987 by Toshiba. Within the discrete market, Motorola holds strong positions in all the major product areas. Leadership in discretes is driven by Motorola's major business sector, communications. Synergy between these products and microprocessors, for instance, allows the sale of a microprocessor to bring in as much revenue in discretes as it does in microprocessors. Motorola will continue to invest in the discrete product area and, despite the complex problems associated with managing a very broad product line with thousands of package types, will continue to maintain its diverse product portfolio.

Serving the broad range of discrete markets also requires a broad range of capabilities including advanced submicron technology for such products as radio frequency (RF) semiconductors and power MOS devices plus leading-edge manufacturing technologies for mature, high-volume semiconductors. These new technologies often combine discrete and integrated circuit technologies to provide new products containing substantial added value.

Logic. In the standard logic arena, Motorola is a major market participant, ranking among the top five suppliers in both bipolar and CMOS in 1988. In that year, the company introduced a new ECL flagship product based on a gate array with gate delays of less than 150ps using its new ECLinPS process (for ECL in picoseconds). Motorola offers products in the CMOS metal gate and high-speed families. The company entered the FACT CMOS market in late 1988 through a licensing agreement with National. Motorola will also second-source Toshiba's new 74BC BiCMOS family, entering the market in mid-1989. The company will continue to expand its product portfolio aggressively for its FACT and ECLinPS families. Motorola is committed to gaining significant market share as a supplier of FAST and expects to remain price competitive in this arena.

ASICs. In addition to working closely with key customers to offer high-performance system solutions in both CMOS and bipolar technologies, a key feature of Motorola's strategy in the ASIC market is to drive industry standards for CAD actively in order to accelerate the availability and utility of open-architecture alternatives.

Motorola is the leading supplier of ECL gate arrays to the merchant market. Motorola's current process, MCA III, has yielded 2,200-gate and 10,000-gate ECL arrays featuring typical delays in the range of 100 to 150ps. In 1989, the company will augment this product family with introductions of devices with 2,600 and 7,600 gates. The next generation of bipolar arrays, the MCA IV, will be fabricated in 1-micron technology with four layers of metal, offering gate densities of 15,000, 25,000, and 50,000. Other architectural features will include a BiCMOS process option, built-in testability, and 512-lead tape automated bonding (TAB) packaging as well as pin grid array (PGA) packaging.

In the arena of CMOS process technology, Motorola has introduced a family of high-density CMOS gate arrays manufactured in a 1.2-micron process. The HDC Series utilizes a sea-of-gates architecture and ranges in gate count from approximately 3,000 to 105,000 gates. The next generation of these CMOS arrays will be manufactured in a 0.8-micron process and will offer a configurable base array option. High I/O applications are driving the migration to CMOS TAB packaging.

Analog. Although a large number of companies are participating in the analog market, few are as broad-line a supplier as Motorola. Motorola's analog business comprises the following eight major segments:

- Op amps
- Interface
- Power
- Telecommunications
- High frequency
- Automotive
- Special products
- Magnetics

The product areas that Motorola will emphasize in the future are:

- Op amps, where a very high performance market has developed (The company's strong position in op amps results from the technology pull of mobile communications and cellular radio.)
- Power devices, where motor control technology is evolving and smart power and BiCMOS will become increasingly dominant
- Telecommunications, where Motorola benefits from synergy with its communications sector and boasts many proprietary products
- High frequency, where Motorola will target the consumer market and invest in the technology and design tools to deliver mixed-signal technology

- Automotive, where Motorola is already a leading supplier in a market that is expected to grow rapidly in the future

- Special products, where Motorola offers custom, high-performance products using advanced processes, tools, and mixed-signal testing

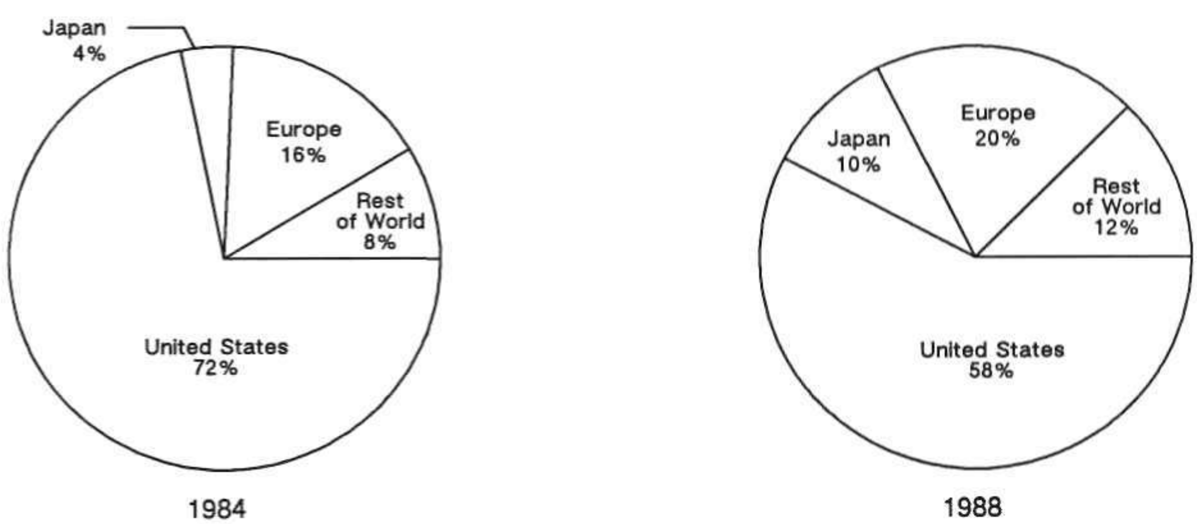
Globalization

Today's competitive environment is dictating that being a world-class manufacturer requires global manufacturing capability. In the future, it will become more difficult to enter a market without having established local manufacturing capabilities or access to them through an alliance.

Motorola is becoming an increasingly international company. Figure 3 shows that the percentage of the company's nondomestic revenue has increased significantly from 1984 to 1988. Motorola has extensive regional manufacturing capabilities. The company operates wafer fabrication facilities in six non-U.S. locations worldwide: Aizu and Sendai, Japan; East Kilbride, Scotland; Toulouse, France; Guadalajara, Mexico; and Seramban, Malaysia. In addition, it has several assembly facilities and five nondomestic design centers.

Figure 3

Motorola's Regional Market Share Based on Semiconductor Revenue (1984 and 1988)



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Source: Dataquest
July 1989

However, it is also instructive to look at the profile in Table 6 of the regional composition of Motorola's revenue in comparison with the other leading semiconductor manufacturers. Considered from a home-base viewpoint, Motorola is most comparable to Toshiba. Whereas Toshiba may target Europe for increased penetration, the table shows that Motorola should concentrate its resources on further penetrating the Japanese market. Currently, Motorola is expending a great deal of effort and expense in building an infrastructure in Japan in order to expand market share there. Motorola has recently opened a large new administrative headquarters building in Tokyo at considerable expense and has instituted a graduate program to recruit new hires from colleges, just as its Japanese counterparts are so adept at doing. In 1988, Motorola recorded a 70 percent revenue increase in Japan. This is an indicator that the company's pursuit of success in Japan is starting to pay off. Growth in this market, the largest semiconductor market in the world, is essential in order for Motorola to remain a broad-based supplier.

Table 6

1988 Estimated Semiconductor Revenue of Top Five Semiconductor Companies by Geographic Region (Millions of Dollars)

	U.S. Revenue	Percent of Semiconductor Revenue	Rank	Japanese Revenue	Percent of Semiconductor Revenue	Rank
NEC	$ 525	11.6%	8	$3,287	72.3%	1
Toshiba	$ 968	22.0%	4	$2,496	56.8%	2
Hitachi	$ 457	13.0%	9	$2,470	70.5%	3
Motorola	$1,770	58.3%	1	$ 290	9.6%	13
TI	$1,186	43.3%	3	$ 599	21.8%	10

	European Revenue	Percent of Semiconductor Revenue	Rank	ROW Revenue	Percent of Semiconductor Revenue	Rank	Worldwide Total Semiconductor Revenue
NEC	$387	8.5%	8	$344	7.6%	4	$4,543
Toshiba	$390	8.9%	9	$541	12.3%	1	$4,395
Hitachi	$246	7.0%	11	$333	9.5%	5	$3,506
Motorola	$616	20.3%	4	$359	11.8%	3	$3,035
TI	$647	23.6%	3	$309	11.3%	7	$2,741

Source: Dataquest
July 1989

Silicon Harbor Project

Table 6 pointed to ROW as a region where Motorola has achieved considerable success. This is not by accident—it is, rather, the result of concerted ongoing investments in the Asia/Pacific region. In 1988, Motorola broke ground for its Silicon Harbor project, a multistory semiconductor design and manufacturing facility on a 7.2-acre site near Hong Kong's Tolo Harbor. This represents the first major project in Hong Kong by a foreign-owned semiconductor company. It will serve both as Motorola's Asia/Pacific headquarters and as its springboard for penetration into the Chinese market. The Silicon Harbor facility will produce bipolar and MOS application-specific standard products, custom design, ASICs, and microprocessors. The project is estimated to cost several hundred million Hong Kong dollars and will help Motorola consolidate its position as a serious competitor in Asia, where it already is making significant headway.

Asia/Pacific

Currently in the Asia/Pacific region, Motorola has established 10 regional sales offices in seven countries and eight test/manufacturing plants in six countries. The company's two design centers located in Hong Kong and Taipei focus on local market needs.

The personal communications field is expected to represent a major opportunity in the 1990s, and Motorola is already strong in mobile radio communications equipment and cordless telephone ICs. With its expertise in both semiconductors and systems, as well as local presence, Motorola would appear to be well positioned for making further inroads in this product area in the future.

China

In China, Motorola will spend "multi-tens of millions of dollars," according to Chairman Robert Galvin, on two factories in Tianjian, the closest port to the capital city of Beijing. The plants will supply semiconductors and mobile radio equipment for the Chinese market and for export.

CHALLENGES

A major challenge facing Motorola is whether or not the company can be successful in all business areas, and, if not, where it will focus its resources.

Motorola has many strengths; the company is confident that it has both the vision and the resources to continue to position itself as a broad-based supplier of semiconductors. The company competes worldwide directly against its Japanese competitors in semiconductors and communications. Motorola enjoys strong customer relationships, a strong sales organization, good technical skills, and a solid balance sheet. Nevertheless, the challenges Motorola faces are many.

To support its contention of being a broad-based supplier, it was necessary that Motorola deal with the gaping hole that memories represented in its product portfolio. Trading members of its popular microcomponent product line with Toshiba for memory technology is not without risk, but the payoff is substantial if Motorola executes well. Motorola's intentions with respect to the memory market must, however, be long-term and committed, despite the vagaries of the market.

The need for increased presence in Japan has also been identified. An aggressive stance with respect to other world regions is meeting with success, but success in the world's largest semiconductor market is critical in order for Motorola to continue to rank among the top-tier semiconductor suppliers worldwide.

Although a relatively small market at this time, the programmable logic device (PLD) market is expected to grow rapidly and will affect the gate array business, where Motorola is very prominent. So although Motorola at this time has no presence in the PLD business, it is conceivable that the company may await standardization in the market before making a move, which Dataquest believes could possibly involve entering the market through an acquisition.

DATAQUEST CONCLUSIONS

Motorola believes that it has both the vision and the resources to position itself as a broad-based supplier. The scope of the company's activities leads Dataquest to conclude that it is committed to being a broad-based supplier by adhering to its policies of ensuring the timely availability of the requisite technologies, delivering superior service to clients (an area within the company's control), and working closely with key customers to better understand their system needs in guiding the company's standard and custom product development efforts. In more established and mature product areas, Motorola concentrates on ongoing cost savings in order to achieve a competitive edge and greater market penetration. Motorola recognizes that it cannot single-handedly support all the activities that it wishes to pursue and so has an aggressive strategic alliance policy with other semiconductor companies and with customers as a means of complementing its own capabilities.

However, the true test of how the sector is measuring up will be evidenced by performance according to these two major sector imperatives, which place Motorola's semiconductor strategy within the context of the overall company:

- Consistent, superior financial performance
- Market share gains worldwide

How successful Motorola is in these quantifiable objectives will determine how well the company is accomplishing its goals and its financial ability to pursue its ambitious strategy. It will take all the skill of Motorola's stable management to handle the company's resources for the best return on investment.

Patricia Galligan

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Source Code: K4

	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
WORLD MKT	8953	11106	14098	14801	15231	19537	28825	24341	30834	38251	50859	57213
U.S. COS	4953	6431	8062	7601	7829	9565	13948	11051	12809	14930	18586	19978
%	55.3%	57.9%	57.2%	51.4%	51.4%	49.0%	48.4%	45.4%	41.5%	39.0%	36.5%	34.9%
JAPANESE COS	2540	2861	3856	5252	5375	7583	11456	10144	14160	18450	25942	29809
%	28.4%	25.8%	27.4%	35.5%	35.3%	38.8%	39.7%	41.7%	45.9%	48.2%	51.0%	52.1%
EUROPEAN COS	1442	1789	2145	1903	1929	2215	3183	2851	3443	4200	4917	5443
%	16.1%	16.1%	15.2%	12.9%	12.7%	11.3%	11.0%	11.7%	11.2%	11.0%	9.7%	9.5%
ASIAN COS	18	25	35	45	98	174	238	295	422	671	1414	1983
%	0.2%	0.2%	0.2%	0.3%	0.6%	0.9%	0.8%	1.2%	1.4%	1.8%	2.8%	3.5%

Source: Dataquest

	1990
WORLD MKT	58414
U.S. COS	21307
%	36.5%
JAPANESE COS	28905
%	49.5%
EUROPEAN COS	6155
%	10.5%
ASIAN COS	2047
%	3.5%

Source: Dataq

TOTSEMI

Table 1
FINAL 1984 MARKET SHARE ANALYSIS
Total Semiconductor
(Millions of Dollars)

15-Feb-91

Company Base	North America	Japan	Europe	Asia/Pacific/ROW	World
	Regional Market				
North America	$9,767	$926	$2,548	$707	$13,948
Percent of Regional Market	75%	11%	52%	32%	48%
Percent of Company Sales	70%	7%	18%	5%	100%
Japan	$2,065	$7,787	$597	$1,007	$11,456
Percent of Regional Market	16%	89%	12%	46%	40%
Percent of Company Sales	18%	68%	5%	9%	100%
Europe	$1,157	$56	$1,717	$253	$3,183
Percent of Regional Market	9%	1%	35%	12%	11%
Percent of Company Sales	36%	2%	54%	8%	100%
Asia/Pacific	$17	$5	$2	$214	$238
Percent of Regional Market	0%	0%	0%	10%	1%
Percent of Company Sales	7%	2%	1%	90%	100%
World	$13,006	$8,774	$4,864	$2,181	$28,825
Percent of Regional Market	100%	100%	100%	100%	100%
Percent of Company Sales	45%	30%	17%	8%	100%

Source: Dataquest
May 1990

TOTSEM1

Table 1
FINAL 1985 MARKET SHARE ANALYSIS
Total Semiconductor
(Millions of Dollars)

15-Feb-91

Company Base	North America	Japan	Europe	Asia/ Pacific/ ROW	World
	Regional Market				
North America	$7,380	$695	$2,428	$548	$11,051
Percent of Regional Market	78%	9%	51%	28%	45%
Percent of Company Sales	67%	6%	22%	5%	100%
Japan	$1,279	$7,387	$549	$929	$10,144
Percent of Regional Market	14%	91%	11%	47%	42%
Percent of Company Sales	13%	73%	5%	9%	100%
Europe	$731	$60	$1,806	$254	$2,851
Percent of Regional Market	8%	1%	38%	13%	12%
Percent of Company Sales	26%	2%	63%	9%	100%
Asia/Pacific	$28	$7	$12	$248	$295
Percent of Regional Market	0%	0%	0%	13%	1%
Percent of Company Sales	9%	2%	4%	84%	100%
World	$9,418	$8,149	$4,795	$1,979	$24,341
Percent of Regional Market	100%	100%	100%	100%	100%
Percent of Company Sales	39%	33%	20%	8%	100%

Source: Dataquest
May 1990

TOTSEMI

Table 1
FINAL 1986 MARKET SHARE ANALYSIS
Total Semiconductor
(Millions of Dollars)

15-Feb-91

Company Base	North America	Japan	Europe	Asia/ Pacific/ ROW	World
	Regional Market				
North America	$8,566	$933	$2,580	$730	$12,809
Percent of Regional Market	79%	8%	46%	29%	42%
Percent of Company Sales	67%	7%	20%	6%	100%
Japan	$1,434	$10,851	$715	$1,160	$14,160
Percent of Regional Market	13%	92%	13%	46%	46%
Percent of Company Sales	10%	77%	5%	8%	100%
Europe	$751	$63	$2,282	$347	$3,443
Percent of Regional Market	7%	1%	41%	14%	11%
Percent of Company Sales	22%	2%	66%	10%	100%
Asia/Pacific	$93	$8	$10	$311	$422
Percent of Regional Market	1%	0%	0%	12%	1%
Percent of Company Sales	22%	2%	2%	74%	100%
World	$10,844	$11,855	$5,587	$2,548	$30,834
Percent of Regional Market	100%	100%	100%	100%	100%
Percent of Company Sales	35%	38%	18%	8%	100%

Source: Dataquest
May 1990

4

TOTSEMI

Table 1
FINAL 1988 MARKET SHARE ANALYSIS
Total Semiconductor
(Millions of Dollars)

15-Feb-91

Company Base	North America	Japan	Europe	Asia/ Pacific/ ROW	World
	Regional Market				
North America	$11,146	$1,965	$3,664	$1,811	$18,586
Percent of Regional Market	70%	9%	43%	31%	37%
Percent of Company Sales	60%	11%	20%	10%	100%
Japan	$3,277	$18,630	$1,466	$2,569	$25,942
Percent of Regional Market	21%	90%	17%	45%	51%
Percent of Company Sales	13%	72%	6%	10%	100%
Europe	$1,006	$115	$3,196	$600	$4,917
Percent of Regional Market	6%	1%	38%	10%	10%
Percent of Company Sales	20%	2%	65%	12%	100%
Asia/Pacific	$415	$62	$165	$772	$1,414
Percent of Regional Market	3%	0%	2%	13%	3%
Percent of Company Sales	29%	4%	12%	55%	100%
World	$15,844	$20,772	$8,491	$5,752	$50,859
Percent of Regional Market	100%	100%	100%	100%	100%
Percent of Company Sales	31%	41%	17%	11%	100%

Source: Dataquest
May 1990

TOTSEMI

Table 1
FINAL 1987 MARKET SHARE ANALYSIS
Total Semiconductor
(Millions of Dollars)

15-Feb-91

Company Base	North America	Japan	Europe	Asia/ Pacific/ ROW	World
	Regional Market				
North America	$9,671	$1,249	$2,845	$1,165	$14,930
Percent of Regional Market	75%	8%	44%	29%	39%
Percent of Company Sales	65%	8%	19%	8%	100%
Japan	$2,110	$13,588	$900	$1,852	$18,450
Percent of Regional Market	16%	91%	14%	47%	48%
Percent of Company Sales	11%	74%	5%	10%	100%
Europe	$913	$70	$2,714	$503	$4,200
Percent of Regional Market	7%	0%	42%	13%	11%
Percent of Company Sales	22%	2%	65%	12%	100%
Asia/Pacific	$164	$20	$39	$448	$671
Percent of Regional Market	1%	0%	1%	11%	2%
Percent of Company Sales	24%	3%	6%	67%	100%
World	$12,858	$14,927	$6,498	$3,968	$38,251
Percent of Regional Market	100%	100%	100%	100%	100%
Percent of Company Sales	34%	39%	17%	10%	100%

Source: Dataquest
May 1990

Table 1
FINAL 1989 MARKET SHARE ANALYSIS
Total Semiconductor
(Millions of U.S. Dollars)

Company Base	Regional Market: North America	Japan	Europe	Asia/ Pacific/ ROW	Worldwide
North American Companies	$11,715	$2,162	$4,032	$2,069	$19,978
Percent of Regional Market	65%	9%	41%	32%	35%
Percent of Company Sales	59%	11%	20%	10%	100%
Japanese Companies	$4,574	$20,628	$1,924	$2,683	$29,809
Percent of Regional Market	26%	90%	20%	41%	52%
Percent of Company Sales	15%	69%	7%	9%	100%
European Companies	$1,025	$130	$3,562	$726	$5,443
Percent of Regional Market	6%	<1%	37%	11%	10%
Percent of Company Sales	19%	2%	66%	13%	100%
Asia/Pacific Companies	$623	$77	$237	$1,046	$1,983
Percent of Regional Market	3%	<1%	2%	16%	3%
Percent of Company Sales	31%	4%	12%	53%	100%
Worldwide	$17,937	$22,997	$9,755	$6,524	$57,213
Percent of Regional Market	100%	100%	100%	100%	100%
Percent of Company Sales	31%	40%	17%	12%	100%

Source: Dataquest
May 1990

Table 1
FINAL 1990 MARKET SHARE ANALYSIS
Total Semiconductor
(Millions of U.S. Dollars)

Company Base	Regional Market: North America	Japan	Europe	Asia/ Pacific/ ROW	Worldwide
North American Companies	$11,942	$2,402	$4,492	$2,701	$21,537
Percent of Regional Market	69%	11%	42%	35%	37%
Percent of Company Sales	55%	11%	21%	13%	100%
Japanese Companies	$3,777	$19,825	$1,814	$2,961	$28,377
Percent of Regional Market	22%	88%	17%	39%	49%
Percent of Company Sales	13%	70%	6%	11%	100%
European Companies	$1,074	$164	$4,117	$851	$6,206
Percent of Regional Market	6%	<1%	39%	11%	11%
Percent of Company Sales	17%	3%	66%	14%	100%
Asia/Pacific Companies	$593	$117	$238	$1,157	$2,105
Percent of Regional Market	3%	<1%	2%	15%	3%
Percent of Company Sales	28%	6%	11%	55%	100%
Worldwide	$17,386	$22,508	$10,661	$7,670	$58,225
Percent of Regional Market	100%	100%	100%	100%	100%
Percent of Company Sales	30%	39%	18%	13%	100%

Source: Dataquest
May 1990

COMPONENTS GROUP

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Research Bulletin

TI ALLIANCE TARGETS HDTV: THE CONSUMER MARKET BECKONS

INTRODUCTION

Anyone who has read a newspaper, not to mention a trade press periodical, in the last year must know by now that the advent of improved-definition TV (IDTV), enhanced-definition TV (EDTV), and high-definition TV (HDTV) has refocused U.S. interest on an estimated $170 billion 1988 consumer market largely lost to the Japanese. Texas Instruments (TI) has announced an important next step in its overall strategy to penetrate the advanced vision systems (AVS) segment of the semiconductor consumer market, which it believes will be the system's technology driver of the 1990s.

THE AGREEMENT

Texas Instruments Japan, Limited, has signed an agreement with Nippon Hoso Kyokai (NHK), the Japan Broadcast Corporation, for its MUSE or "Hi-vision" advanced TV receiver technology. Transferring NHK's technology to TI will involve an explanation of the decoder, transfer of the transistor-level logic circuit diagrams and enabling memory codes, and review of the circuits comprising the MUSE system. TI will use this acquired system knowledge to develop chip sets to participate in these three HDTV markets based on different standards: MUSE in Japan, HD-MAC in Europe, and the future U.S. HDTV standard. Financial details of the agreement were not revealed, although it was made known that TI will pay for the technology transfer.

TI'S STRATEGY

Why is TI pursuing this market? The significance of HDTV cuts across many of TI's strategic thrusts, particularly as it concerns the following:

- TI's identity as a Japanese supplier
- The importance of the consumer electronics market
- The technology benefits of HDTV to TI's semiconductor business

In 1988, TI's semiconductor sales to the Japanese market totaled approximately $600 million, an increase over the previous year of almost 50 percent. TI is now the 10th largest Japanese semiconductor supplier and the largest U.S. participant in the Japanese semiconductor market. Given TI's identity as a Japanese company, its thrust into the AVS market is headed by Masa Hayashida of TI Japan, who will be supported by TI's worldwide resources. From a trade perspective, TI's approach answers one of the product deficiencies often cited by Japanese companies as reasons for not purchasing more U.S. semiconductors—that U.S. semiconductor companies do not produce the consumer devices they need.

Although it may not be associated readily with the consumer electronics market, TI recognizes that this is a market it cannot afford to ignore—for many reasons. Aside from the sheer dollar volume represented by this market, the economies of scale associated with it are in keeping with TI's role as a commodity semiconductor manufacturer. As Pat Weber, president of TI's Semiconductor Group, noted during the company's recent Technology Trends Seminar, "The consumer market hones TI's quality and cost performance." From the standpoint of specific semiconductor product areas, TI believes that the consumer market will be increasingly important to success in analog ICs. Even in a product area like DRAMs, so closely identified with the data processing market,

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TI believes that noncomputer applications will account for approximately 40 percent of the memory market by the mid-1990s.

The Ripple Effect

Aside from its importance to consumer electronics, HDTV, in TI's words, "will emerge as a large market with broad implications for the entire electronics industry." Dataquest believes, as does TI, that HDTV will permeate other industries such as training and simulation, films, medicine, telecommunications, and the military/aerospace industry. Through this agreement, TI will also pursue complementary AVS segments including high-performance audio systems, video camcorders, advanced cameras, and video tape recorders. With roughly one-third of its business coming from the defense industry, a market currently in decline, addressing these other markets takes on added significance for TI.

Also significant are the spin-off semiconductor technologies that will be driven by HDTV—technologies that address a spectrum of TI's product offerings in memories, microcomponents, DSP, and analog. Examples of such products include 200- to 300-MBps processors, video processor chips, A/D converters, video frame storage devices, fiber-optic transceivers, and advanced compression and processing algorithms for signal processing.

Perhaps most important to TI's position in data processing is its vision of HDTV as the vehicle by which computers will become pervasive in the home—integrating telecommunications, entertainment, and data processing. This convergence would represent a quantum leap over the personal/home computer as we understand it today. With the market opportunities that this would create, it is not surprising that TI seems to be positioning itself to be a major supplier of components to the PC market. Evidence of this can be gleaned from current activities at TI, which include:

- The development of software automation tools aimed at creation of object-oriented data bases
- The relationship between TI's concept of hypermedia as the new user-interface paradigm and its efforts in high-performance PC chip sets, graphics chip sets, DSP, and speech synthesis
- Its entry into 32-bit RISC microprocessors through an alliance with Sun Microsystems
- TI's contract from the Defense Advanced Research Procurement Agency (DARPA) to develop a semiconductor process technology for display generation

Dataquest Conclusions

Dataquest believes that HDTV and the intermediate markets of IDTV and EDTV represent a significant opportunity for U.S. companies. More is at stake than the considerable revenue associated with the consumer TV market. Although the ancillary market opportunities are strategically important, the long-term implications for the mainstay of the U.S. electronics market—data processing—makes U.S. participation in this market a strategic imperative. These issues are discussed in detail in a Dataquest report entitled *High-Definition Video Technology: The Collision between Television and Computers*.

Michael Boss
Patricia Galligan

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Research Newsletter

QUARTERLY SEMICONDUCTOR COMPANY FINANCIAL RESULTS

INTRODUCTION

Dataquest regularly reports on semiconductor company financial results through its weekly on-line news service, *The DQ Monday Report*. As a service to the Products, Markets, and Technology segment binderholders, a summary of this information is provided herein.

Table 1 summarizes the net sales and income disclosures from selected semiconductor companies based on data from quarterly report periods that ended during the May through July time frame. This information is compared with the 1988 May through July time frame and is provided in millions of dollars. Table 2 provides a similar summary for fiscal year revenue and income for applicable

TABLE 1
Quarterly Financial Summaries for Selected Semiconductor Companies (Millions of Dollars)

Company	End of Quarter	Quarter Revenue	Percent Change*	Quarter Income	Percent Change*
Adaptec	(6/30, Q1)	$ 23.2	65%	$ 2.0	581%
AMD	(6/25, Q2)	$ 274.9	(11%)	$ 12.1	(54%)
Altera	(6/30, Q2)	$ 14.5	57%	$ 2.6	42%
Burr-Brown	(7/1, Q2)	$ 44.1	(4%)	$ 2.1	(32%)
Chips & Technologies	(6/30, Q4)	$ 61.8	43%	$ 10.1	60%
Cirrus Logic	(6/30, Q1)	$ 14.8	142%	$ 2.5	3,748%
Cypress	(7/3, Q2)	$ 50.6	58%	$ 7.6	62%
Intel	(7/1, Q2)	$ 747.3	3%	$ 99.3	(24%)
Linear Tech.	(7/2, Q4)	$ 17.7	21%	$ 2.4	12%
IDT	(7/2, Q1)	$ 51.6	19%	$ 5.2	2%
Logic Devices	(6/30, Q2)	$ 4.0	140%	$ 0.8	241%
LSI Logic	(7/2, Q2)	$ 140.9	52%	$ 4.5	(38%)
Maxim Integrated Products	(6/30, Q4)	$ 11.7	39%	$ 1.5	23%
Motorola	(6/30, Q2)	$2,385.0	14%	$154.0	28%
National Semiconductor	(5/28, Q4)	$ 419.1	**	$ 77.1	244%
Texas Instruments	(6/30, Q2)	$1,563.5	**	$106.1	16%
Weitek Corporation	(7/1, Q2)	$ 11.5	37%	$ 1.6	90%
Western Digital	(6/30, Q4)	$ 243.5	12%	$ 4.3	(707%)
VLSI Technology	(7/2, Q2)	$ 70.7	32%	$ 0.7	(76%)
ZyMOS Corporation	(6/30, Q2)	$ 8.5	68%	($ 0.3)	N/M

*Compared with corresponding period a year ago
**Negligible change, less than 1 percent
N/M = Not Meaningful

Source: Company Literature

SIS Newsletters 1989 Executive Issues

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TABLE 2
Fiscal Year Financial Summaries for Selected Semiconductor Companies (Millions of Dollars)

Company	Fiscal Year Revenue	Percent Change*	Fiscal Year Income	Percent Change*
Chips & Technologies	$ 217.6	54%	$33.0	49%
Linear Technology	$ 64.7	26%	$ 8.9	**
Maxim Integrated Products	$ 42.1	49%	$ 5.5	55%
National Semiconductor	$1,647.9	15%	($23.2)	N/M
Western Digital	$ 992.1	29%	$58.7	3%

*Compared with corresponding period a year ago
**Negligible change, less than 1 percent N/M = Not Meaningful

Source: Company Literature

companies. Descriptive summaries of quarterly performance highlights for the companies listed follow these tables.

ADAPTEC, INC.

Adaptec announced its second quarter of record revenue. According to the company's CFO, Paul G. Hansen, Adaptec has been experiencing increasing shipments of its SCSI products, as well as improved manufacturing efficiencies at the recently established Singapore facility. The company anticipates a continuing trend of increasing revenue and profitability. Adaptec's cash balance and line of credit will provide the company with sufficient resources to fund ongoing expansion programs during the second quarter.

ADVANCED MICRO DEVICES, INC.

Although Advanced Micro Devices (AMD) reported financial results that showed an improvement over its first quarter results, sales and income were hit quite hard when compared with the same quarter a year ago. AMD's chairman and CEO, W.J. Sanders III, noted that the company shipped 80286 microprocessors in record volumes. Demand for programmable logic devices (PLDs) was recovering, but EPROM shipments, although up, were under considerable price pressure. Mr. Sanders said that AMD would continue to manage its business very closely, especially given the expectation that the company would see flat revenue for the rest of the year.

ALTERA CORPORATION

Results for Altera's second quarter included a nonrecurring charge of $300,000 associated with restructuring of the company's facilities leases. These results marked Altera's 10th consecutive quarter of record profits. Company chairman and CEO, Rodney Smith, stated that the overall order rate was strong throughout the quarter.

BURR-BROWN CORPORATION

The company attributed its decline in earnings to the rapid dollar appreciation during the quarter. With almost 70 percent of its business overseas, Burr-Brown tends to be very sensitive to currency shifts. If currency effects were eliminated, the company would have experienced sales growth of approximately 3 percent over the second quarter of 1988. Orders booked in the quarter were down approximately 9 percent from the first quarter and 7 percent from the corresponding quarter a year ago.

CHIPS & TECHNOLOGIES, INC.

In fiscal 1989, Chips & Technologies (C&T) invested more than 15 percent of sales in product design and development. According to the company, its CHIPset solutions are being well accepted by the PC AT market segment. Record bookings during the fourth quarter mean that the company is entering its new fiscal year with a very healthy backlog. C&T president Gordon A. Campbell said that based on a strong product portfolio, a substantial order backlog, and a high level of design-in activity, the company is optimistic about its growth prospects during the upcoming fiscal year.

CIRRUS LOGIC, INC.

Michael L. Hackworth, president and CEO of Cirrus Logic, said that this quarter's sales were higher than expected because of a more rapid phase-in of extra production capacity. Overall, incoming orders continued to be strong both in the company's display graphics and mass storage businesses, and progress in the Japanese marketplace was encouraging.

CYPRESS SEMICONDUCTOR CORPORATION

The company achieved its 22nd consecutive quarter of increasing revenue. Cypress Semiconductor believes that an ongoing ability to bring new products to market will be helpful in maintaining the company's revenue growth in the upcoming quarters. Fifteen new products were introduced in the second quarter. Cypress also set another bookings record for the quarter.

INTEL CORPORATION

Income for the second quarter, although up slightly from the first quarter of 1989, was down significantly from the same quarter a year ago. This quarter's results include a $17 million charge to cover costs associated with the planned closing in 1990 of an old wafer fabrication facility in Livermore, California. Intel will try to place the 400 employees affected by the closure in other company plants. According to Intel, second quarter orders were higher than those in the first quarter, with a book-to-bill ratio slightly above 1:0. New orders for advanced microprocessors and 1Mb EPROMs were strong. Intel employees will receive cash bonuses totaling $14 million for the first half of fiscal 1989.

LINEAR TECHNOLOGY CORPORATION

Although the company recorded a 26 percent increase in sales for fiscal 1989, net income was down slightly from the previous year. However, during 1988, the company benefited by a $2 million tax net operating loss carryforward, so on a comparative basis (exclusive of the tax benefits) income for fiscal 1989 increased 29 percent over the prior year. Linear Technology increased its international sales presence by adding personnel to existing offices in addition to opening two new offices in the Far East. At the same time, the company announced approval by its Board of Directors of a company stock repurchase plan that is intended to offset dilution in share ownership resulting from employee stock option and stock purchase plans.

INTEGRATED DEVICE TECHNOLOGY, INC.

Integrated Device Technology (IDT) announced record sales in its first quarter. The company described itself as cautiously optimistic, and demand for its products is such that it is continuing to ramp-up production at a moderate rate. IDT expects to continue to grow in the current quarter.

LOGIC DEVICES, INC.

The company reported record net sales and income for its second fiscal quarter. However, company president Bill Volz cautioned that should the current softness continue, third quarter results would not be able to sustain such growth rates. Second-quarter results mark the 15th consecutive quarter of profitability for the company, which supplies SRAMs, DSP devices, and math coprocessors.

LSI LOGIC CORPORATION

According to Wilfred J. Corrigan, chairman and CEO of LSI Logic, earnings did not meet expectations in the second quarter because total revenue grew more moderately than anticipated. Consequently, factory utilization was lower than expected. The company did, however, set a record in new orders. In response to a more cautious business outlook among its customers, Mr. Corrigan said that LSI Logic would be controlling costs closely.

MAXIM INTEGRATED PRODUCTS, INC.

Maxim reported record revenue for its fourth fiscal quarter, which ended in June. According to the company, its fourth-quarter bookings substantially exceeded both third-quarter bookings and fourth-quarter shipments. Jack Gifford, president and CEO, stated that increasing demand for the company's new products in all major world regions contributed to Maxim's continued growth.

MOTOROLA INC.

Motorola posted record results for its second quarter, although margins declined in the communications and semiconductor sectors. Sales for the semiconductor products sector grew 9 percent, new orders rose 11 percent, and backlog increased. However, George Fisher, president and CEO, said that because of competitive pricing in discrete and standard logic products and increased R&D expenditure, operating profits were flat. Orders increased in all major market regions, led by Asia/Pacific's continued growth in the consumer, communications, and personal computer industries. The computer, industrial, and military segments were slightly higher in orders, while automotive, consumer, and distribution orders declined.

NATIONAL SEMICONDUCTOR CORPORATION

National Semiconductor Corporation released fourth quarter and fiscal year 1989 results from continuing operations this week. Results from fiscal 1989 and 1988 have been restated to reflect the sales of National Advanced Systems (NAS) and Datachecker Systems. For the quarter that ended May 28, National's revenue decreased slightly, to $419.1 million, over fourth quarter a year ago. Income of $77.1 million showed a marked improvement over the previous year, recording an increase of 244 percent. These results include a post-tax gain of approximately $175 million from the sale of NAS, which offset operating losses of almost $98 million in the quarter. (This is inclusive of a one-time restructuring charge of approximately $45 million related to the consolidation of manufacturing capacity.) The company reported a net loss for fiscal year 1989 of $23.2 million on revenue of $1.6 billion as compared with income of $62.7 million from fiscal year 1988 revenue of $1.4 billion. National's president and CEO, Charles Sporck, commented that the company saw marked improvement in the fourth quarter, and this improvement in performance is expected to continue into first quarter 1990. The company should return to profitability in the second quarter of fiscal 1990.

TEXAS INSTRUMENTS, INC.

Company revenue for the quarter essentially was unchanged compared with the same quarter a year ago. Semiconductor sales by Texas Instruments (TI) were up slightly over last year, but increases in semiconductor memory sales were essentially offset by weakness in demand for bipolar products and the effect of currency changes. TI's orders of $1.3 billion for the second quarter were down 5 percent over the same period last year and down 9 percent in semiconductors. Results for the quarter also included royalty income of $63 million from patent license agreements. President and CEO Jerry Junkins stated that, in response to what TI views as a period of slower growth in its major markets, the company would continue tight control of operating expenses and reduction of product costs while maintaining a high level of R&D to strengthen the company's technology base and deliver new products.

VLSI TECHNOLOGY, INC.

Although VLSI Technology's reported net income of $705,000 represents a marked improvement over the loss of $6.2 million reported in the first quarter, these results still were affected by the company's efforts to recover from the last quarter's problems concerning the delay of the San Antonio, Texas, fab's production schedule and capacity constraints. However, VLSI achieved record levels of new bookings, which means the company is entering its third quarter with a strong backlog. According to the company, order strength was broadly based across virtually all product lines and geographical markets, and the company's overall business outlook remains quite good.

WEITEK CORPORATION

Weitek reported record sales and income in its second fiscal quarter, which ended July 1. Company president Arthur Collmeyer attributes Weitek's strong financial performance to its success in the ultrahigh-performance numeric processing business, in which the company specializes.

WESTERN DIGITAL CORPORATION

Roger W. Johnson, chairman, president, and CEO of Western Digital, characterized the company's fiscal year revenue as essentially flat, attributing this to slower growth rates in the PC industry and several major internal product and technology transitions. Mr. Johnson stated that overall results were adversely affected by the unprofitable performance of the integrated systems line and, to a lesser extent, the disk drive line. Mr. Johnson also noted, however, that a combination of cost improvement measures, along with increased orders for core logic chip sets, should result in improved performance of the integrated systems product line.

ZYMOS CORPORATION

A company spokesperson attributed the second quarter net loss to the cost of developing, producing, and introducing new products. The net loss of $324,000, although down significantly from a $476,000 loss for the second quarter of 1988, was up from first quarter 1989's loss of approximately $188,000. However, having achieved operating profitability over the past two quarters, the company is making progress and anticipates a strong second half of the year.

Patricia Galligan

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FOR SILICON VALLEY FABS, THE QUAKE WAS A HICCUP

SUMMARY

Dataquest clients in Europe and Asia recently witnessed scenes of shocking devastation in the wake of the earthquake that struck Northern California on Tuesday, October 17. Many of our clients are wondering what effect the quake had on Silicon Valley chipmakers. Dataquest analysts have been in touch with a number of semiconductor suppliers in the San Francisco Bay Area and are pleased to report that for the most part, it is "business as usual" in the Silicon Valley.

ASSESSING THE DAMAGE

Tuesday's earthquake, which registered 7.1 on the Richter scale, certainly was the cause of a great deal of personal tragedy—the horror of which has been well documented by the international press. It must be remembered, however, that the worst of the quake damage was fairly localized. Silicon Valley chipmakers (and many of their major systems customers) have the good fortune of being located in areas less affected by the quake, such as San Jose, Santa Clara, and Sunnyvale. Based on conversations with our semiconductor manufacturing clients, Dataquest analysts report the following:

- Silicon Valley wafer fabs received little or no structural damage. Temporary losses of power caused the cancellation of production shifts immediately following the earthquake. As far as we know, all local manufacturers were back to full production schedules as of Thursday, October 19.

- Some semiconductor suppliers reported damage to pipes conveying gases and chemicals. National Semiconductor, for example, was forced to make immediate repairs to a waste treatment plant. No significant leaks were otherwise reported.

- As one might imagine, the earthquake created some yield problems for in-process wafers. In some cases, companies scrapped boats of wafers. The net effect on production, according to local chip manufacturers, should not result in lead time problems or order cancellations. Despite the disruption to production shifts, most sales and administration staff were back at their offices the day after the quake. The power outages and disruptions to communications that continue to plague other areas affected by the quake have spared Silicon Valley.

- One problem that is affecting almost all Silicon Valley companies is the ability of their employees to get to work. Portions of several major arteries into the area from outlying communities were damaged. The closing of some Bay Area schools, although temporary, also caused working parents to miss time from their jobs in order to arrange for child care. In addition, employees residing in some of the hardest-hit areas sustained damage to their homes. In communities such as Los Gatos and Santa Cruz, some residences were completely destroyed. It is estimated that up to 10,000 people are homeless in the Santa Cruz area, less than one hour's commute time from Silicon Valley. The effects of these dislocations on the personal lives of a number of Silicon Valley workers may linger for some time.

SOME EQUIPMENT COMPANIES ARE HARDER HIT

The damage assessments reported from electronic equipment manufacturers in the Bay Area are fairly consistent with those from their semiconductor vendors. There are some exceptions, however. According to a report in The Wall Street Journal (Thursday, October 19), Hewlett-Packard sustained damage estimated in millions of dollars and will experience a "minimal suspension" of manufacturing activity for an indefinite period. Flooding caused by broken water pipes closed IBM's storage device plant in San Jose. Apple Computer received damage to a building in Cupertino that was formerly owned by Four Phase. For the most part, however, a return to full production by local manufacturers typically was expressed in terms of days.

THE WAKE OF THE QUAKE

For clients unfamiliar with the San Francisco Bay region, of which the Silicon Valley is a part, the pattern of destruction caused by the second-strongest earthquake in the area's history may seem arbitrary. It is not, however, only a matter of randomness that Silicon Valley was less affected than San Francisco, which is farther away from the quake's epicenter. For one thing, buildings constructed in the Silicon Valley typically are newer than those in San Francisco and were built to conform to stringent codes regarding earthquake safety. As stated by a report from the Santa Clara County Manufacturing Group, released on October 19, "...our industry sustained relatively minor damage due to the newness of our facilities, the fact that many of our building and chemical areas have been reinforced for earthquakes, and because our companies do extensive training for their emergency response teams."

MORE THAN MEETS THE EYE

The extent to which the Silicon Valley was spared the fate of harder-hit areas of Northern California can be appreciated from damage estimates that just now are being reported. While these estimates vary from $5 billion to $10 billion, the estimated damage to Santa Clara County (the home of Silicon Valley) currently has been placed at about $220 million—with a good portion of this estimate reflecting the extensive damage in the town of Los Gatos.

Although reports from major Silicon Valley chipmakers have been positive thus far, one wonders if an uglier reality lurks below their surface. While the possible long-term effects of the quake are difficult for us to speculate on, the fact remains that the Silicon Valley's chipmaking foundation rests on seismically unstable soil. The thought of sensitive wafer fab equipment such as CVD furnaces, steppers, and ion implantation machines being shaken around during the earthquake and its numerous aftershocks conjures up the possibility that local fabs may not yet have achieved a complete return to prequake yields.

DATAQUEST CONCLUSIONS: AN ARGUMENT FOR DECENTRALIZATION

The October 17 earthquake occurred in the middle of Dataquest's annual Semiconductor Industry Conference, which was held in Monterey, California—a location closer to the quake's epicenter than San Francisco. For our clients, this conference was surely one to remember, and Dataquest is grateful that they suffered nothing beyond anxiety. Ironically, the quake underscored our conference theme of "globalization." Consider the example of National Semiconductor: with only 8 of its 23 worldwide manufacturing operations located in the Silicon Valley, a less fortunate outcome of the quake would not necessarily have been disastrous for its clients. With more semiconductor suppliers placing production closer to the regions they serve, damage to any given facility can be countered by shifting capacity to another. This flexibility should be a comforting thought to semiconductor users. After all, uncertainty is not just a fact of life for those of us living in the shadow of a killer quake.

Michael J. Boss

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PMT Executive Memo

BELOW THE ICEBERG'S TIP: THE LOSS OF DOMESTICALLY OWNED SILICON WAFER SUPPLY

SUMMARY

In the U.S. semiconductor market, much of the editorial energies of 1988 have been spent over the issues of DRAM availability and the dependence of U.S. systems manufacturers on a handful of key Japanese vendors. Sermons warning of the dangers of this dependency have been delivered from a number of pulpits: the press, the Defense Science Board, Sematech, the Semiconductor Industry Association, and the American Electronics Association, not to mention the less publicized misgivings of some U.S. electronics companies.

As an admonitory example of the dangers of market share erosion, however, the state of domestic DRAM supply may be just the tip of a larger, more ominous, technology iceberg. During the final months of 1988, two announcements were made that portend a major change in the regional ownership of the merchant silicon and epitaxial wafer market. The first announcement, made in November 1988, was that Monsanto Company had agreed to sell its silicon operations (the Monsanto Electronic Materials Company) to Huels AG of West Germany. The second announcement, made less than a month later, was that Osaka Titanium Company, Ltd. (OTC) of Japan had entered into negotiations to purchase the semiconductor materials division of Cincinnati Milacron, one of the largest suppliers of epitaxial wafers in the United States.

This newsletter, the first in an ongoing series of editorial pieces designed exclusively for subscribers to the Products, Markets and Technology (PMT) segment of Dataquest's Semiconductor Industry Service (SIS), offers some analysis on the current state of domestic silicon wafer supply in light of the Monsanto and Cincinnati Milacron announcements.

LOSING MARKET SHARE

The impact of both the Monsanto and Cincinnati Milacron acquisitions on the regional composition of silicon wafer supply ownership is illustrated in Table 1. Based on 1987 market analysis by Dataquest's Semiconductor Equipment and Materials Service (SEMS), the market share of U.S.-owned merchant silicon wafer companies will drop to 2 percent worldwide—with a mere 8 percent of the domestic market—if the two acquisitions are approved.

Table 1

Shifts in Market Shares of Regionally Owned Merchant Silicon and Epitaxial Wafer Companies

	1987 Actual Share	With Monsanto Acquisition	With Cincinnati Milacron Acquisition
World Market Share			
Japanese Companies	70%	70%	72%
European Companies	16%	26%	26%
U.S. Companies	14%	4%	2%
United States Market Share			
Japanese Companies	32%	32%	40%
European Companies	23%	52%	52%
U.S. Companies	45%	16%	8%

Source: Dataquest
February 1989

WHO'S LEFT?

With the acquisition of Monsanto' and Cincinnati Milacron's wafer divisions, silicon production by U.S.-owned merchant suppliers will drop below the level of captive silicon production in the United States. This will leave eight merchant suppliers under U.S. ownership: Crysteco, Epitaxy, Inc., General Instruments Power Semiconductor Division, M/A-COM Semiconductor Products, Pensilco, Recticon, Spire Corp., and Virginia Semiconductor. These companies, with 1987 world sales ranging from $1.0 million to $9.5 million, are small, niche-oriented market participants. In addition to these, four captive silicon producers—AT&T, IBM, Motorola, and Texas Instruments—have internal silicon operations to supply some portion of their own requirements.

DEEP-POCKET REQUIREMENTS

Looking at the market share ranking of merchant silicon wafer suppliers in the Table 2, it becomes apparent that all of the major merchant silicon companies in the world today have large corporate parents. This type of relationship provides a cash flow buffer against downturns in the business cycle as well as a source of funding for new facilities and capacity expansions. In today's business environment, it is not clear that a standalone entrepreneurial silicon operation could compete and survive against the major silicon suppliers with their deep-pocket parents.

Table 2

Top Five Merchant Silicon Suppliers after the Monsanto/Cincinnati Milacron Acquisitions Based on 1987 Worldwide Revenue (Millions of Dollars)

Ranking			1987 Sales Reflecting
Before	After	Company	Acquisition
1	1	Shin-Etsu Handotai	$484.7
3	2	Osaka Titanium Co.	$259.5
2	3	Mitsubishi Metal	$265.3
8	4	Huels AG	$248.0
4	5	Wacker	$214.8

Source: Dataquest
February 1989

Both Monsanto and Cincinnati Milacron's wafer divisions were part of larger, diversified businesses whose funding and strategic vision could extend beyond the current business cycle. The fact that they are being sold by their larger parent companies is a repetition of an increasingly familiar refrain in U.S. business. Rather than emulating the vertical integration and divisional synergies of their international competitors, U.S. companies seem more driven than ever to divest themselves of businesses that are peripheral to the markets they dominate, or that do not have the kind of immediate growth potential that will appeal to investors.

Positioned as a major manufacturer of robots and metrology and inspection systems for industrial automation applications, Cincinnati Milacron may have asked itself if owning an epitaxial wafer division made sense. Positioned as a supplier of key materials, OTC may have asked the same question. The difference in the two answers has some disturbing long-term consequences for the U.S. semiconductor industry, itself a supplier of strategic components. The absence of large, U.S. companies with a long-term strategic commitment to the critical materials requirements of the domestic chip industry creates a dependency on offshore supply that should give cause for concern.

STRATEGIC IMPLICATIONS

Recognition of the strategic importance of domestically owned merchant silicon wafer production, whatever its merits as a business venture, may have some impact on the successful conclusion of the Monsanto and Cincinnati Milacron deals. One of the concerns of the current DRAM situation has been that U.S. computer companies may not be able to rely on their Japanese suppliers, also computer manufacturers, to share their most advanced IC technology. The same argument can certainly be applied to the basic materials that enable production, regardless of the offshore origin of the supplier.

In light of this, the foreign acquisitions of the leading U.S. silicon wafer manufacturer (Monsanto Electronic Materials Company) and one of the largest epitaxial wafer producers (Cincinnati Milacron's epi wafer division) may encounter a brick wall in the form of the recently passed Omnibus Trade Bill. The trade bill amends Title VII of the Defense Production Act of 1950, allowing the president of the United States to block a foreign acquisition if it is determined, upon investigation, that U.S. national security is compromised.

DATAQUEST CONCLUSIONS

In early November, Dataquest analysts spent two days in research visits with corporate and product management at Motorola Inc. Part of one day was spent at Motorola's new MOS 6 fab, which will bring up the 1Mb DRAM process gained from the company's technology agreement with Toshiba. Although excited about the prospects of stepping back into the DRAM business, Motorola representatives expressed concern over yet another issue of dependency: In order to bring the Toshiba process up at MOS 6, Motorola has had to use materials and equipment from Japanese suppliers. Even with its own captive silicon operations, recent events in the merchant silicon wafer market have, no doubt, given Motorola something else to worry over.

There is, however, a big difference between the loss of domestic supply versus the loss of domestically owned suppliers in a key materials area. The difference apparently has not been lost on the Departments of Defense and Commerce of the U.S. government—as of this writing, a governmental task force has recommended to the president that Huels AG be allowed to go through with its acquisition of Monsanto's Electronic Materials Company. The rationale: Since no viable alternative exists in the form of a domestic interest in the company, a foreign owner would at least inject needed capital into the operation, thus preserving it as a domestically based source of production. U.S. semiconductor manufacturers, in light of their renewed commitment to regaining technological leadership through consortia efforts such as Sematech, must now give serious consideration to whether this is assurance enough for them.

Michael J. Boss

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PMT Executive Memo

THE NEC/INTEL JUDGEMENT: WHAT DOES IT MEAN?

SUMMARY

At the end of a bout of courtroom pugilistics, such as we observed in the NEC/Intel trial, one looks for the court to raise the gloved hand of a contestant and declare, "The Winner." In reality, however, understanding just what was won and by whom may not be so straightforward—and in the case of the court's decision on the NEC/Intel copyright infringement case, both sides have declared victories! Let's take a closer look at the implications of Judge William Gray's recent decision for both the litigants and the industry.

At first glance, NEC's declaration of victory seems the more credible. Since the beginning of the trial, NEC had claimed that it merely needed to win one of the many issues before the court (copyrightability of microcode, infringement, Intel's forfeiture of copyright, and the status of the V20/30 as "improvements" over the µPD 8086/88), while Intel needed to win on all. As it turns out, NEC scored on both the forfeiture and infringement issues.

But what has NEC actually "won?" To be sure, a legal cloud has been lifted from its V20 and V30 microprocessors. Although the V30 has been designed into some laptop PC models, both the V20 and V30, along with their Intel counterparts, have now been eclipsed technologically. Well before Judge Gray's decision, NEC had introduced a "hardwired" version of the V30, the V33, which in addition to bypassing the need for microcode, significantly outperforms the older V30 device. It is unlikely, therefore, that the recent court decision will dramatically increase the number of V20/30 devices sold in the United States. NEC does, however, believe that its courtroom victory will make its V40 and V50 microprocessors more appealing design-in choices for embedded control applications. Here NEC can compete with Intel without being hobbled by the onus of litigation.

NEC's victory on the issue of infringement creates another possibility: the pursuit of its countersuit against Intel on the charges of anticompetitive business practices. Here, NEC's assessment of the financial impact of Intel's suit on its V-Series devices may determine whether or not it wishes to press forward with this suit. Given the company's size relative to the damages it might collect, the need to focus its energies on expanding products and markets, and its relationship with Intel as a major customer, NEC may find the old axiom, "Quit while you're ahead," to be particularly appropriate to the situation. Foregoing further legal action would also yield better PR than going after the shining star of the Silicon Valley.

WHAT DID INTEL LOSE?

The most obvious question following Judge Gray's decision concerns just what Intel might have lost, since it was not only ruled that NEC was innocent of infringement on Intel's copyright on its 8086/88 microcode, but that Intel lost its copyright to begin with as a result of omissions in the affixing of the copyright notice. In view of this decision, it is possible that Intel's numerous second sources will be considering whether there is any further sense in mailing royalty checks to Intel for licenses to copyrights it can no longer claim.

Immediately following the NEC/Intel decision, there was wide speculation in the press that Intel might be besieged by a tidal wave of 80386 clones, previously held in check only by the fear of legal reprisal. In Dataquest's opinion, this possibility is no more likely than it was before Judge Gray's decision. There are a number of reasons for this:

- Cloning any high-end microprocessor still involves maneuvering around patented architectures. Would NEC have been able to launch its V-Series to begin with if it had not obtained patent licenses from Intel? Patent law has little tolerance for similarity, "substantial" or no, and therefore remains a very effective force in the protection of intellectual property.

- Intel's high-end microprocessor path represents a fast-moving target. Intel has continued to push the performance parameters of its 386 devices to a point where imitating a slower version in the face of softening demand makes no sense. In addition, Intel will raise the bar again with its upcoming RISC processor and its 80486 CISC microprocessor.

- Regardless of patent considerations and market timing, producing devices of the complexity of an 80386, and supporting the marketing and engineering efforts required to establish yourself as a viable source for companies who will be betting their systems on you, requires both technical expertise and substantial financial resources. Although many Japanese companies can obviously take on these market demands, the focus of much of Japan's microprocessor interest is aimed at TRON, not at cloning U.S. chips.

- Regardless of Judge Gray's decision on the issue of microcode infringement, copyright is still a part of the intellectual property arsenal available to Intel or any other microprocessor supplier. Add to this arsenal patent and trade secret law and the protection of mask works under the Semiconductor Chip Protection Act, and you hardly have an industry vulnerable to the whims of technology pirates. The cost of litigation alone, regardless of the outcome, will remain a daunting factor to any but the largest of semiconductor manufacturers.

DOES COPYRIGHT HAVE TEETH?

It is on this last point, the copyrightability of microcode, that Intel feels that it has won a victory not only for itself, but for the entire semiconductor industry. But in its application to microcode, as understood through Judge Gray's decision, what kind of teeth does copyright really have? The judge's decision makes it clear that the familiarity of NEC's microcode designer with the 8086/88 microcode, by virtue of having disassembled it, did not constitute copying when the knowledge was applied to the creation of the V-Series microcode. In one of the most telling statements on the applicability of copyright to microcode to be found in Judge Gray's 40-page decision, he cites two previous copyright cases in the opinion that "a defendant may legitimately avoid infringement by intentionally making sufficient changes in a work which would otherwise be regarded as substantially similar to that of the plaintiffs."

In the final analysis, the protection offered to microcode by copyright law appears extremely limited. Since in the case of creating software-compatible devices, some degree of functional constraint can always be argued to limit microcode design options, Judge Gray's ruling suggests that microroutines, particularly the shorter and simpler ones, "may be protected only against virtually identical copying." Given such an interpretation, no clear line can be drawn between legitimate reverse engineering and plagiarism.

WHAT NEXT FOR THE INDUSTRY?

In a sense then, Judge Gray's decision defines where microprocessor manufacturers add value from the court's point of view. Since microcode is the by-product of a microprocessor architecture (which can to some extent be protected by patent) and a macroinstruction set (which is in the public domain), the real value is in the architecture. The message to the industry from the NEC/Intel decision is that it had better look to strong patents as the first line of intellectual property defense.

Does this mean that Judge Gray's decision is a bad one? In seeking an answer to this question, one must understand that a judge's appointed role is to guard the intent of law in its application to litigated disputes, not to find in the favor of a U.S. industry—no matter what its importance. From this standpoint, Judge Gray has acted wisely upon the court's understanding of the nature and limitations of copyright law. From a practical perspective, the semiconductor industry must now ask itself not whether Judge Gray's decision was fair, but whether it is satisfied with the type of protection that copyright can offer an asset such as microcode. If the answer to this question is "no," than the next step should be to consider if microcode is deserving of a special type of protection that is neither clearly patent nor copyright in nature. It was this kind of consideration that eventually led to the passing of the Semiconductor Chip Protection Act for semiconductor mask works.

Michael J. Boss

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Research *Newsletter*

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PMT Executive Memo

DO ASIC MANUFACTURERS NEED THEIR OWN SEMATECH?

By now it appears that almost everyone who is even a casual observer of the semiconductor industry has come to the realization that ASICs are not just another hot product. At the heart of the ASIC phenomenon is a design methodology that points to the way successful components suppliers will continue to add value in this industry.

Recently, Dataquest published an ASIC market forecast predicting that worldwide ASIC consumption would grow at a compound annual rate of nearly 16 percent between 1989 and 1994. This growth will result in a worldwide market worth nearly $18 billion in five years! ASICs already account for more than 20 percent of worldwide integrated circuit consumption. Clearly, dominance in this market is a matter of strategic importance to regional as well as corporate interests.

GOOD NEWS/BAD NEWS

Looked at from the point of view of global competitiveness, the news for the United States is good, especially when compared with the U.S. position in DRAMs. Based on preliminary market share data, U.S.-based companies accounted for nearly 52 percent of worldwide ASIC shipments in 1988. By comparison, Japan-based companies claimed 39 percent of the worldwide ASIC market.

This does not, however, suggest that ASICs are the plum of the U.S. semiconductor industry. Since 1984, the U.S. share of the worldwide ASIC market has declined roughly 7 percent, while Japan's share has grown by about double that figure. As a result of this increased penetration of the ASIC market, three of today's top five ASIC vendors are Japanese. In 1983, only one of the top five worldwide ASIC suppliers was based in Japan.

Looking at Japan's growing ASIC strength, we must be careful not to draw the misleading conclusion that we are witnessing the demise of U.S. leadership in yet another segment of the semiconductor market. For the sake of balance, it should be stressed that much of the Japanese companies' ASIC revenue comes from internal sales, as opposed to the predominately merchant nature of U.S. ASIC revenue. U.S. companies also enjoy a leading position in cell-based design, ASIC CAD tools, and advanced PLD architectures, as well as the synergistic advantages of leadership in the high end of the computer market.

GROWING COMPETITIVE PRESSURES

Nevertheless, Japan is not far behind. Japanese semiconductor companies have gained licenses to U.S. RISC technology that will augment their own cell libraries (it was a Fujitsu gate-array implementation that brought Sun Microsystems' SPARC device to market), and have formed a number of alliances with U.S. CAD tool vendors to improve their design software capabilities. Although Japan has been conspicuous by its absence in the PLD market, Fujitsu recently announced a PLD product that it will begin shipping in 1989.

Ultimately, it may be that the vertically integrated nature of Japanese companies will prove to be the strongest card in their ASIC hands. The reason for this comes down to the fundamental issue behind the struggle for market share: the ability of a company or region to invest in its basic technological and manufacturing capabilities.

During the next two years, ASIC suppliers will find themselves increasingly caught in a cross fire between weaker demand, local content requirements, and technology lag. Although Japanese ASIC suppliers will be no more immune to these forces than their U.S. competitors, they very likely will be better able to weather them financially.

Between 1989 and 1990, Dataquest expects the worldwide ASIC market to grow only 6 percent, from $8.6 billion to $9.1 billion—a sharp contrast to the double-digit growth that ASICs have experienced for many years. At the same time the worldwide ASIC market is slowing, ASIC vendors are having to confront the necessity of becoming regional suppliers in order to compete in a global market. The reasons for this are several, and have to do with local content laws (Europe as it approaches 1992), end-user demands for more complex designs and faster design turnaround, rapid changes in products and applications, and the corresponding need for faster production response.

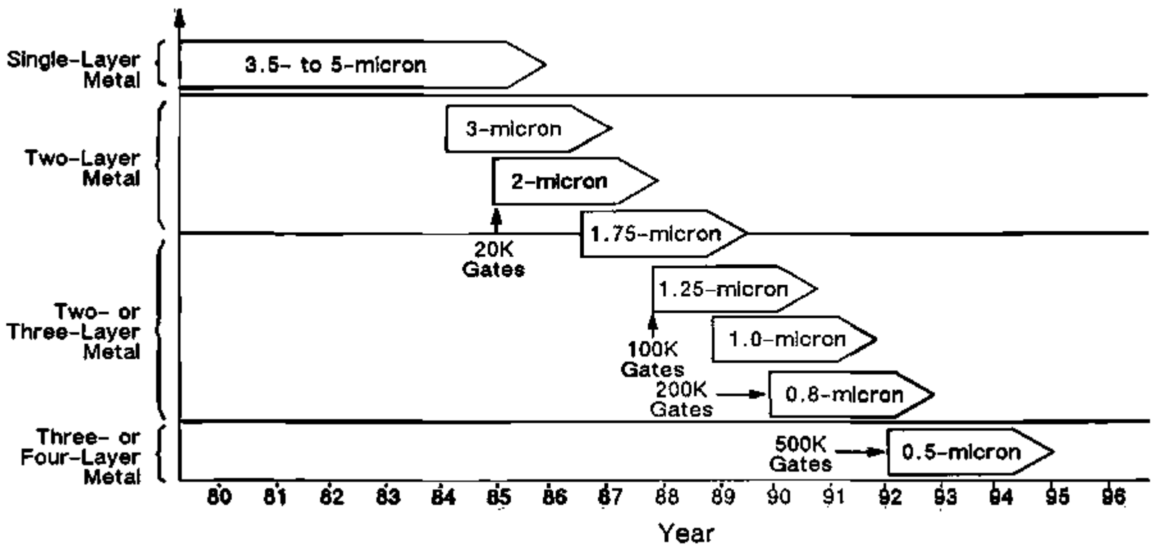
Combined, these factors will favor those ASIC suppliers with a manufacturing presence in markets they serve. This presence will not only require establishing sales and distribution channels in offshore markets, but will necessitate significant investments in design centers, field engineering support, and ultimately, in wafer fabrication facilities as well.

DIVERGING TECHNOLOGIES

For ASIC suppliers, the period between the late 1980s and the early 1990s will prove a technology watershed. As shown in Figure 1, CMOS ASIC technology has progressed from 3.5- to 5-micron range design rules requiring single-layer metal interconnects to gate densities in the 100,000 to 200,000 range that require 1.25- to submicron geometries and two or three layers of metallization. In terms of offering the architectural flexibility required to be a leading-edge ASIC supplier, today's technology is rapidly reaching its limits. To move into the next major generation of ASIC products, which will involve designs using up to 500,000 gates, ASIC manufacturers will need to manufacture devices at the 0.5-micron linewidth level, using three to four layers of interconnection.

Figure 1

The CMOS ASIC Technology Road Map



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Source: Dataquest May 1989

WHERE WILL TOMORROW'S PROCESS TECHNOLOGY COME FROM?

The cost of making the leap from today's generation of ASIC devices to tomorrow's will not only lengthen the journey of ASIC suppliers along the technology road map illustrated above, but will make the path a more costly one to follow. Given an increasingly crowded ASIC market, this barrier alone will undoubtedly weed out a number of companies whose profit margins during the upcoming industry slowdown make it financially impossible, or inadvisable, to stay in the race. Needless to say, the vertical integration of Japanese ASIC vendors will prove advantageous in the ASIC market of 1990.

Also advantageous to Japanese ASIC companies will be the strength of their memory-driven CMOS process technology, which continues to push the leading edge of device density and yield. From this standpoint, U.S. ASIC companies will find themselves to some degree dependent on process technology that has gone the way of the DRAM—to Japan. With diminishing revenue and margins forecast for the next two years, how will U.S. ASIC suppliers be able to advance their process technology to keep pace with that of their Japanese competitors, let alone surpass it?

ENTER SEMATECH

During its somewhat turbulent funding quest, critics of the U.S. semiconductor manufacturing consortium pointed out that basing future manufacturing technology on memories was an antiquated notion. The process driver of the future, they argued, would be ASICs. Sematech's proponents have argued that the consortium's "manufacturing device vehicles" (MDVs), DRAMs and SRAMs, would strengthen the U.S. foundation in equipment, materials, and process technology in a way that would ultimately benefit an LSI Logic as much as a Motorola.

To a degree, the Sematech argument is a valid one. As a process driver, DRAMs remain the ideal vehicle for pushing the absolute limits of line geometry. Memory production provides a "test pattern" that ensures the highest levels of productivity and reliability in equipment. Beyond this lowest common denominator, however, the requirements of ASIC suppliers and memory manufacturers begin to diverge, and this divergence is growing. Future memory products stress trench technology, optimum cell design, high-volume production, and cyclical yield and reliability improvements. By contrast, success in leading-edge ASICs demands processes that stress complex interconnects, planar surface technology, low-quantity/quick-turnaround production, rapid yield and reliability improvements, and high pin count packages.

However the Sematech mission may be expanded to address the priorities of ASIC manufacturing technology, the present reality of Sematech's MDVs falls short of meeting the process technology needs of tomorrow's ASIC products. Perhaps it is a mistake to think that Sematech should even try to be the panacea of all the challenges facing the U.S. semiconductor industry. The problem is, however, that given the environment in which U.S. ASIC manufacturers will be operating over the next two years, the industry's ability to fund its way over the technology hurdles that it faces may be seriously diminished.

Sematech arose to fill a process technology void left by the departure of U.S. semiconductor companies from a critical component market. It is entirely possible that ASIC manufacturers may themselves face a similar void in the not-so-distant future. Ultimately, the issue of whether ASIC companies require their own unique version of Sematech, and some sort of government support, must be judged on their market share success. If the United States has learned from history, government's participation in securing the future of U.S. ASIC technology will, if required, take place <u>before</u> the serious erosion of domestic ASIC supplier bases and before end users are forced to rely on the latest technology from their offshore systems competitors.

The issue, as with Sematech and DRAMs, is not about propping up noncompetitive companies, but about sustaining a technology that embodies the future of the semiconductor and electronics industries. While semiconductor memories drive improvements in the cost and performance of electronics systems, ASICs are becoming the embodiment of these systems in silicon. Their strategic value to the U.S. electronics industry is therefore too critical to risk being second best.

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Andy Prophet

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Research Bulletin

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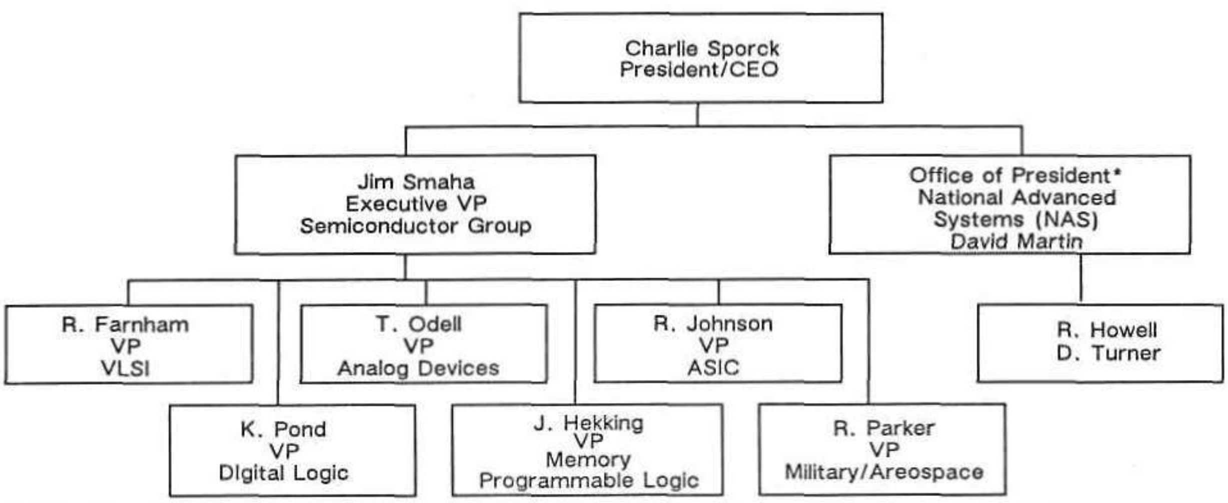
NATIONAL SEMICONDUCTOR RESTRUCTURES

National Semiconductor has undergone a tremendous amount of change in its struggle to identify a structure that will result in profitable operations. Organizationally, the most significant outcome of these efforts so far has been the shedding of its nonsemiconductor-related lines of business, allowing the company to focus entirely on the successful positioning of its components products. Figure 1 illustrates the revised organizational structure of National Semiconductor in the wake of announcements made during the past two months. Because of the number and nature of these announcements, Dataquest offers this Research Newsletter to our Products, Markets, and Technology clients in order to bring them up to date on National's restructuring efforts.

Figure 1

National Semiconductor Organizational Structure
(As of March 1989)



*Subject to change upon the completion of the sale of 50 percent interest in NAS to Memorex Telex, when NAS will operate as a separate entity.

0003306-1

Source: National Semiconductor

In December 1988, National Semiconductor announced the sale of its retail systems unit, Datachecker Systems, to a United Kingdom-based company, ICL. This move was followed in mid-January 1989 by an agreement with Memorex Telex to form a joint venture in which each company would own a 50 percent interest in National Advanced Systems (NAS). Memorex Telex, a Dutch company, is a $2 billion supplier of plug-compatible computer equipment and accessories. The deal with Memorex Telex called for National to receive a cash payment of $250 million and 4 million shares of Memorex Telex common stock. In addition to its 50 percent share of NAS, the agreement gave Memorex Telex an option to purchase the remaining stock in the organization, which would be operated as a separate entity headquartered in Santa Clara, California. At the end of February 1989, National broke off its tentative agreement with Memorex Telex, which had apparently encountered difficulties in financing the buyout of NAS. Instead, National has accepted a $398 million cash offer from Hitachi Ltd. of Japan and Electronic Data Systems (EDS), a subsidiary of General Motors Corporation. Under the agreement, NAS will be sold to a joint venture created by Hitachi and EDS. NAS acts as a distributor of IBM-compatible, large and medium-size computers and peripherals made by Hitachi.

Shortly after the initial disclosure of its deal with Memorex Telex, National announced that it would lay off 2,000 employees. The work force reduction affects all levels of staff in Asia, Europe, and the United States, and it will take place through March 1989. The number represents about 5 percent of the corporation's reported head count as of the close of fiscal year 1988. National, which reported a loss of approximately $56 million for the first half of its fiscal year 1989, has said that the reductions are necessary to bring the company's staffing levels and cost structure into alignment with its current business environment.

As evidence of its renewed emphasis on its core semiconductor businesses, National recently announced the formation of a new VLSI division, which comprises the company's microprocessor, microcontroller, advanced peripherals, and interface groups. This new division will report to vice president Ray Farnham. The memory and programmable logic groups will be combined under John Hekking. The military and aerospace group will report to Randy Parker. National intends to strengthen its position in the military market, in which it became a more powerful contender through its acquisition of Fairchild. All of these groups will report to James Smaha, executive vice president of the semiconductor group. Clark Davis will be in charge of the newly formed function of worldwide strategic planning. The strategic market development group will be headed by Walt Curtis. These last two individuals will report to Joe Van Poppelen, vice president of semiconductor marketing.

National's information systems group, of which NAS is the major part, accounted for approximately 43 percent of National's fiscal 1988 revenue of $2.5 billion. Its 1988 fiscal year ended May 29. The divestiture of NAS signals a major change in National's strategy, and a significant impact will be felt on the company's revenue. Nevertheless, National should see an improvement in profitability as a result of the sale of NAS. Partly due to the yen appreciation during the past few years, which has affected the cost of its equipment purchases from Hitachi, NAS has experienced increased pressure on its profit margins. By increasing its reliance on its semiconductor products, however, National becomes more vulnerable to the boom/bust cycles that have up to now typified the semiconductor industry. Just how National goes about positioning its broad line of components products will bear watching as the company stakes its future on being a pure-play semiconductor company.

Michael J. Boss

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QUARTERLY SEMICONDUCTOR COMPANY FINANCIAL RESULTS

INTRODUCTION

Dataquest regularly reports on semiconductor company financial results through its weekly on-line news service, The DQ Monday Report. As a service to Products, Markets, and Technology clients, a summary of this information is provided below.

Table 1 summarizes the net sales and income disclosures from selected semiconductor companies based on data from quarterly report periods ending December 1988/January 1989. The data are compared with year-earlier periods. Table 2 provides a similar summary for fiscal-year revenue and income for applicable companies. Descriptive summaries of quarterly performance highlights for the selected companies follow the tables.

Table 1

Quarterly Financial Summaries for Selected Semiconductor Companies

Company	Latest Qtr. Revenue	Percent Change	Latest Qtr. Income	Percent Change
Altera	$ 10.7M	63%	$ 2.1M	174%
AMD	$248.0M	5.5%	($ 34.0M)	N/M
California Micro Devices	$ 6.4M	(13%)	$ 2.4M	(95%)
Chips and Technologies	$ 54.4M	68%	$ 7.9M	41%
Cypress Semiconductor	$ 41.2M	70%	$ 6.3M	58%
IDT	$ 43.5M	36%	$ 2.9M	(11%)
Intel Corp.	$727.0M	27%	$ 86.0M	(10%)
KLA Instruments	$ 41.5M	63%	$ 2.8M	46%
Lam Research	$ 31.8M	80%	$ 2.4M	168%
Linear Technology	$ 15.7M	28%	$ 2.1M	(11%)
LSI Logic	$119.4M	53%	$ 5.3M	(8%)
Motorola, Inc.	$ 21.9M	18%	$124.0M	22%
SEEQ Technology	$ 14.5M	(4%)	$ 1.1M	(42%)
Silicon General	$ 9.6M	55%	$0.453M	N/M
Texas Instruments	$ 16.9M	10%	$ 95.0M	4%
VLSI Technology	$ 64.9M	38%	$ 2.9M	56%
Weitek	$ 10.1M	47%	$ 1.4M	196%

N/M = Not Meaningful

Source: Company Information

Table 2

Fiscal Year Financial Summaries for Selected Semiconductor Companies

Company	Fiscal Year Revenue	Percent Change	Fiscal Year Income	Percent Change
Altera	$ 37.9M	83%	$ 7.1M	248%
AMD	$ 11.3M	13%	$ 19.3M	N/M
Cypress Semiconductor	$139.4M	80%	$ 20.8M	55%
Intel Corp.	$ 27.8M	51%	$453.0M	83%
LSI Logic	$379.0M	45%	$ 24.7M	118%
Motorola, Inc.	$ 82.5M	23%	$445.0M	45%
Texas Instruments	$ 63.0M	13%	$366.0M	14%
VLSI Technology	$221.2M	29%	$ 6.7M	(6%)
Weitek	$ 35.2M	65%	$ 4.0M	279%

N/M = Not Meaningful

Source: Company Information

Altera

The leading supplier of CMOS PLDs in 1988, Altera attributed this record performance to ongoing strong demand for its mature products, and to initial shipments of its new Multiple Array matrix parts and development systems.

AMD

AMD's fourth-quarter fiscal 1988 loss included an unusual charge associated with a work force reduction, a plant closure, and other restructuring activities. Softness in the PC industry negatively affected sales in the microprocessor and PLD areas. EPROMs, however, achieved record sales, and more than half of the company's EPROM revenue was generated from CMOS EPROMs.

California Micro Devices (CMD)

CMD's revenue was negatively affected by a drastic drop in product demand from GTE. Higher development costs associated with 1.5-micron MOS processing technology also had a detrimental effect on profitability. Company chairman Chan Desaigoudar said that the affected division is restructuring in order to handle the reduced demand from GTE and the increased demand from foundry customers. Thus, more favorable results are expected in the latter half of the company's current fiscal year.

Chips and Technologies

According to president and CEO Gordon Campbell, increased sales for the company's most recent quarter reflected increased demand for AT-compatible chip set products, particularly the company's higher-speed line for 286- and 386-based systems. Shipments to OEMs and deliveries from distributors to customers increased.

Cypress

The company attributed much of its outstanding results to the successful expansion of capacity and improvement of yields attained by its new Round Rock, Texas, wafer fabrication facility. In the fourth quarter, one half of the company's product shipments came from this facility. A rash of new product introductions in the third quarter resulted in Cypress experiencing strong new-product performance in the fourth quarter.

IDT

In January, IDT indicated that it was lowering estimates for its third-quarter results. Demand was weaker than expected, although the company believes that the disparity between product availability and demand was of a temporary nature. New orders booked during the quarter and backlog at the quarter's end both were at record levels, and the company is "cautiously optimistic" about the fourth quarter.

Intel

The company experienced another outstanding year. However, inventory corrections at the end of the year—when supply and demand for the 80386 reached parity—resulted in a weak quarter. Intel views this event as a correction phenomenon, not the signal of a downturn. In separate announcements, Intel reported that it had adopted a shareholder rights plan to protect the company in the event of a takeover bid, and that it had appointed 10 new operating group vice presidents.

KLA

The company stated that, while orders for its systems increased strongly during its most recent quarter, continued investment in the start-up of two new business areas and an increase in engineering and R&D investments negatively affected financial results in the first half of fiscal 1989.

Lam Research

Lam reported a record level of backlog in its second quarter. The company's new Rainbow etch systems, which reached their 100th order milestone in the quarter, accounted for 65 percent of orders booked. Much of this increased sales activity came from the Pacific Rim market, while the domestic market continues to show strength as well.

LSI Logic

The company said that its Canadian affiliate would take a one-time restructuring charge in the fourth quarter. This charge was associated with the termination of sales of PC products, which amounted to a $5 million negative impact on net income. LSI's book-to-bill ratio was running in excess of 1.10 in the fourth quarter, and the dollar volume of new orders grew about 20 percent from the prior quarter. The company expects that orders in the first quarter of 1989 will be be stronger.

Motorola

Sales in communications, cellular telephone, and semiconductor products remained strong during Motorola's most recent quarter. With respect to the semiconductor products sector, sales increased 25 percent and orders rose 21 percent from the year-earlier period. Demand is especially strong in Japan and the Pacific Rim market.

Silicon General

The company reported results for its semiconductor business only, because it is in the process of turning its telecommunications activities into a separate business entity. Record revenue for the quarter reflected good demand from the company's military sector, as well as good demand from its other semiconductor markets. The company is optimistic about its business prospects for the next few quarters.

SEEQ

The company's poor results in its first quarter of 1989 were due to poor wafer fabrication productivity and lower-than-expected yields. As a result, the company did not meet its shipping commitments. SEEQ believes that it has addressed its production problems. Bookings for the quarter were at a 23-year high, with most of the strength coming from new CMOS product lines. This backlog, combined with a return to normal manufacturing, should result in improved future performance.

Texas Instruments (TI)

TI's semiconductor business achieved record net sales and significantly improved operating performance primarily because of demand for its memory products. Demand for DRAMs and EPROMs was especially strong. However, a mature part of the company's business, bipolar logic, is being displaced by other logic technologies and, as a result, pricing pressures were severe. Component revenue experienced an approximate 27 percent increase in 1988, reaching $3.1 billion in sales. TI's income includes royalty of $124 million from DRAM patent litigation settlements. This amount compares with $191 million gained by TI in similar royalty payments last year. TI is expecting slower growth in 1989; shortages will ease in memory products, and pricing pressure will continue in mature, general-purpose logic and linear products. In a letter to stockholders, TI chairman, president, and CEO Jerry Junkins indicated that the company will continue cost-reduction actions to keep operations aligned with market demand. These actions will include a program in the first quarter to reduce employment levels in selected areas of the company's operations.

VLSI Technology

Fourth-quarter bookings remained relatively strong, equaling approximately the levels of a strong third quarter. Chip set business for the Asian market was very weak, but the company's European operations reported a strong quarter. Margins in the fourth quarter were adversely affected by the continued start-up expenses related to the company's new Texas wafer fab, but the additional capacity and advanced process technology from the new facility is expected to contribute to improved financial results during the course of 1989.

Weitek

The company saw strong performance from its processor and coprocessor product lines, where revenue more than doubled in 1988 over 1987. Weitek's outlook for 1989 sales is optimistic.

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QUARTERLY SEMICONDUCTOR COMPANY FINANCIAL RESULTS

INTRODUCTION

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Table 1 summarizes the net sales and income disclosures from selected semiconductor companies based on data from quarterly report periods that ended during the February through April time frame. This information is compared with the 1988 February through April time frame and is provided in millions of dollars unless otherwise indicated. Table 2 provides a similar summary for fiscal year revenue and income for applicable companies. Descriptive summaries of quarterly performance highlights for the companies listed follow these tables.

Table 1

Quarterly Financial Summaries
for Selected Semiconductor Companies
(Millions of Dollars)

Company	Latest Quarter Revenue	Percent Change	Latest Quarter Income	Percent Change
Altera Corp.	$ 12.5	59.0%	$ 2.3	103.0%
California Micro Devices	$ 7.6	(4.0%)	$ 76.0*	(87.0%)
Chips and Technologies	$ 57.4	59.0%	$ 9.4	71.0%
Cypress Semiconductor	$ 46.2	58.0%	$ 7.1	61.0%
Dallas Semiconductor	$ 17.1	46.0%	$ 2.1	6.0%
Exar Corporation	$ 18.3	12.0%	$959.0*	N/M
IDT	$ 47.6	28.0%	$ 4.2	(2.0%)
IMP	$ 12.2	13.0%	($ 3.3)	N/M
Intel Corporation	$ 713.0	12.0%	$ 97.0	3.0%
Linear Technology	$ 16.5	23.0%	$ 2.2	4.0%
Logic Devices	$ 3.8	134.0%	$791.0*	434.0%
LSI Logic	$ 133.9	83.0%	$ 8.0	71.0%
Micron Technology	$ 113.8	95.0%	$ 29.2	72.8%
National Semiconductor	$ 589.0	3.0%	($ 44.6)	N/M
Silicon General	$ 8.2	11.0%	$275.0*	16.0%
Siliconix	$ 26.4	(9.0%)	($ 6.7)	N/M
Texas Instruments	$1,561.0	6.0%	$ 85.0	0
VLSI Technology	$ 60.0	37.0%	($ 6.2)	N/M
Western Digital	$ 243.2	28.0%	$ 4.4	(46.0%)
Xicor Inc.	$ 22.0	13.0%	$ 2.9	0.8%
ZyMOS Corporation	$ 7.7	(10.0%)	($188.0)*	N/M

Table 2

Fiscal Year Financial Summaries
for Selected Semiconductor Companies
(Millions of Dollars)

Company	FY Revenue	Percent Change	FY Income	Percent Change
Exar Corp.	$ 75.3	25%	$ 4.9	N/M
IDT	$180.7	49%	$ 17.9	55%
IMP	$ 52.5	7%	$169.0*	(97%)

*Thousands of dollars
N/M = Not Meaningful

Source: Company Literature

Altera

Altera's sales during the first quarter of 1989 were 17 percent over those of its fourth quarter of 1988. Operating income grew to $2.7 million, up from $1.2 million in the first quarter of 1988 and $1.9 million for the fourth quarter of 1988. These results mark Altera's nineteenth consecutive quarter of increased sales and the company's ninth consecutive quarter of record profits. Altera's balance sheet currently shows a healthy $22.0 million in cash and short-term investments, $38.0 million of equity, a 5 to 1 ratio, and no long-term debt. Altera chairman and CEO Rodney Smith notes that the company's order rate during the quarter has remained strong and that, in general, business has increased in all channels worldwide.

California Micro Devices

For the first nine months of fiscal 1989, California Micro Devices has reported a loss of $675,000, compared with income of $1.4 million earned during the same period last year. Revenue for the first three quarters was $19.7 million compared with $20.8 million during the same period in fiscal 1988. The company attributes its loss in large part to a $1.5 million provision for acquisition expenses made during the first quarter. Although California Micro Devices has lost some revenue as a result of reduced product demand from GTE, the company's chairman and CEO, Chan Desaigoudar, has estimated new orders for the third quarter at $13 million. He also reports that the Microcircuits Semiconductor Division has corrected its previous manufacturing problems and has increased its yields on 1.5-micron CMOS wafer fabrication.

Chips and Technologies

For the nine-month period that ended on March 31, 1989, Chips and Technologies posted net sales of $155.8 million, an increase of 59 percent over net sales for the comparable period last year. Net income for the first nine months of fiscal 1989 increased 45 percent over 1988 to $23.0 million. President and CEO Gordon Campbell attributes his company's performance to the sales growth of Chips and Technologies' high-performance PC AT-compatible chip set products. During the third quarter, the company announced the formation of its Mass Storage Operation group and its first major product: a hard disk drive controller chip set for IBM PS/2 Micro Channel-compatible computers.

Cypress Semiconductor

The first quarter of fiscal 1989 marks 21 consecutive quarters of increasing revenue for Cypress Semiconductor, with revenue and net income up 12 percent and 13 percent, respectively, over the fourth quarter of 1988. President and CEO T.J. Rodgers notes that his company has continued to maintain 20 percent operating profit levels and an investment in R&D amounting to 26 percent of sales. As a result of this investment, Cypress and its subsidiary, Aspen Semiconductor Corporation, introduced 11 new products between them, bringing the total number of products in the Cypress catalog to 114.

Dallas Semiconductor

Net income for the first quarter of 1989 increased 7 percent over the fourth quarter of 1988, while net sales for the first quarter of 1989 grew 3 percent over the fourth quarter of 1988. First quarter of 1989 net income reflected an extraordinary credit of $157,000.

Exar Corporation

Exar Corporation has reported its financial results for the fourth quarter and fiscal year that ended on March 31. For the fourth quarter, Exar achieved net income of $959,000 on net sales of $18.3 million. This compares with a net loss of $3.8 million on sales of $16.4 million for the same period last year. Exar's sales for the year totaled $75.3 million--a 25 percent improvement over the $60.2 million reported for fiscal 1988. Exar's net income for fiscal 1989 reached $4.9 million compared with a net loss of $12.8 million for last year. Exar's fiscal 1989 results include 19 percent of the net loss of its subsidiary Exel. This proportion is due to a transaction completed in March 1988, in which Rohm Co., Ltd., the majority shareholder in Exar, acquired an 81 percent interest in Exel. Exar also notes that part of its fiscal 1989 revenue increase was attributable to a 36 percent increase in the sale of wafer services to Rohm.

IDT

Integrated Device Technology (IDT) ended its fiscal year on April 2. Revenue for fiscal 1989 was $180.7 million, a 49 percent increase over fiscal 1988. Net income was $17.9 million, an increase of 55 percent over the previous year. Dr. John Carey, chairman and CEO of IDT, noted a rebound in fourth quarter sales and earnings after a weak third quarter. In March the company broke ground on a 135,000-square-foot complex on nine acres of recently purchased land in North San Jose, California. The new facility will house a 6-inch, Class 1, half-micron wafer fab, which IDT hopes will see first silicon by the end of fiscal 1990.

Intel

In January, Intel had said that it expected its first quarter 1989 net income to decline in comparison with the fourth quarter of 1988's figure of $86 million. The company credited its higher-than-anticipated results on cost controls and good factory performance, combined with strong sales in March. President and CEO Andrew Grove notes, however, that a great percentage of first quarter orders were for delivery within 30 days, which, combined with a low backlog, "means that our visibility into the future remains limited."

International Microelectronic Products (IMP)

IMP's net revenue was $52.5 million with a net income of $168,500 for the fiscal year ending on March 25. Compared with fiscal 1988, net revenue increased by 7 percent in fiscal 1989, while net income decreased from $5.7 million during the previous year. In addition to inventory corrections in PCs, IMP president and CEO Barry Carrington explained his company's poorer profit performance as attributable to start-up difficulties on a new product. This constrained fourth-quarter sales at a time when the company was increasing its spending for capacity expansion. IMP believes that it has overcome these start-up problems, and it has nearly completed its conversion to larger diameter wafers in order to increase capacity.

Linear Technology

The company's third fiscal quarter for 1989 included a benefit from a net operating loss carryforward. On a comparative basis, income before extraordinary tax credit showed a 23 percent increase compared with the same period last year. The company achieved another quarter of steady sales growth and maintained pretax profits of 22 percent as a percentage of sales.

Logic Devices

The company's recent quarter results mark its 14th consecutive profitable quarter. Logic Devices' president Bill Volz credits initial revenue shipments of his company's new fast SRAM families with Logic Devices' strong first quarter performance.

LSI Logic

President and COO George Wells notes that although first quarter revenue is up 12 percent over fourth quarter 1988, LSI Logic has achieved a book-to-bill ratio of approximately 1.0 to 1.1, with bookings increasing each month of the quarter. The company now is operating at a revenue run rate of half a billion dollars a year. In addition, operating income for the first quarter of 1989 set a company record at $12.1 million, while operating expenses as a percent of revenue were at the lowest level in three years at 27.1 percent. During the first quarter, LSI introduced its Tape Quad Flat Pack plastic package, a surface-mount device with up to 500 pins.

Micron

For the first half of fiscal 1989, Micron has reported net income of $61.4 million on revenue of $224.2 million. This compares with revenue of $101.5 million and net income of $25.4 million for the comparable period in fiscal 1988. Micron chairman and CEO Joe Parkinson has noted increased market acceptance of his company's DRAM, fast SRAM, and video RAM (VRAM) products during Micron's second quarter. During the month of February, Micron began initial production testing and qualification of its FAB III plant, which offers 53,000 square feet of Class 1 clean room within a 120,000-square-foot facility.

National Semiconductor

For the first nine months of fiscal year 1989, National has reported a net loss of $100.3 million on sales of $1,849.0 million. This compares with net earnings of $40.3 million on sales of $1,615.7 million for the same period last year. During its third and most recent quarter, National reported a gain of $45.1 million from the sale of Datachecker Systems Inc. to ICL. The company also reported a one-time pretax restructuring charge of $8.5 million related to its worldwide work force reduction announced in January. National president and CEO, Charles Sporck, has noted a decline in bookings in late 1988, a reduced revenue base, pricing pressure on certain product lines, and consolidation costs associated with the acquisition of Fairchild, contributing to a "disappointing performance" by National's Semiconductor Group during the third quarter. National has signed a letter of intent with Electronic Data Systems (EDS) and Hitachi Limited for the sale of National Advanced Systems (which contributed positively to the company's operating performance during the quarter). This sale is expected to close during the fourth quarter, and it will mean almost $400 million in cash for National.

Silicon General

Financial results for the third quarter of 1989 are for the company's semiconductor business only, because Silicon General is in the process of making its telecommunications business a separate company. President and CEO Dan Rasdal observes that his company's shipments to disk drive producers have been lower than in earlier quarters. In the second and third quarters, however, demand has been strong in defense electronics, industrial power conversion, and automotive electronics.

Siliconix

Despite actions taken to improve gross margin and reduce spending, Siliconix, with shipments below the $29 million level was unable to avoid a loss. In February, the company decided to obsolete certain products and cease development work on A/D converters and gate arrays. This decision resulted in an inventory write-off related to these products totaling $1.1 million.

Texas Instruments

Net sales billed for semiconductors in the first quarter of 1989 were down slightly from the fourth quarter of 1988. Nevertheless, semiconductor sales during the first quarter have experienced double-digit growth over first quarter 1988. Profit from operations has increased 27 percent to $68.0 million from last year's first quarter, primarily because of higher semiconductor margins. This increase more than offset the effect of the company's lower margins in defense electronics and a continued loss in digital products. Royalty income for TI's DRAM litigation earned the company $32.0 million, down from $52.0 million during last year's first quarter. According to the company, its patent portfolio has been strengthened, and it will begin a new round of negotiations with its licensees late this year. During the company's annual shareholders' meeting, chairman, president, and CEO Jerry Junkins commented that a significant portion of TI's $760.0 million capital spending budget will be for submicron CMOS wafer fabs for memory and logic products.

VLSI Technology

Although up from the same period a year ago, VLSI's revenue was down 7 percent from the previous quarter. The company had warned earlier that the slowdown of its new San Antonio, Texas, wafer fab would have a negative impact on its first quarter 1989 results. In addition to the delay of the San Antonio fab's production schedule, revenue also was affected by continued capacity constraints, rescheduling of deliveries by selective customers, and continuing general softness and product demand changes in the personal computer market. VLSI has instituted additional expense and head count controls, and will introduce its next-generation design software during the second quarter.

Western Digital

Revenue for the first nine months of fiscal 1989 increased to a record $748.6 million, a 52 percent increase over the same period in 1988. Net income for the first nine months totaled $30 million, a 4 percent increase over the similar period last year. Western Digital's third-quarter earnings were affected by declining revenue levels and by costs associated with a reduction in force. Roger Johnson, Western Digital's chairman, president, and CEO, noted that although the company's video and communications businesses experienced record demand and operating results, overall performance was affected by soft demand for integrated systems products and the effects of the company's transition from standalone controllers to integrated disk drives. With its April increase in orders, Western Digital has an optimistic near-term outlook.

Xicor

Xicor president Raphael Klein has noted a strong demand for Xicor's products since the first of the year. In order to meet this demand, the company incurred significant overtime and quick-turn assembly charges during the first quarter. Mr. Klein also noted increased cost competitiveness as a factor keeping Xicor's profits from rising higher. In 1988, Xicor set in motion a three-year, $50 million program to modernize its production and R&D capabilities, including the building of a new 6-inch wafer fab line.

ZyMOS Corporation

ZyMOS has announced its financial results for the first quarter of fiscal 1989. The company recorded net income of $188,000 on revenue of $7.7 million, compared with a loss of $2.9 million on revenue of $8.6 million for the same period in 1988. President and CEO Dave Handorf stated that $1 million of ZyMOS' first-quarter revenue came through the sale of technology. Product sales, which make up the remaining $6.7 million, represented a $1.5 million increase over the fourth quarter of 1988. A spokeperson at ZyMOS claims that the higher revenue figure for the first quarter of 1988 was attributable to significant shipments of "end-of-life purchases resulting from ZyMOS' decision to discontinue older technology processes and low-margin products and focus on higher-margin PC chip sets, VGA products, and SuperCell ASIC capability."

Patrica Galligan

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VERTICAL INTEGRATION U.S.–STYLE: THE FORMATION OF U.S. MEMORIES

SUMMARY

On Wednesday, June 23, 1989, a new company announced its intention to become the fifth U.S.–owned, noncaptive supplier of dynamic random access memory (DRAM) chips. The company is U.S. Memories. More significant than the fact that another manufacturer will join the ranks of a domestic supplier base that has been on the "endangered species list" since the 1985 industry downturn is the fact U.S. Memories will be a jointly owned venture funded initially by seven major U.S. electronics and semiconductor companies. The companies contributing seed money to the start–up are Advanced Micro Devices, Digital Equipment Corporation, Hewlett–Packard, Intel, IBM, LSI Logic, and National Semiconductor.

The new memory manufacturing entity will be headed by Sanford (Sandy) Kane, who will resign from his present position as vice president of technology at IBM to become the president and CEO of U.S. Memories. U.S. Memories' current objectives are to meet its approximately $1 billion funding requirement and to select a site by the end of this year. As ambitious as it may seem, the company also has stated its goal of building a wafer fabrication facility that will be in full–volume production of 4Mb DRAMs by the first half of 1991.

Whether or not U.S. Memories succeeds in its ambitious aim to be in volume production of cost–competitive, leading–edge memory products by mid–1991, the very act of its formation is evidence of profound changes in the U.S. electronics industry and its relationship with government. In the three years since the signing of the controversial semiconductor trade agreement with Japan, the U.S. semiconductor industry has implemented a major change in its culture and, quite possibly, in the infrastructure in which it operates. This newsletter looks at the major obstacles facing the formation of U.S. Memories and its larger significance to the U.S. semiconductor industry.

OBSTACLES

Between U.S. Memories and its vision of high-volume, leading-edge DRAM manufacturing in the early 1990s lie a number of hurdles. These include successfully addressing potential antitrust barriers, convincing other systems and components companies that they have a vested interest in participating in the new venture, and overcoming a late start in the 4Mb DRAM market--particularly in relation to Japanese competitors. We will now look more closely at these issues.

Antitrust Concerns

Sematech and other electronics research cooperatives, such as the SRC and the MCC, paved the way for dealing with antitrust issues involving joint R&D efforts by major U.S. electronics companies. U.S. Memories is unique, however, in that for the first time in electronics industry history, several U.S. semiconductor manufacturers and their customers have proposed sharing resources, risk, and output. Antitrust considerations now will have to be applied to the manufacturing issue. It is highly likely, however, that Sematech already has been sounding this issue with the federal government, and U.S. Memories expects no major obstacles in this regard.

Participation by Chipmakers

Made conspicuous by their absence from the roster of domestic semiconductor companies contributing to U.S. Memories are Micron Technology, Motorola, and Texas Instruments (TI). For these companies, U.S. Memories represents a potential competitor. The fact that they are represented in the Semiconductor Industry Association (SIA), the board of which unanimously approved U.S. Memories' formation, indicates no outright hostility to the new venture. Nevertheless, with impressive commitments already made to the DRAM market, it is unlikely that today's domestic DRAM leaders will find it a matter of vested interest to participate directly in U.S. Memories.

Other U.S. chip manufacturers may, however, want to give the matter some serious thought. To begin with, the DRAM market is simply too big to ignore. Dataquest currently forecasts that worldwide MOS memory consumption as a whole will have a compound annual growth rate (CAGR) of nearly 26 percent between 1988 and 1993—representing about 40 percent of the estimated $94 billion market for integrated circuit products that we have forecast for the next four years. In turn, DRAM products will make up the majority of this market. Although personal computer products will account for an ever-larger proportion of DRAMs (56.5 percent by 1990), PCs are becoming a less volatile, if slower-growing, end market. With increasing pervasiveness in other systems' applications, DRAMs constitute an important part of the product mix for any company wishing to satisfy the broad demands of the worldwide electronics market. Participation in U.S. Memories offers a way for domestic suppliers to address their customers' memory needs without the massive investment and risk that have come to characterize participation in the DRAM market.

Participation by Systems Companies

The announcement of U.S. Memories does not mark the first time that the semiconductor user community has been approached for investment in a U.S. DRAM manufacturing start-up company. Just seven months ago, Pierre Lamond of Sequoia Capital unsuccessfully pursued a joint venture, dubbed "Megaram," that would have created a 1Mb DRAM factory from the joint investment of a number of major memory users. Curiously, one of the companies approached is now an investor in U.S. Memories--Digital Equipment Corporation. One advantage that the new start-up offers chip users, in terms of investment risk, is that, unlike the Megaram proposal, U.S. Memories has the participation of a number of leading chipmakers. In addition, the process formula to be used by U.S. Memories is coming from the very company believed to be the largest producer of leading-edge DRAMs--IBM.

However appealing the theme "Buy American" is these days, it will not be reason enough for U.S. chip users to risk committing to the proposed purchase of 50 percent of U.S. Memories' chip production. To be sure, U.S. systems companies seem more sensitive to the long-term implications of depending on present or future competitors for their advanced component technology since the acrimonious finger pointing that took place between the semiconductor supplier and user communities following the U.S.-Japan Semiconductor Trade Arrangement.

Nevertheless, when all is said and done, U.S. Memories is another start-up company that will have to compete on the same quality, price, and delivery terms as every other chip supplier. Assuming that all of these conditions are met competitively by U.S. Memories, an example of the advantages it might offer customers/investors can be found in the equity investment deal cut last October between Amstrad of the United Kingdom and Micron Technology. Unlike the 20-plus Micron customers, who at the time of the Amstrad agreement had signed two-year noncancellable DRAM supply contracts, the British PC manufacturer did not have to commit to a fixed delivery schedule. In addition to negotiating prices on a quarterly basis, Amstrad was able to start with a ceiling price based on the weighted average of all other noncancellable contracts for the previous 90 days. Amstrad's investment position in Micron also gave its chairman a seat on Micron's board and, presumably, some say, in future product and marketing decisions. Because membership has its privileges, U.S. semiconductor users will have to weigh not only the risks of investing in U.S. Memories, but the possible risks of not getting involved.

Playing Catch-Up

The goals of U.S. Memories to select a site, build a new fab, and engage in volume production of 4Mb DRAMs by the first half of 1991 are not only extremely ambitious, they fly in the face of history. Based on data compiled by Dataquest's Semiconductor Equipment and Materials Service (SEMS), the average time involved for U.S. semiconductor companies to get from permit to full production is three to three and a half years. By contrast, the average for Japanese companies is about one year less than that. Of late, the United States has seen some notable exceptions to this three-year average, such as Cypress Semiconductor's Round Rock, Texas, facility and Sematech's fab facility in Austin, Texas. In fact, the first formal technology transfer made by Sematech to its member companies, many of which now are involved in U.S. Memories, was in the form of information pertaining to the design and construction of its fab.

Given this information, U.S. Memories' targeted first half of 1991 entry date into the 4Mb DRAM market is, at the very least, aggressive from a start-up company standpoint. Although the company's introduction date is ahead of the forecast peak year for 4Mb DRAMs, most Japanese DRAM manufacturers will be ramping up 4Mb DRAM production during 1990, and customer samples of 16Mb DRAMs will be available in 1991. Those companies that have reached peak volume production levels of 4Mb DRAMs by the time that U.S. Memories enters the market in 1991 could price their products too low for a late entrant to compete, particularly when the FMV price regulations are due to elapse in 1991 along with the rest of the U.S.-Japan Semiconductor Trade Arrangement.

RETURNING TO THE DRAM MARKET

In 1986, the U.S. semiconductor industry, represented by the Semiconductor Industry Association (SIA), and the U.S. government, represented by the Department of Commerce (DOC), took a controversial first step toward bringing the United States back into the commercial mainstream of commodity memory chip production. That first step was the creation of the U.S.-Japan Semiconductor Trade Arrangement--an agreement that was roundly criticized for bringing chaos to the world market for semiconductor memories, causing a two-tiered pricing system that forced U.S. systems companies to pay higher prices for key components than their Japanese competitors, causing shortages of 1Mb DRAMs, and ultimately benefiting the Japanese electronics industries through higher profit margins for memory chips.

Implicit in the arrangement was the belief that in "leveling the playing field" of semiconductor trade, the DOC would create an incentive for a resurgence of U.S. suppliers in the MOS memory market, particularly in the all-important segment of high-density DRAMs. From the federal government's standpoint, the rampant erosion of U.S. market share in this product segment would ultimately create an unhealthy dependence of U.S. electronics companies on Japanese semiconductor suppliers--a threat to national security. From the standpoint of U.S. semiconductor companies, the loss of the DRAM market meant not only exclusion from the largest revenue segment of the business, but the beginning of an insidious death spiral. Because advanced memory products serve to drive manufacturing process technology and equipment, lack of participation in this market would ultimately impair U.S. competitiveness in other segments of the chip market.

The return of U.S. semiconductor companies to high-volume, cost-competitive DRAM manufacturing was seen as a panacea for all of these concerns. Despite hand wringing in Washington and the invectives of their domestic customer base, however, U.S. chipmakers did not flock back to the DRAM business--the expanded DRAM commitments of Alliance Semiconductor, Micron Technology, and Motorola, notwithstanding. The reasons for this widespread reluctance, while not entirely comprehensible to those outside the industry, basically can be reduced to very pragmatic risk/reward considerations. To reenter the DRAM market at the leading edge, companies would have to play an incredible game of technology catch-up, invest in excess of $300 million dollars for a plant to run a highly complex process, and most likely hit full production during softening market conditions and the expiration of the trade agreement.

A QUESTION OF BALANCE

Positing a wholesale return to the DRAM business by U.S. semiconductor companies on the basis of the U.S.-Japan Semiconductor Trade Arrangement alone is like balancing on a one-legged stool. With its focus on pricing and market access, the arrangement addresses the environment that U.S. companies will compete in, not the basic infrastructure of the industry. The creation of Sematech, however, has since added another leg to the stool. Having as its charter the advancement of the domestic materials and equipment industries, Sematech links government labs, university research, semiconductor manufacturers, and equipment and material vendors in a way that promises to compress the cycle time between the identification of a next-generation integrated circuit and the availability of the equipment that will cost-effectively produce it.

U.S. Memories adds an important third leg to the stool on which major U.S. participation in the high-density memory market rests: the collective assumption of high costs and associated risks of large-scale memory manufacturing. Both Motorola and TI have addressed these issues through their alliance strategies, as well as through their participation in Sematech. Although the SIA and the American Electronics Association had spoken earnestly and often about the necessity of a user/vendor consortium effort, no one seemed very eager to put their money where their mouths were.

TOWARD VERTICAL INTEGRATION

U.S. Memories has dramatically changed all that by involving both semiconductor suppliers and users in the shared investment in leading-edge memory production. If successful, it will serve as a natural complement to Sematech by providing the high-volume manufacturing environment in which equipment and production techniques transferred by the consortium can be competitively proven. More importantly, U.S. Memories is a bellwether indicator that memory manufacture has begun to take on the aspects of vertical integration that characterize Japanese companies. Combined, Sematech and U.S. Memories link the research efforts of academia and industry, the process technologies and manufacturing experience of major semiconductor suppliers, the financial and end-user input of semiconductor customers, and the equipment and material foundation upon which the whole structure rests.

Although the realization of U.S. Memories' goals faces many significant hurdles, its very announcement indicates an important change in the culture of the U.S. semiconductor industry—no more business as usual. From now on, the industry will be less vulnerable to the charges that although it is willing to complain about trade practices, it is not willing to cooperate—that it is long on talk and short on action.

DATAQUEST CONCLUSIONS

Finally, U.S. Memories' creation points to an evolution in the relationship between government and industry in the United States. In just the past three years, the federal government has gone from trade intervention on behalf of industry, to investment in cooperative R&D unrelated to specific defense projects, to offering to play a seed-funding role in the development of a high-definition television (HDTV) consortium. Regarding U.S. Memories, the U.S. government can once again play a constructive role in the electronics industry by clearing away antitrust obstacles to the participation of leading industry competitors in a jointly owned manufacturing concern. In these endeavors, the federal government is involved in an evolution no less profound than the industry's—the evolution from referee to coach. The distinction is crucial to the future competitiveness of the U.S. electronics industry, for whereas the referee is concerned only that the rules of the game be followed by all its players, the coach has a vested interest in the outcome of the match.

Michael J. Boss

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Research Newsletter

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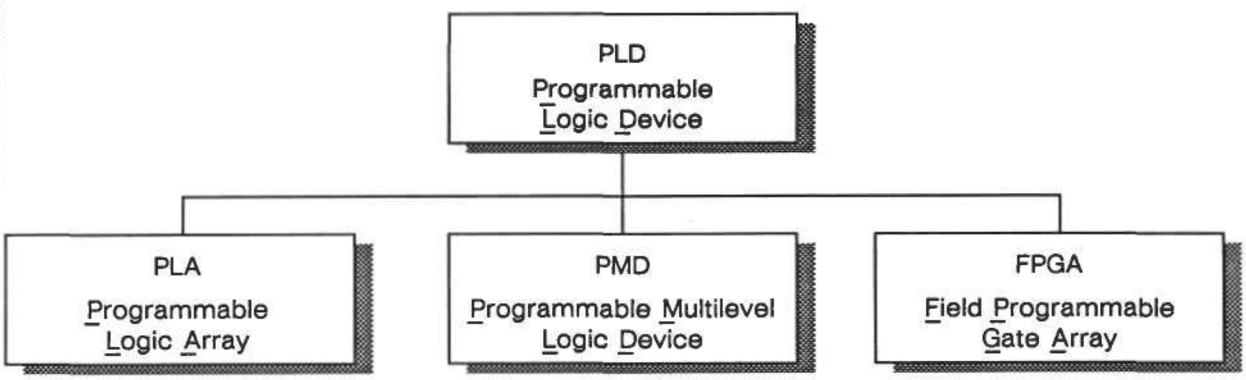
THE PLD EVOLUTION

SUMMARY

PLDs are going through a rapid evolutionary cycle. Fueled by high-density, high-performance process technologies, PLDs have evolved from low-density, low-functionality devices to products capable of implementing up to 9,000 equivalent gates. PLDs have grown from one to three basic architectures. The first is the traditional programmable logic array (PLA), which incorporates up to two levels of logic; the second is the programmable multilevel logic device (PMD), which evolved from the PLA but is capable of implementing multiple levels of logic; and the third, field programmable gate array (FPGA), traces its roots back to conventional gate arrays (see Figure 1). The latter two are capable of implementing very complex logic functions while still maintaining the inherent benefits of a PLD—low risk, low development cost, and quick time to market.

Figure 1

PLD Family Tree



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July 1989

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Although the traditional PLA still provides more than 95 percent of the 1988 PLD sales revenue, Dataquest believes that it is time to define the other PLD categories and to track and forecast them separately from the PLA. Starting this process now will provide more meaningful analysis and forecasts to our clients, while resulting in only a modest modification to historical data.

SIMPLE QUESTIONS

Simple questions deserve simple answers. The answer to the question, "What is a PLD?" is, of course, "A PLD is a programmable logic device. Next question?" However, much confusion surrounds that "simple" question today. Dataquest's definition of a PLD is quite generic. Put simply, a PLD is any device containing logic elements, which, in its packaged form, can be programmed to implement an application-specific function.

This definition covers logic devices of all complexities. A device may contain dedicated I/O with fixed internal interconnects, or it may be able to configure any pin as an input, output, or I/O with complete flexibility in interconnecting the various elements within the device. It may contain a single logic array, or it may provide a nearly infinite number of internal logical levels.

The term PLD is meant to be as generic a descriptor as possible while still referring only to logic devices. Any use of broader terminology invariably would include other programmable devices such as PROMs, EPROMs, and EEPROMs. Inclusion of the word "logic" in the general descriptor specifically excludes these nonlogic products.

Another question is: "What are the various subgroups within the PLD category?" Dataquest has observed three, which are as follows:

- PLAs—These devices have fixed or preconnected architectures capable of providing up to two levels of logic without using additional input, output, or I/O cells or pins (e.g., PAL, GAL, PEEL, and 22V10-type devices). (PAL is a registered trademark of Advanced Micro Devices; GAL is a registered trademark of Lattice Semiconductor; PEEL is a registered trademark of Integrated CMOS Technology.)

- PMDs—These are devices with primarily fixed or preconnected architectures that can implement multiple levels of logic (more than two) without using additional input, output, or I/O cells or pins (e.g., PML, PEEL-Array, and MAX-type devices). (MAX is a registered trademark of Altera Corporation; PML is a trademark of Signetics.)

- FPGAs—These devices are based on programmable interconnect technology. Typically, they are capable of implementing multiple levels of logic, as is a PMD; however, they contain no preconnected routing channels (e.g., LCA- and ACT-type devices).

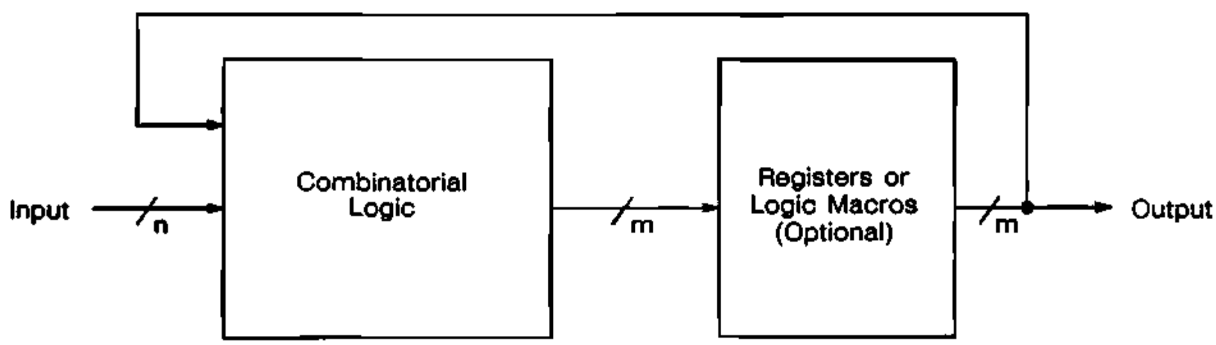
PLDs DEFINED

Programmable Logic Array (PLA)

PLA devices incorporate a one- or two-level programmable logic array with fixed interconnect paths (see Figure 2). This is the basic architecture of the original PLD product offerings, and it still is the primary contributor to the 1989 PLD sales revenue forecast of $898 million.

Figure 2

Typical PLA Block Diagram



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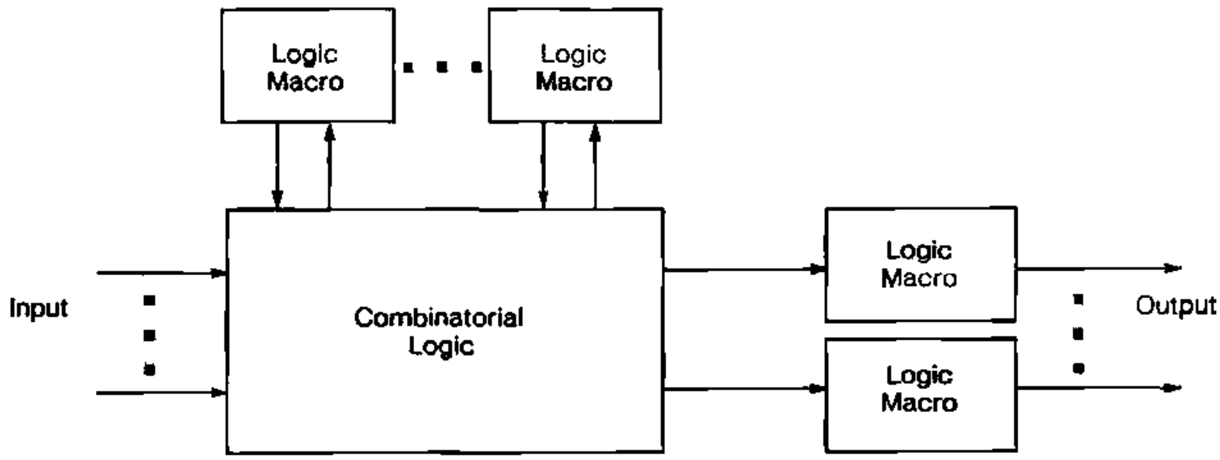
Programmable Multilevel Logic Device (PMD)

PMDs evolved from the basic PLA (see Figure 3). However, PMDs incorporate architectures to efficiently implement complex logic functions that cannot be addressed by the basic PLA. Typically, they are preconnected, as in a PLA; however, their architecture is not limited to an and-or array feeding a register bank. PMDs can implement multiple levels of logic (more than two) without sacrificing input, output, or I/O cells or pins. Simultaneously, these devices enjoy the benefits of a basic PLA in that they are easy to understand, development tools are available, and timing is predictable.

Figure 3

Typical PMD Block Diagram



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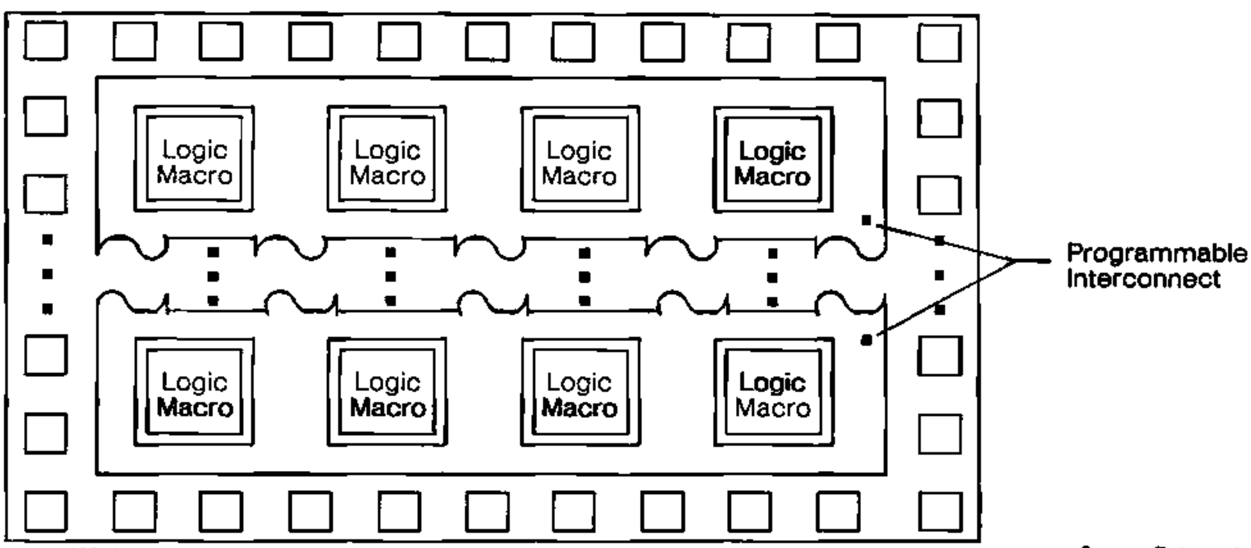
Field Programmable Gate Array (FPGA)

FPGAs incorporate an array of programmable logic elements that are not preconnected. Interconnections between the various elements are user programmable (see Figure 4).

Figure 4

Typical FPGA Block Diagram



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The programmable interconnect consists of predetermined levels of interconnect that can be connected to, or disconnected from, other interconnect lines as defined by the user. The device is analogous to a gate array in that it requires the use of the programmable interconnect in order to operate. The gate array analogy continues in that the performance of the device is a function of the fixed delays of the logic elements, as well as the variable delays of the interconnect paths. The interconnect delays in an FPGA can be quite substantial, as they consist of not only the resistance of the metal or polysilicon trace but also the resistance, capacitance, and propagation delay of the programmable switch used to connect one trace to another.

The development tools for FPGAs are somewhat more complex than those required for PMDs in that they must perform some form of AC timing analysis and require auto place and route software.

DATAQUEST CONCLUSIONS

The rapid transition of PLDs from low-density two-level logic replacements to devices that can implement multilevel logic functions of up to 9,000 equivalent gates demands that the PLD category be broken into finer resolution. The term "programmable logic device" (PLD) remains the generic descriptor, as any broader term does not exclude nonlogic devices. To reiterate, the PLD category easily breaks down into three distinct subcategories, as follows:

- Programmable logic array (PLA)
- Programmable multilevel logic device (PMD)
- Field programmable gate array (FPGA)

All future forecasting and product analysis will be based on these PLD definitions. Dataquest believes that this is the most comprehensive and meaningful way to analyze and forecast the PLD market.

Michael Boss
Jerry Banks

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Research Newsletter

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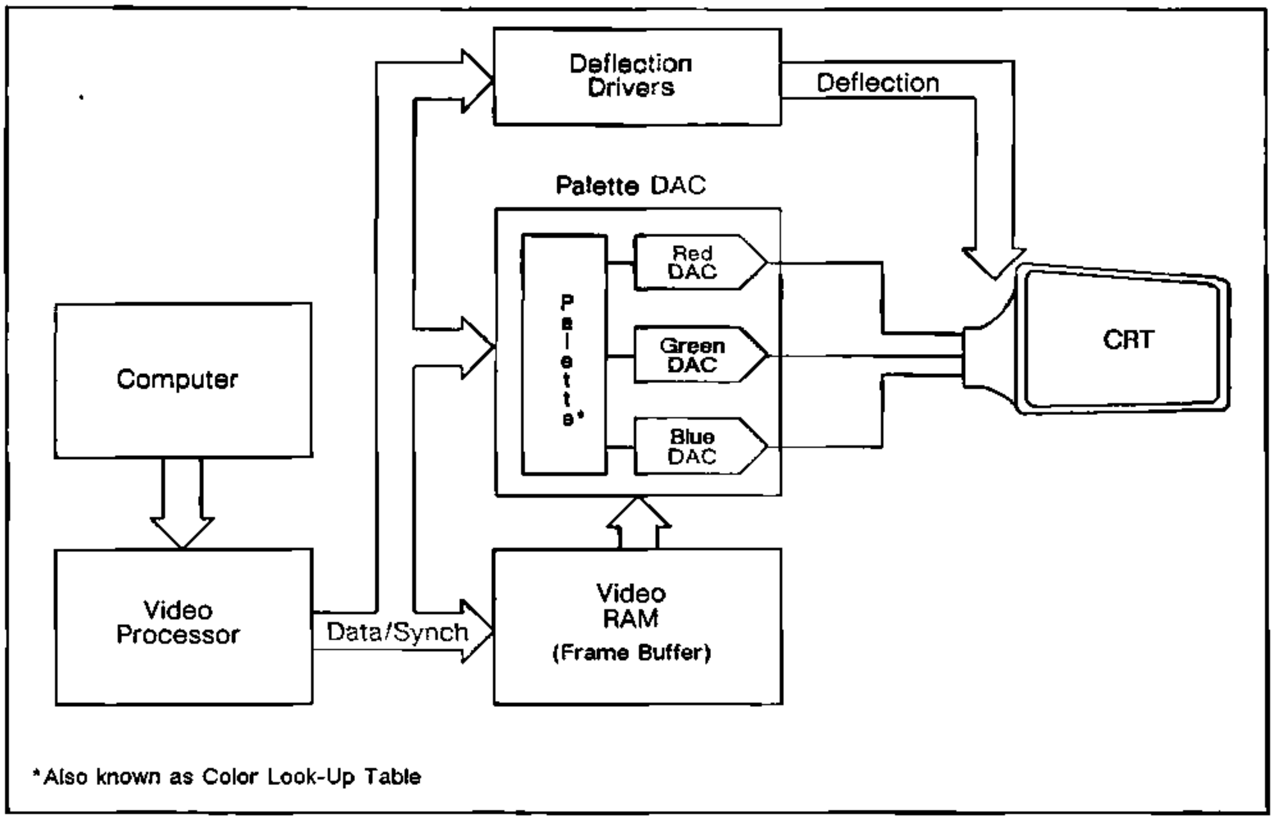
THE COLOR OF MONEY: ONE OF MANY HUES PROVIDED BY PALETTE DACs

OVERVIEW

A specialized digital-to-analog converter (DAC) that has become prominent in the graphics product market is known as the video DAC. Video DACs encompass a variety of products variously called RAM-DACs, palette DACs, and RGB DACs in addition to the more general term, video DAC. These products originated as high-speed, low-resolution DACs designed for creating images from computer-generated graphics data. As high-resolution computer graphics became more commonplace, the original hybrid triple DACs gave way to monolithic video DACs. More recently, these have been combined with RAM to create on-chip color lookup tables (CLUTs). This is the so-called color palette DAC, or RAMDAC. The introduction by IBM of the VGA graphics standard for PS/2 PCs, as well as the growth in graphics workstations, has greatly expanded interest in analog color graphics generation. As any color is created by combining the red, green and blue primary colors, analog signals are needed to modulate the intensity of the primary colors to create the wide range of hues needed for realistic graphics. Figure 1 shows a typical application of a triple DAC in a graphics application.

Figure 1

Palette DAC Application



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Source: Dataquest September 1989

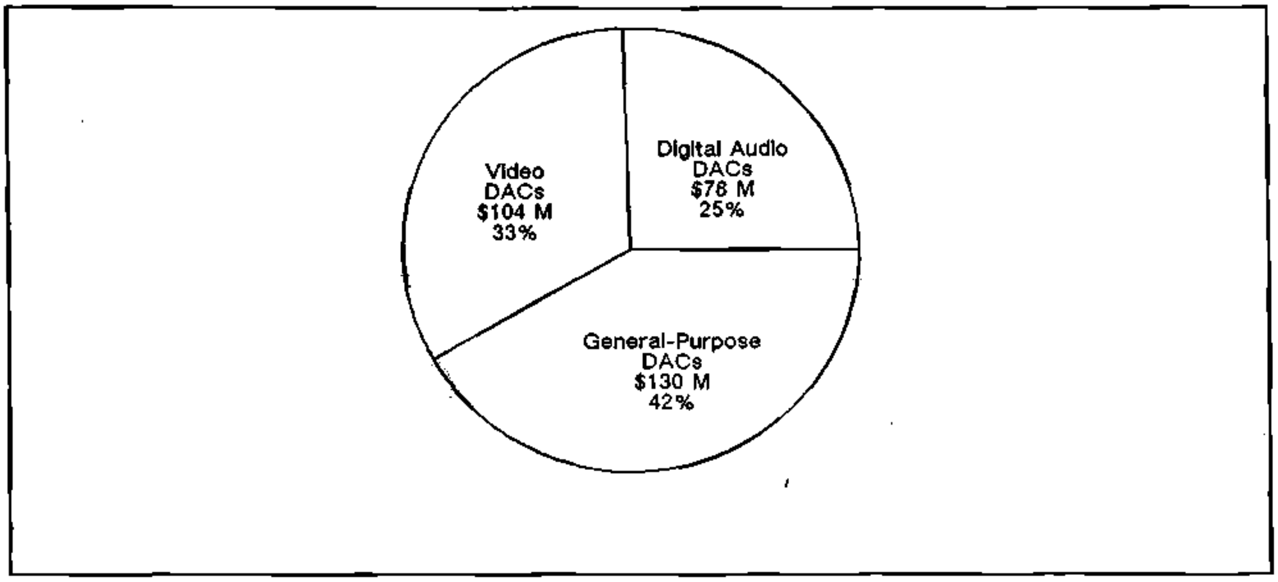
THE MARKET

The video DAC product market has exploded in the past year with rapid growth of workstation graphics products and the VGA standard in the PC arena. Video DACs have grown to a substantial portion of the monolithic DAC market, as shown in Figure 2. Presently, video DACs represent one-third of the market, and they are expected to grow to more than 41 percent of the monolithic DAC market by 1993.

Figure 3 shows unit sales breakdown by conversion speed. In 1988, the bulk of the video DACs consisted of lower-resolution applications such as VGA (640 x 480). This mix will change dramatically during the next five years, as the faster products needed for improved resolution become more available and at a lower cost. Super VGA (800 x 600) and other higher-resolution PC standards, such as IBM's 8514/A adapter and Compaq's noninterleaved graphics (both at 1,024 x 768 resolution), as well as the high-performance graphics used in workstations, will drive this resolution race. Figure 4 relates the conversion rate to the screen resolution in pixels (number of pixels per line times number of lines).

Figure 2

DAC Market by Segment



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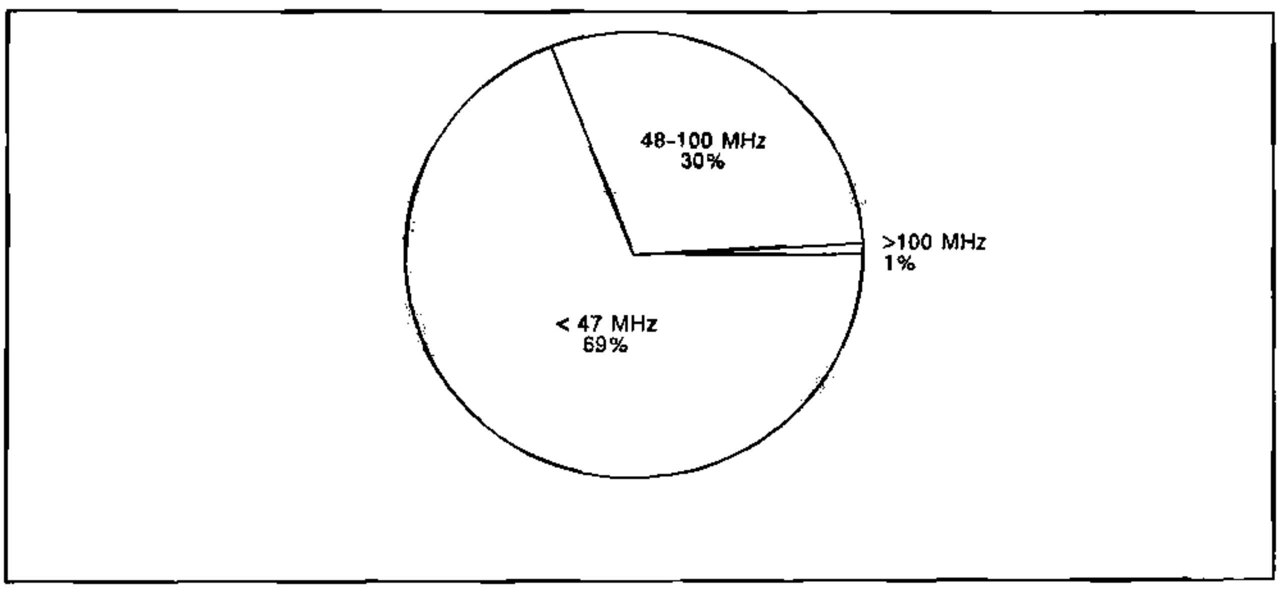
Source: Dataquest September 1989

Figure 3

1988 Video DAC Unit Sales by Conversion Rate



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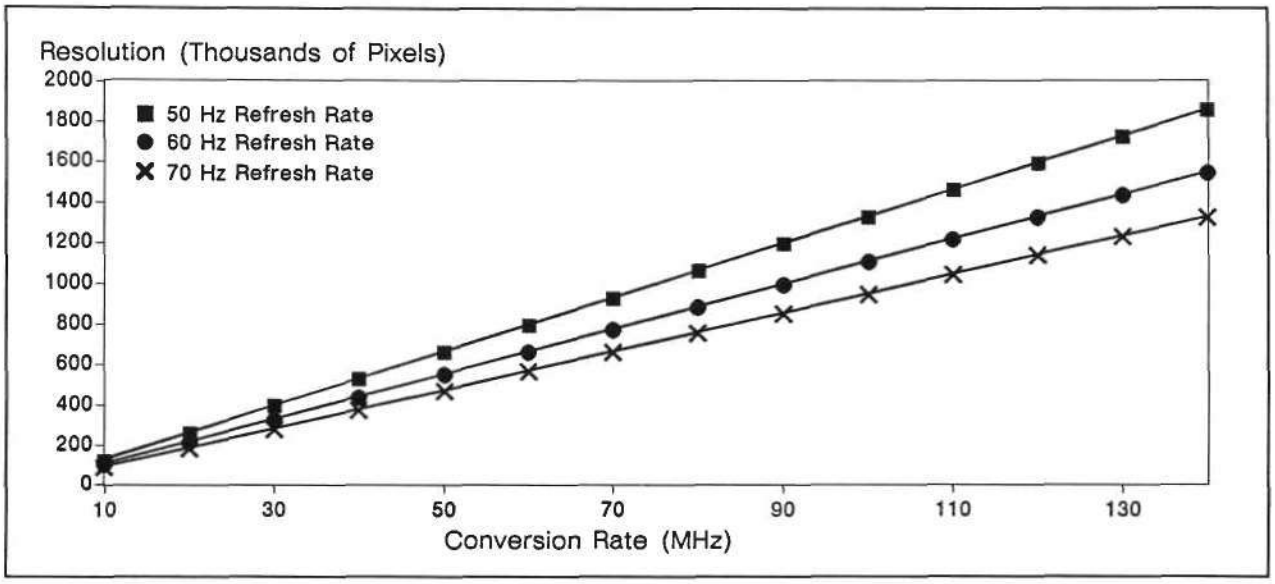
Source: Dataquest September 1989

Figure 4

Video DAC Resolution versus Conversion Rate



0004996-4

Source: Dataquest
September 1989

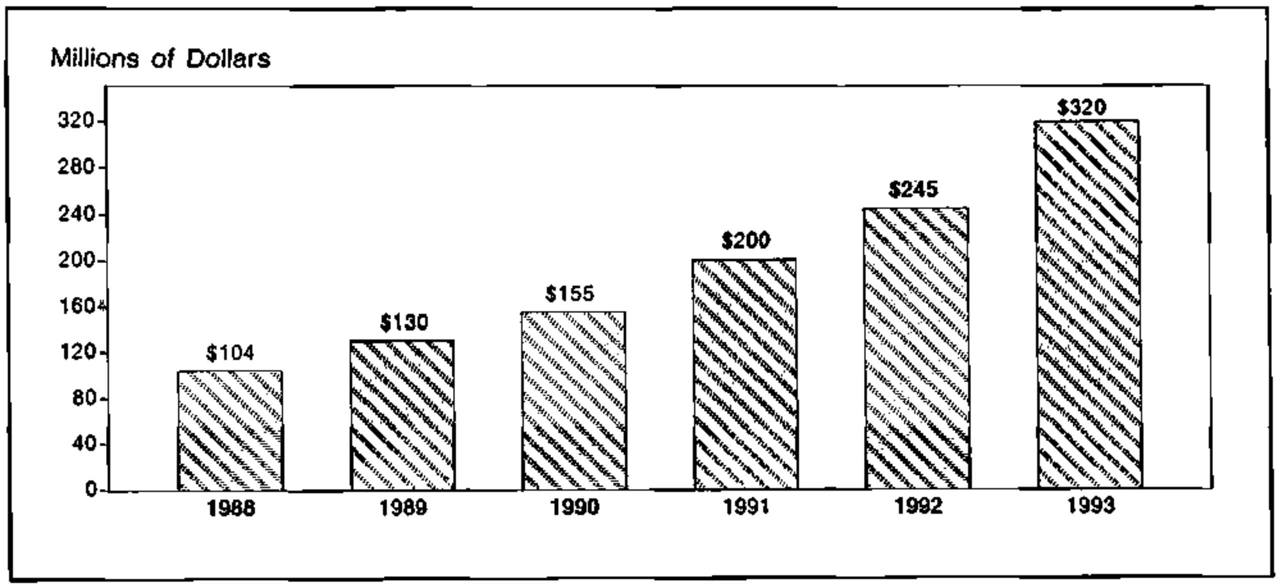
FORECAST

Growth in graphics workstations and greater graphics emphasis both in PCs and PC applications is widening the application of these products while pressing conversion speed higher. Figure 5 shows the anticipated growth in video DAC revenue from 1988 through 1993.

Although we forecast revenue to increase by a compound annual growth rate (CAGR) of 25 percent during this five-year period, we expect the number of units to grow even faster, by more than 41 percent CAGR (see Figure 6). Such growth may be a signal that significant price erosion can be expected.

Figure 5

Video DAC Revenue Forecast
1988–1993



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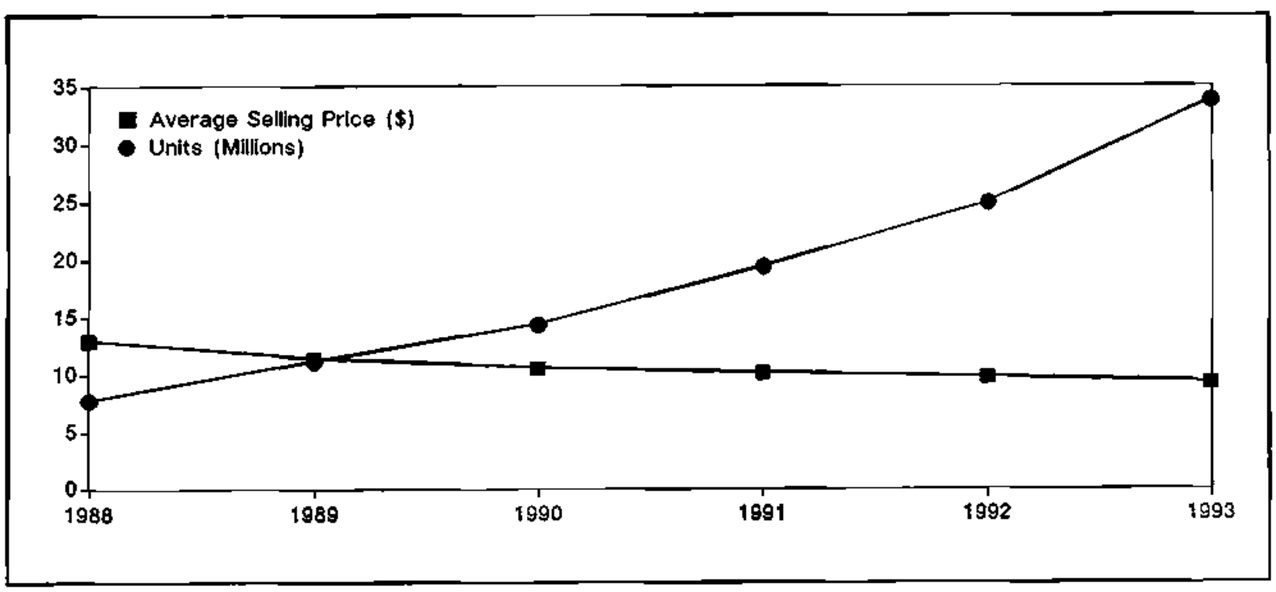
Source: Dataquest
September 1989

Figure 6

Palette DAC Unit and ASP Forecast



0004996-6

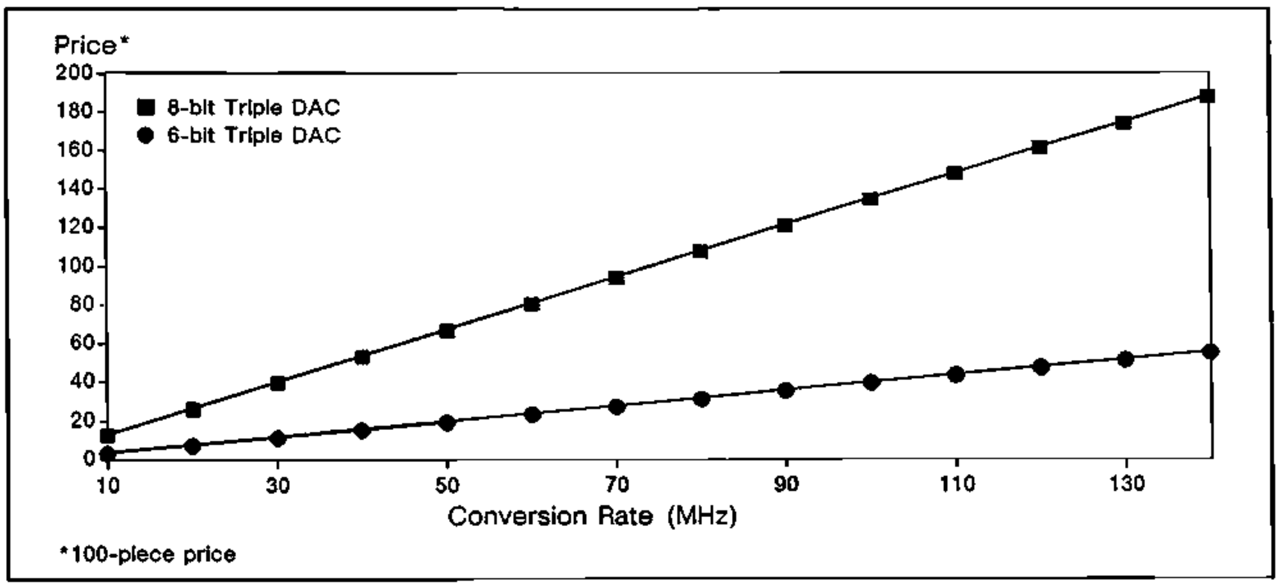
Source: Dataquest
September 1989

PRICING

Video DAC pricing varies widely. Although pricing is related to the conversion rate, the product features, and the size of the lookup RAM (the palette), the conversion rate appears to be the dominant pricing factor. Figure 7 shows an approximate pricing curve for 8-bit and 6-bit triple palette DACs by conversion rate (1988 prices, 100 pieces). The 8-bit pricing curve can be described as approximating a price line of $1.35 per megahertz—at 100 pieces, large-quantity pricing is approximately one-half of this. The 6-bit palette DACs follow a similar trend line, but at approximately 40 cents per megahertz, also at 100 pieces.

Figure 7

Palette DAC Pricing versus Conversion Rate (8-Bit Triple-Palette DAC, 100-Piece Price) Approximate Trend Lines



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Source: Dataquest September 1989

Palette DACs have seen considerable price erosion in the first half of 1989 as new suppliers have entered the market. Price erosion will occur for all of these products, but the 8-bit triples are expected to show the most dramatic changes as 8 bits becomes the graphics standard. Dataquest believes that the 8-bit products will show more than a 50 percent price decline during the next five years. This price erosion could be accelerated if high-definition video appears in the consumer market. These changes in product resolution will effectively mask the ASP erosion that would otherwise be expected if resolutions and product mixes (PC graphics to workstation graphics) remained constant.

SUPPLIERS

Suppliers presently in the video DAC market include the following: AMD, Analog Devices, Brooktree, Cirrus Logic, Harris, IDT, Inmos, Intech, Motorola, National Semiconductor, Philips, Signal Processing Technologies, Inc., Silicon Systems, Triad Semiconductor, and VLSI Design.

SUMMARY

This product is in one of the fastest lanes of IC growth. Being involved in computer graphics, CAD/CAM, high-definition TV, medical imaging, and other leading-edge product areas makes the future for these products bright indeed. With a large number of traditional DAC suppliers and many mixed-mode ASIC suppliers entering the market, however, the outlook is for fierce competition, eroding prices, and the palette DAC product's rapid evolution. Higher conversion rates and lower glitch energies will give improved definition, while larger palettes, overlay palettes, and other interface and control enhancements will add features to the product. Vendors not willing to invest in developing high-performance, highly integrated video products will find tough going in the market.

Fred Jones
Gary Grandbois

Dataquest
a company of The Dun & Bradstreet Corporation

Research Newsletter

THE U.S. SEMICONDUCTOR MARKET: A BUMP AT THE END OF THE SOFT LANDING?

SUMMARY

Dataquest has predicted that over the next year, the U.S. semiconductor industry will achieve the industry equivalent of what has been referred to in macroeconomic terms as a "soft landing." Although industry growth will moderate substantially from that of 1987 and 1988, the factors that will bring about this moderation will be very different from the dynamics of the last industry recession, as contrasted in Table 1.

Given the basic differences in the industry dynamics of 1985 versus 1989, we believe that the nadir of the industry's latest cyclical downturn will be far less extreme than that of the last. Nevertheless, there are now some indicators in the U.S. semiconductor market that presage a rougher than expected landing during fourth quarter 1989. This newsletter provides a look at the current U.S. market environment, based on the most recent forecast efforts of Dataquest semiconductor analysts. In particular, this newsletter focuses on the following industry dynamics:

- Trends in the U.S. economy
- The outlook for the computer market
- End-user inventories and procurement plans
- Semiconductor price and market trends

ECONOMIC OUTLOOK

A growing consensus among U.S. economists is that the longest economic peacetime expansion on record is slowing down. This slowdown will be reflected in real gross national product (GNP) growth of 3.0 percent in 1989 versus the nearly 4.0 percent growth witnessed in 1988. The U.S. economy will further slow in 1990, with GNP growth falling to 1.8 percent, according to economists at The Dun & Bradstreet Corporation. The forecast for 1991 calls for renewed vigor in the economy, with GNP growing 3.5 percent over 1990.

Dataquest believes that most of the economic growth that will take place this year occurred during the first quarter. Despite the strengthening recently seen in the dollar, Dun & Bradstreet

TABLE 1
Comparison of Recession Characteristics 1985-1986 versus 1989-1990

1985-1986	1989-1990
Drastic declines in electronic equipment production	Slower growth in electronic equipment production
Excessive end-user inventories	Tighter inventory control by end users
Rapid expansion of manufacturing capability/excess capacity	Upgrading of capability and improvement in ratio of revenue-to-investment in property, plant, and equipment
Decline of average selling prices (ASPs) below anticipated learning curve	Slower ASP decline

Source: Dataquest
October 1989

SIS Newsletters 1989 PMT

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economists believe that the large U.S. trade deficit (forecast to be $110 billion in 1989 versus $120 billion last year) should continue to keep downward pressure on the dollar. Should the dollar fall, however, interest rates will likely increase—directly because of the Federal Reserve's attempts to stabilize and support the dollar, and indirectly because of acceleration in inflation resulting from higher prices for imported goods.

Despite this guarded outlook, there are signs that the U.S. economic slowdown will result in a soft landing rather than a crash. Among the most encouraging of these signs are the following:

- Reduced job creation rates and consumer spending growth in the first half of 1989 should take some of the steam out of inflationary pressure.
- Although inflation rates jumped upward earlier in the year, some of that acceleration was due to more transitory factors such as oil and food prices.
- Export and investment sectors of the U.S. economy should remain relatively strong. As a result, equipment investment spending will be one of the strongest areas of the economy. Until the dollar and interest rates stabilize, however, investment in additional plant capacity will probably lag behind increases in equipment sales to both domestic and foreign manufacturers.

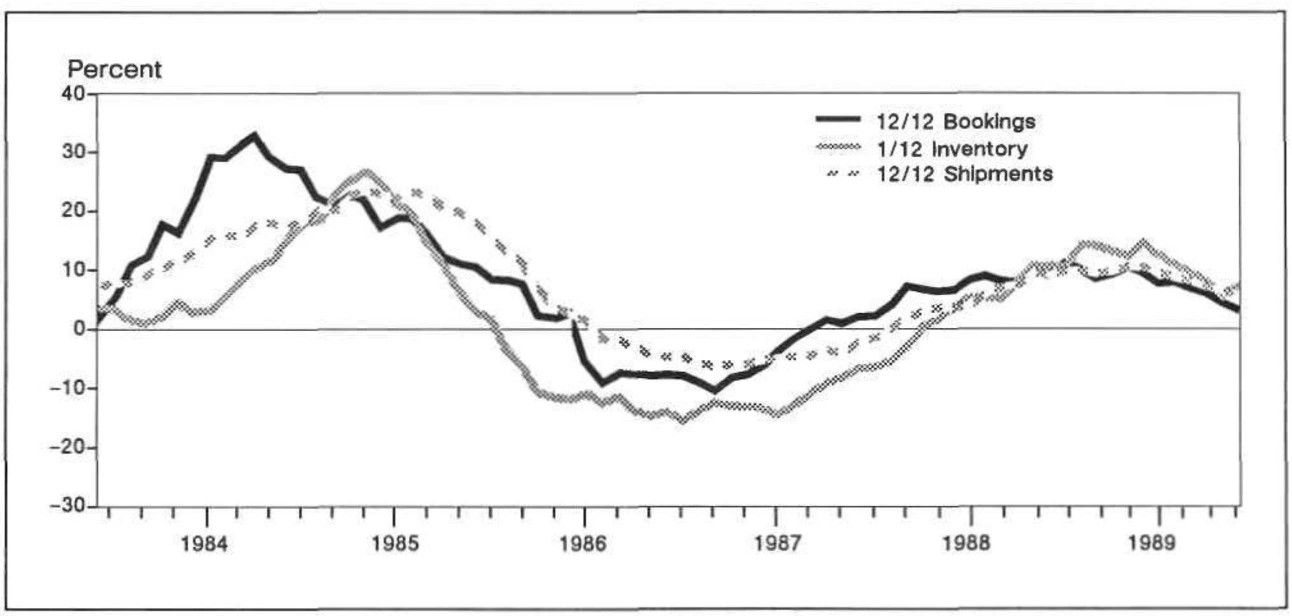
A recently published Dun & Bradstreet Business Expectations Survey seems to confirm these economic assumptions. Expectations for higher third quarter sales are down slightly from second quarter survey results. Expectations for selling price increases, profit gains, and inventory additions were similarly reduced. The latest optimism index for sales fell from 74 in the second quarter to 67 in the third—its lowest level since mid-1987.

Consistent also with the soft landing scenario, the Dun & Bradstreet survey reveals that inflation expectations are the lowest since the end of 1987. In addition, the survey notes that firms are not as adamant about adding to their inventories as they were in the second quarter, and hiring plans are slightly off from their 1988 peaks. If factors such as these can keep the lid on inflation, the U.S. economy may yet avoid interest rate hikes of a degree that would put an end to the 80-plus-month-old expansion.

ELECTRONIC EQUIPMENT SLOWDOWN

Monthly data from the U.S. Department of Commerce (DOC) shows that with the exception of radio and TV, bookings and shipments rates of change for major electronic equipment segments have either moderated or declined when measured on a 12/12 basis (see Figure 1). The DOC data for

FIGURE 1
Computers and Office Equipment Rate of Change



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Source: U.S. Department of Commerce

July shows a continuing slowdown in annualized shipments of computers and office equipment—from a 12/12 growth rate of 7.0 percent in June to 6.3 percent for July. More disturbing, however, is the fact that computer and office equipment orders, on an annualized basis, have fallen from a growth rate of about 10 percent in January of this year to less than 4 percent in July.

Looking at quarterly DOC data for computer shipments and orders, the situation looks even more grim. Quarterly growth rates in computer and office equipment shipments have been declining steadily since the beginning of this year, with the three-month period ending in July running only 3.9 percent above the same period in 1988. Relative to the same three-month period last year, quarterly bookings for computers and office equipment have declined nearly 3.0 percent from last year. At the same time, computer inventories have been increasing since the end of last year, with the average number of weeks of inventory running at just over nine weeks of sales—its highest level in two years.

THE PC OUTLOOK

Personal computer production currently accounts for 11.5 percent of North American chip consumption. Dataquest forecasts that the value of North American PC production in 1989 will be nearly $21 billion—a slightly more than 10.0 percent increase over last year.

During the next five years, we forecast North American PC production growth to peak in 1992 at 13.9 percent, as the next generation of systems is brought to market. We expect workstation growth to peak in 1989 at 38.4 percent, as unrelenting competition puts pressure on prices and the installed base widens.

Price pressure at the systems level will be mirrored in the semiconductor industry, even for chip suppliers at the leading edge of the micro, logic, and memory markets. Among the harbingers of harder times recently reported by Dataquest analysts are the following:

- LSI Logic announced that it expects to report a loss for the quarter ending in September of approximately $2 million to $3 million. This loss is attributed primarily to underutilization of capacity, pricing pressures, and disappointing revenue from its Headland Technology affiliate—a supplier of chip sets to the PC market.
- Chips & Technologies, a leading chip set supplier, has also lowered its earnings expectations, citing general softness in the PC market.
- Intel has warned that its third quarter financial results would be negatively affected by slower than expected sales of the 80386 microprocessor and that earnings could fall below those reported for the second quarter.

INVENTORY MANAGEMENT: THE SEESAW EFFECT

The infamous chip shortages of 1988 constrained the production capabilities of many computer manufacturers, and with growing availability of semiconductor products since fourth quarter 1988, computer inventories rose dramatically. At the same time, computer companies have worked down their order backlogs to very low levels. As a result, inventory management has become crucial.

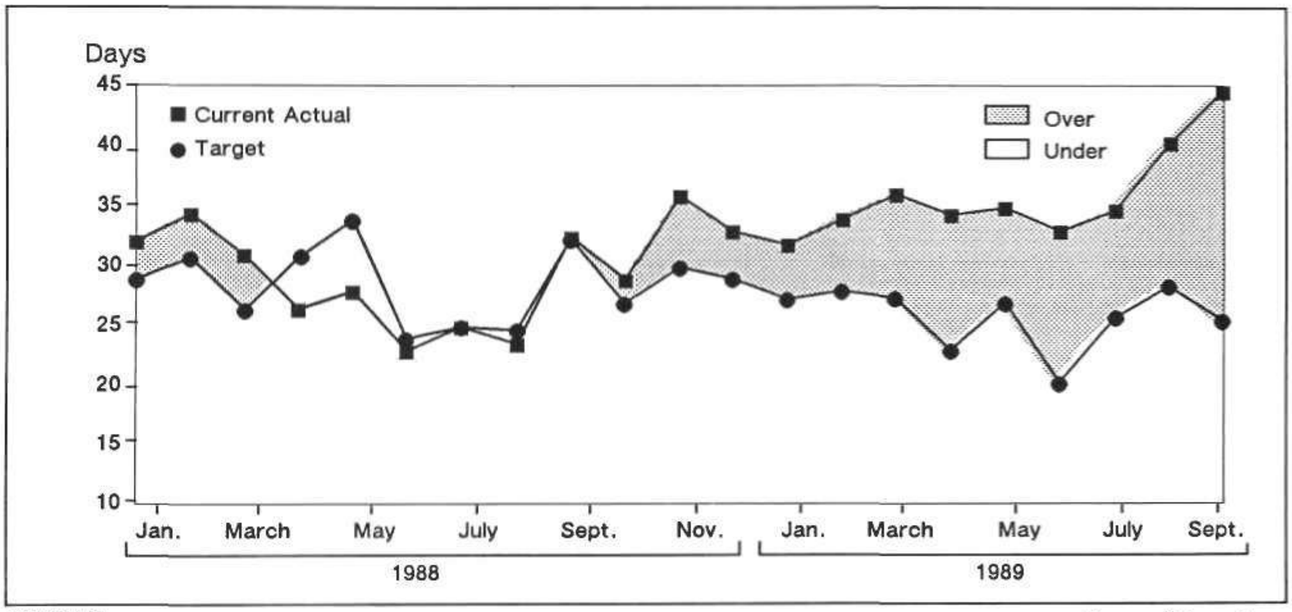
Given this climate of more carefully managed inventories, greater availability of key components, and declining ASPs, semiconductor users will rely more heavily on spot market buys and will order products closer to the date of scheduled production to minimize their inventory costs. Inventory control has now become as important an issue as price.

Dataquest's monthly survey of electronics original equipment manufacturer (OEM) procurement plans reveals that in spite of fairly static targets between the months of June through September, actual levels of semiconductor inventories have continued to rise for electronics OEMs. As shown in Figure 2, actual inventory levels rose in September to 44.8 days from 40.3 days in August. The good news is that both electronics OEMs as a whole and computer OEMs in particular have been able to reduce their non-DRAM inventory levels, which means that DRAM inventories are now the primary cause of the current disparity between target and actual semiconductor inventory levels.

ORDERS AND PRICE TURN DOWN

Not surprisingly, respondents to Dataquest's September procurement survey indicated that they would lower their September orders by 29 percent compared with the previous August. When indexed to December 1988, September's procurement survey marks the third straight month of order reductions. The fact that semiconductor buyers are

FIGURE 2
Actual versus Target Inventory Levels
Electronics OEMs



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Source: Dataquest
October 1989

seeing a deceleration in their systems sales and are attempting to keep their semiconductor inventories in line with their target levels is reflected in the recent relationship between semiconductor orders booked to shipments billed (Figure 3). In September, the U.S. book-to-bill fell below unity for the third consecutive month, reaching its lowest point since October 1988.

Despite the continuing decline in the level of semiconductor orders since April of this year, actual shipments to the U.S. market in August were $1,239.4 million—a 15.3 percent increase over the previous month and a new record for a four-week month. Shipments billed in the U.S. semiconductor market reflect an increased level of "turns" business, which is consistent with the behavior pattern of inventory-conscious semiconductor buyers. On a three-month average, shipments to the U.S. market have declined for the last three months in a row.

Given the buyers' market mentality of the current U.S. semiconductor business, semiconductor suppliers should expect to see more spot orders, an increase in turns business, and therefore more intense competition and pricing pressure. As shown in Figure 4, the downward trend in semiconductor ASPs overall has accelerated during the late second-early third quarter.

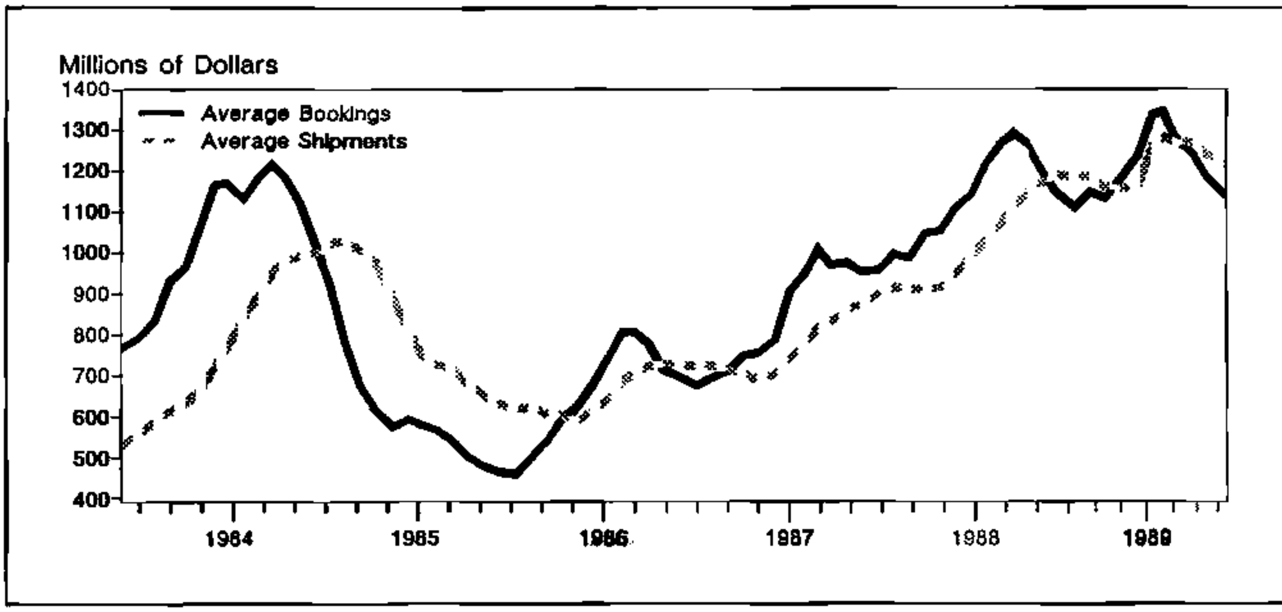
PRODUCT SUMMARIES

The booming semiconductor market of 1988 was founded primarily on very strong growth in the memory market and to a lesser degree, on microprocessor market growth. Trends for the first half of 1989 mark this year as a period of declining semiconductor prices and shorter lead times. Figure 5 illustrates quarterly changes in North American semiconductor consumption by major product segment, based on Dataquest's most recent semiconductor forecast. A summary of pricing and shipment trends for MOS memories, microcomponents, ASICs, and standard logic follows the figure.

Memory

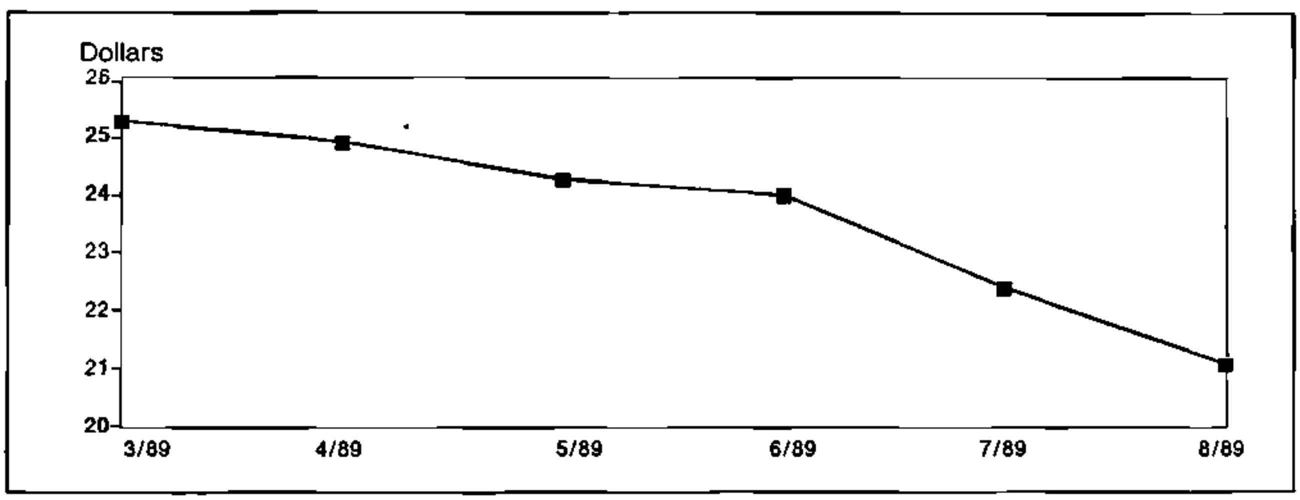
Events in the DRAM segment of the memory market continue to set the stage for memory price and lead-time declines. For the more than two years since the commencement of volume production of 1Mb DRAMs in first quarter 1987, the price remained relatively high (about ¥2,000 based on a yen/dollar exchange rate of 144). In April of this year, a gradual downward trend was observed, which accelerated in the July time frame, reaching a range of ¥1,800 to ¥1,700 (based on a yen/dollar exchange rate of 130).

FIGURE 3
Three-Month Average of U.S. Semiconductor Market Orders Booked versus Shipments Billed (Millions of Dollars)



0005231-3 Source: WSTS

FIGURE 4
Semiconductor ASPs



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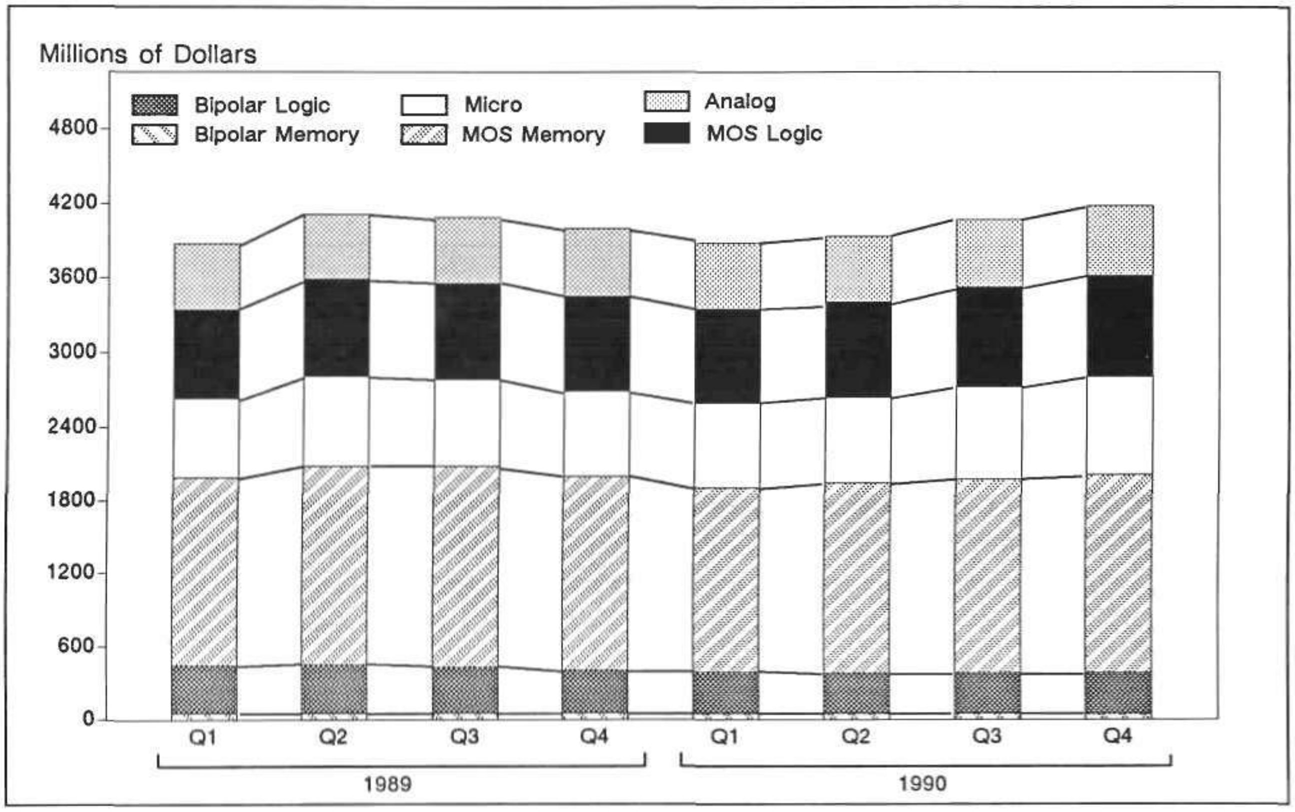
Source: U.S. Department of Commerce
World Semiconductor
Trade Statistics
Dataquest
October 1989

FIGURE 5
North American Semiconductor Consumption by Major Product Segment (Millions of Dollars)



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Source: Dataquest October 1989

In an effort to avoid a precipitous decline in DRAM pricing and excessive supplies of such devices, the response by Japanese suppliers has been to try to manage their memory business—in this case by shifting some of the previously planned capacity expansion from 1Mb DRAMs to 4Mb DRAMs or SRAMs. The efforts by first-tier Japanese DRAM suppliers to preserve the relatively high prices of 1Mb DRAMs will also be tempered by increasing market participation from some of the smaller Japanese 1Mb DRAM manufacturers, as well as by the Korean suppliers, who are aggressively investing in 1Mb DRAM production capability. Samsung, for instance, has succeeded in gaining market share through an aggressive pricing strategy.

However, another trend that has emerged of late is a building of inventory by suppliers of the 1Mb DRAM. The inventory increases have been most conspicuous in North America, South Korea, and Hong Kong, although no world region has escaped this development as of midyear 1989. These market conditions mean that there is ongoing pressure on suppliers to reduce 1Mb DRAM inventories. Consequently, a continued decline in prices is expected to put the volume contract price of the 1Mb DRAM in the United States at about $10 in the fourth quarter. Most Japanese DRAM suppliers have responded to the excess supply of 1Mb DRAMs by cutting production 10 percent or more in an effort to control the supply/demand situation and hence salvage their margins.

Microcomponents

The slowdown in U.S. computer shipments has translated into downward pricing pressure in commodity 8- and 16-bit microprocessors, as well as the high-speed 16- and 32-bit devices. Lead times now range from 4 to 12 weeks, with the most dramatic lead-time improvement occurring in the 80286 segment. Some further shortening of lead times is anticipated. Shortened lead times combined with a more cautious business outlook on the part of some semiconductor suppliers will lead to further price declines as these companies attempt to lure contract business back from distribution channels. With respect to logic chip sets, the increased number of competitors combined with slower growth in PC unit shipments is leading to severe ASP declines in this area.

ASICs

Nearly all ASIC devices are declining in price this year with the exception of the 3-micron gate array, an older product now being displaced from systems. CMOS gate arrays are declining in terms of both price per gate and nonrecurring engineering costs, with the trend now quite apparent in the 2.0-micron and 1.5-micron segments. Some gate array suppliers are competing aggressively on pricing against manufacturers of cell-based ICs as part of the current battle for system design-ins. Pricing on the gate array front has led to more aggressive pricing in MOS PLDs in an attempt to narrow the gap in prices of PLDs versus gate arrays. Low-end bipolar PLDs are currently experiencing severe pricing pressure.

Cell-based IC prices are decreasing at a more moderate pace, but Dataquest believes that mounting competition from embedded array products (in which a memory cell is embedded in the base wafer) will result in serious pricing pressure during 1990.

Standard Logic

During the first half of 1989, the supply of standard logic products has exceeded demand, with corresponding downward pressure on pricing. The downward trend in pricing for the mature bipolar and HCMOS products has quickened, while pricing for newer families such as the 74AS and 74ALS should continue to decline at an aggressive rate as volume grows. Demand for bipolar standard logic in small-outline packages has bolstered its pricing, and the product is currently subject to extended lead times.

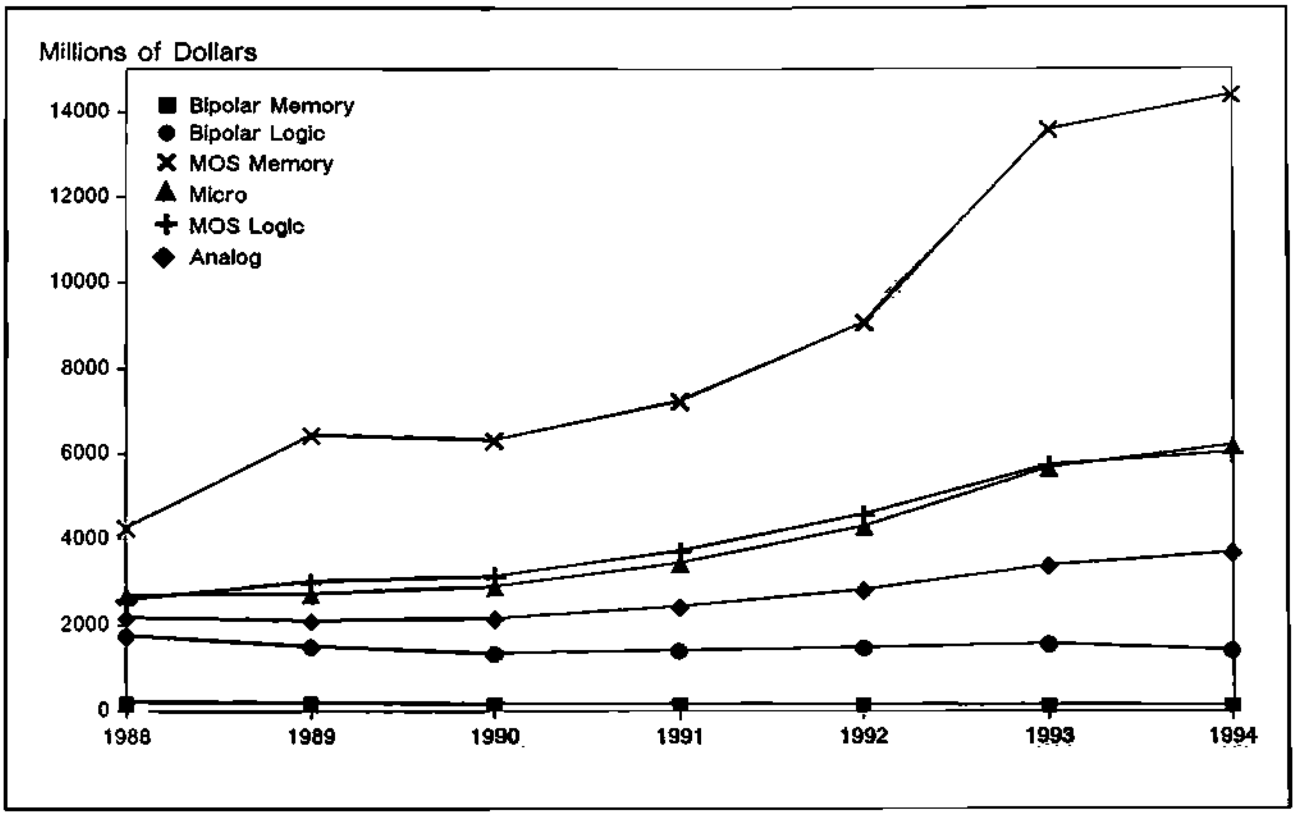
DATAQUEST CONCLUSIONS

Based on our most recent forecast data, Dataquest believes that the U.S. semiconductor market has entered into a slowdown as of third quarter 1989. The current recession in the U.S. semiconductor industry will be marked by negative quarterly growth from third quarter 1989 through first quarter 1990, with an upturn beginning in the second quarter of that year. As illustrated in Figure 6, this upturn will herald four successive years of industry growth that will positively affect all major product segments, with the exception of bipolar memory ICs.

Figure 6 reveals the good news-bad news message behind Dataquest's current forecast. The good news is that overall, the current industry downturn will be mild and brief. The bad news is that the modest growth that does take place between now and 1991 will be largely attributable to leading-edge MOS memory devices and segments of the MOS logic business, the market dynamics for which appear more volatile as 1989 progresses. This means that for many semiconductor companies, there will be little comfort to be derived from Dataquest's relatively sanguine outlook. Compared with the last industry downturn in 1985 and 1986, however, the effects of the current slowdown will more likely lead to belt-tightening than massive financial loss. Product line and regional market presence will be important factors in how well a semiconductor supplier weathers the next four quarters.

Michael Boss
Trish Galligan

Figure 6
North American Semiconductor Consumption by Product Segment 1988-1994 (Millions of Dollars)



0005231-6

Source: Dataquest
October 1989

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Research Newsletter

PMT Executive Memo

MOTOROLA ANSWERS IBM'S CLARION CALL

SUMMARY

On October 25, 1989, IBM dedicated its Advanced Semiconductor Technology Center (ASTC) in East Fishkill, New York—a facility that in 1991 will house the first privately owned synchrotron storage ring for X-ray lithography. During the dedication ceremonies, which were attended by U.S. Commerce Secretary Robert A. Mosbacher as well as other industry, government, and academic leaders, IBM issued a call for government and industry cooperation in X-ray lithography "because of the enormous capital costs associated with the new technology" and offered to share its "X-ray capability with selected firms."

IBM's call for a national X-ray lithography program was heeded by the largest U.S. semiconductor supplier. Motorola became the first, and so far only, company to announce its collaboration with IBM on the development of practical X-ray tools for the manufacture of devices based on geometries of 0.25 micron and below. This announcement is important from a number of perspectives, including the following:

- The IBM/Motorola agreement increases the U.S. resources now being applied to X-ray lithography advancement.
- The agreement underscores IBM's increasing role in strengthening the U.S. semiconductor industry infrastructure.
- The agreement highlights the importance of nonoptical lithography techniques to the future of ultralarge-scale-integration (ULSI) IC development in the United States.

With respect to these points, this newsletter provides Dataquest clients with details of the IBM/Motorola agreement, reviews the potential impact of synchrotron orbital radiation (SOR) in the manufacture of future-generation semiconductor devices, compares the X-ray lithography efforts now under way in the United States with efforts in other regions, and takes a closer look at IBM's role in SOR through its new ASTC facility.

THE IBM/MOTOROLA AGREEMENT

Under the terms of the 21-month agreement, Motorola will pay IBM a "nominal" sum of money and will assign six to eight engineers to work at the National Synchrotron Light Source at Brookhaven National Laboratory in Upton, New York, which currently houses a synchrotron X-ray source that is shared by IBM. A compact synchrotron from Oxford Instruments of England is scheduled to be installed at IBM's ASTC in late 1991, after which time the joint IBM/Motorola program will transfer from Brookhaven to East Fishkill. The Advanced Lithography Facility, where the synchrotron actually will be housed, still is under construction and is expected to be completed next year.

The goal of the current phase of the relationship requires Motorola to assist IBM in perfecting the application of IBM's X-ray capability to a semiconductor "test vehicle" at 0.35-micron geometry. At Motorola's discretion, the current technical cooperation program could be extended to a second contract, enabling Motorola to build its own X-ray production facility based on IBM technology and similar to IBM's ASTC.

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WHAT IS SOR?

What is SOR and why is it of concern to companies such as IBM and Motorola? A synchrotron ring is basically a storage chamber into which electrons are injected and then circulated at an accelerating pace. Magnets bend the path of the speeding electrons, throwing off X-rays that travel down beam lines to exposure stations, or "ports." At these ports, mask-wafer alignment tools position the silicon wafers as the X-rays pass through the photo mask, leaving the circuit pattern imaged in the resist-coated wafer.

X-ray technology has numerous advantages over today's light-based optical lithography systems. These advantages include the following:

- X-rays have a shorter wavelength than light and can therefore be used to draw finer circuit lines.
- Unlike lasers, which can produce light only at discrete energies, SOR can be tuned to a broader spectrum of frequencies.
- X-rays pass through minute dirt particles that can block image-producing light in conventional lithography systems, making X-ray technology less sensitive to surface contaminants.
- Although electron-beam (e-beam) lithography offers significant improvements in resolution over conventional optical systems, the write time for each wafer is too slow for a volume production environment. At present, e-beam lithography is favored more for small batches of custom ICs and for the creation of masks.

Dataquest believes that the shift to X-ray lithography for R&D purposes by 1990 is inevitable because of the physical limitations of photolithography. Current optical steppers are capable of submicron geometries, but Dataquest believes that such optical steppers will reach a manufacturing limit between 0.25 and 0.50 micron, despite expected advances in mask and photoresist technologies. Below that level, researchers are exploring various approaches, as listed in Table 1.

SUBSTANTIAL INVESTMENT STARTING YESTERDAY

At the recent Dataquest Semiconductor Industry Conference (held October 16 through 18), Dr. Graydon Larrabee, Director of Texas Instruments' Microelectronics Manufacturing Science and Technology Program, presented a paper on the topic of wafer fab equipment technologies for succeeding device generations. TI believes that there is a 10+ year cycle, timed from the start of development to vendor qualification, for each succeeding generation of DRAM devices. Figure 1 illustrates this cycle with a timetable. Table 2 outlines TI's vision of the critical elements of the emerging technologies.

From TI's data, one could conclude that the development of new technologies in order to achieve vendor qualification of 256Mb DRAMs in 1997 should have been in process during the past three years—including work on X-ray lithography sources!

CURRENT EFFORTS

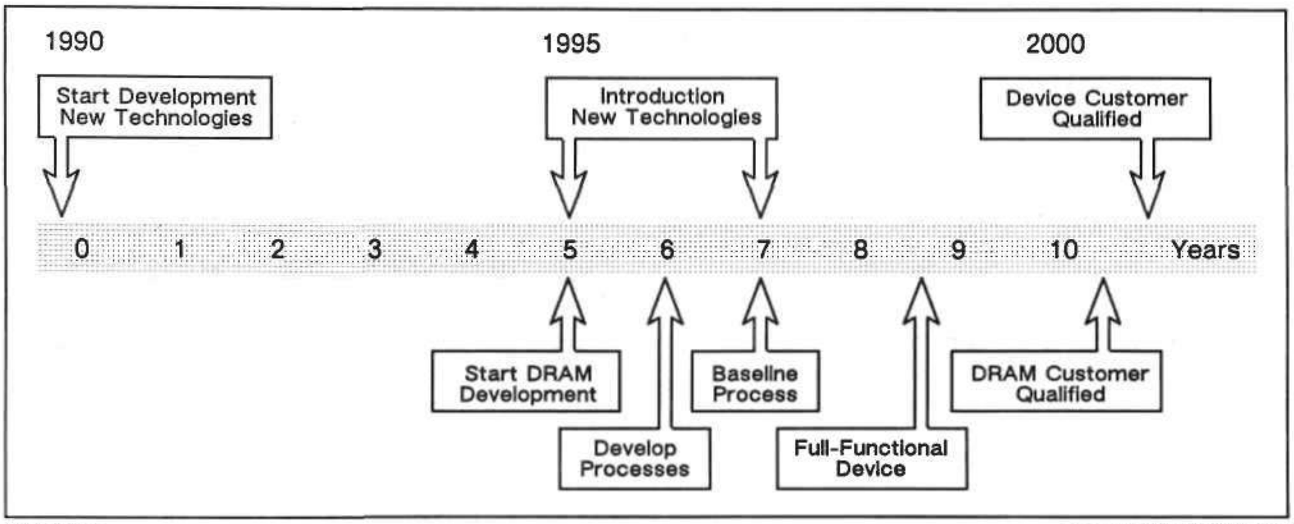
Japanese researchers currently are focusing on SOR technology because they believe that it offers the highest wafer throughput of all X-ray techniques and theoretically can achieve the geometries

TABLE 1
Submicron Lithography Approaches

Technology	Dimensional Limits (Micron)
Optical stepper	To 0.5
Excimer laser/deep-UV (i.e., step-and-scan)	0.6 to 0.35
Plasma X-ray	0.5 to 0.25
Direct-write e-beam	0.5 to 0.2
SOR	0.25 to 0.1
Focused ion beam	sub-0.2

Source: Dataquest
December 1989

Figure 1
Next-Generation Device Development
(0.15-Micron Minimum Geometries)



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Source: Texas Instruments

TABLE 2
Tools and Technologies for Succeeding Device Generations

	0.8µ	0.6µ	0.35µ	0.25µ	0.15µ
Year of Vendor Qualification	1989	1991	1994	1997	2000
Stepper Technology	G-line	G-, I-line	DUV	DUV, X-ray	X-ray
DRAM Size	4Mb	16Mb	64Mb	256Mb	1,024Mb

DUV = Deep ultraviolet

Source: Texas Instruments

required for 64Mb and 256Mb memories. Moreover, if compact SOR rings are developed, they could be used with steppers on existing fab lines.

The National Synchrotron Light Source, along with other U.S. laboratories, has pioneered large oval-shaped synchrotron rings for basic research. The federal government also is assisting in the development of X-ray sources at Louisiana State University and the University of Wisconsin. In the private sector, IBM received a $17.4 million contract from the U.S. Defense Advanced Research Projects Agency (DARPA) to conduct research in X-ray mask technology for the Naval Research Lab. IBM currently rents two SOR beam lines from the Brookhaven Lab, where it has designed and built an X-ray lithography exposure station that has been used to make actual devices.

While some debate continues in the United States over the relative merits of SOR because of the installed base of optical steppers and competition from excimer lasers and electron beam equipment, Japan is rapidly building momentum in the area of compact SOR rings for megabit SRAM and DRAM production. Dataquest believes that future ULSI labs will use ultrasmall SOR equipment, such as the 0.5m-diameter SOR machine currently being developed by NEC and Sumitomo Heavy Industries.

WHAT IS SEMATECH DOING?

Given the urgent need for the development of nonoptical lithography systems, one might ask why X-ray lithography has not been at the top of the

Sematech agenda. Sematech has, in fact, encouraged the establishment of an X-ray lithography initiative and has urged its member companies to participate in such an effort. Furthermore, one of the Sematech Centers of Excellence, the University of Wisconsin at Madison, is dedicated to X-ray lithography research. The problem facing Sematech's more direct involvement at this time is one of funds.

Estimates are that the individual components of the X-ray lithography implementation puzzle (i.e., masks, resist technology) each may carry a $100 million to $200 million development price tag—the equivalent of one-half to all of the current Sematech annual budget. Because manufacturers at the leading edge of device densities typically are DRAM producers, the majority of Sematech's participating companies would not find immediate investment in X-ray lithography to be to their greatest short-term advantage.

IBM: A COMPANY FOR ALL SEASONS

IBM has been involved in research on SOR for at least 10 years and currently plays a critical role in the implementation of basic research. IBM claims to be the first company to successfully form 0.5-micron patterns on silicon wafers using X-ray photolithography techniques. According to IBM president Jack Kuehler, IBM will have spent $435 million on the development of X-ray lithography by early summer 1990; and by the time production based on X-ray technology begins, IBM investment will have exceeded $1 billion.

As with Sematech and U.S. Memories, IBM once again stepped forward to offer its resources to the U.S. semiconductor merchant market and the equipment and material base that supports it. IBM executives also have urged the U.S. government to play a useful role in maintaining U.S. competitiveness in world markets along with industry participation in high-technology cooperative initiatives such as IBM's.

DATAQUEST CONCLUSIONS

Investment on the massive scale of X-ray lithography is too much for a single company, even IBM, to bear. The issue of advanced lithography is of particular concern to companies that require advanced memory technology—hence IBM's and Sematech's call for a national X-ray lithography program. Mr. Kuehler noted that some companies turned IBM down when it proposed a research technology cooperative to develop X-ray tools for 0.25-micron geometries. Motorola was the first major U.S. merchant semiconductor supplier to answer IBM's clarion call—perhaps not a moment too soon.

Referring back to Dr. Larrabee's Dataquest presentation, new technology development must start next year for gigabit-density memory devices that will be customer qualified in the year 2000. According to Dr. Larrabee's timetable, shown in Figure 1, the baseline process for such a device must be established by the seventh year after the start of development. Logically, this timetable would imply the characterization of the lithography system that would mass produce devices based on that process. Therefore, it seems as if Texas Instruments is a likely candidate for participation in an X-ray lithography effort, although TI's intention in this respect is as yet unknown. What is clear, however, is that the time for industry commitment is at hand.

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Research *Newsletter*

QUARTERLY SEMICONDUCTOR COMPANY FINANCIAL RESULTS

INTRODUCTION

Dataquest regularly reports on semiconductor company financial results through its weekly on-line news service, *The DQ Monday Report*. As a service to the Products, Markets, and Technology segment binderholders, a summary of this information is provided herein.

Table 1 summarizes the net sales and income disclosures from selected semiconductor companies based on data from quarterly report periods that ended during the August-through-October 1989 time frame. This information is compared with that of the 1988 August-through-October time frame and is provided in millions of dollars unless otherwise indicated. Table 2 provides a similar summary for fiscal year revenue and income for applicable companies. Descriptive summaries of quarterly performance highlights for the companies listed follow these tables.

TABLE 1
Quarterly Financial Summaries for Selected Semiconductor Companies
(Millions of Dollars except Where Otherwise Noted)

Company	Quarter End	Latest Quarter Revenue	Percent Change	Latest Quarter Income	Percent Change
Adaptec, Inc.	Sept. 29, Q2	$ 26.5	70%	$ 3.0	1,409%
Advanced Micro Devices	Sept. 24, Q3	$274.8	4%	$ 12.1	68%
Altera Corporation	Sept. 30, Q3	$ 15.7	55%	$ 2.9	43%
California Micro Devices	Sept. 30, Q1	$ 8.4	49%	$425K	N/M
Chips and Technologies	Sept. 30, Q1	$ 70.9	61%	$ 9.1	60%
Cirrus Logic	Sept. 30, Q2	$ 18.0	211%	$ 3.4	312%
Cypress Semiconductor	Oct. 2, Q3	$ 51.8	40%	$ 7.9	45%
Dallas Semiconductor	Oct. 1, Q3	$ 23.2	49%	$ 3.3	9%
IDT	Oct. 1, Q2	$ 54.1	17%	$ 5.8	1%
Intel Corporation	Sept. 30, Q3	$771.4	(2%)	$ 72.0	(50%)
IMP	Sept. 24, Q2	$ 17.1	15%	$236K	(87%)
Lattice Semiconductor	Sept. 30, Q2	$ 8.3	60%	$ 1.3	150%
Linear Technology	Oct. 1, Q1	$ 17.8	20%	$ 2.5	12%
Logic Devices	Sept. 30, Q3	$ 3.9	43%	$829K	59%
LSI Logic	Oct. 1, Q3	$133.7	42%	($35.7)	N/M

(Continued)

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TABLE 1 (Continued)
Quarterly Financial Summaries for Selected Semiconductor Companies
(Millions of Dollars except Where Otherwise Noted)

Company	Quarter End	Latest Quarter Revenue	Percent Change	Latest Quarter Income	Percent Change
Maxim Integrated Products	Sept. 30, Q1	$ 12.3	29%	$ 1.7	43%
Micron Technology	Aug. 31, Q4	$103.0	(9%)	$ 16.0	(63%)
Motorola, Inc.	Sept. 30, Q3	$2,408	20%	$ 89.0	2%
National Semiconductor	Aug. 27, Q1	$397.6	11%	($21.9)	N/M
SEEQ Technology	Sept. 24, Q4	$ 10.1	(35%)	($ 2.4)	N/M
Silicon General	Oct. 1, Q1	$ 9.1	5%	$425K	88%
Texas Instruments	Sept. 30, Q3	$1,538	(2.5%)	$ 65	(31%)
Unitrode Corporation	Oct. 28, Q3	$ 37.2	(9%)	$244K	(33%)
Weitek Corporation	Sept. 30, Q3	$ 12.8	38%	$ 1.8	64%
Western Digital	Sept. 30, Q1	$224.9	(9%)	($ 2.7)	N/M
Xicor, Inc.	Sept. 10, Q3	$ 21.2	4%	$863K	(77%)
VLSI Technology	Oct. 1, Q3	$ 77.1	31%	$ 3.3	44%
ZyMOS Corporation	Sept. 30, Q3	$ 10.1	57%	($500K)	N/M

K = Thousands
N/M = Not Meaningful

Source: Company Literature

TABLE 2
Fiscal Year Financial Summaries for Selected Semiconductor Companies
(Millions of Dollars)

Company	Quarter End	Fiscal Year Revenue	Percent Change	Fiscal Year Income	Percent Change
Micron Technology	Aug. 31, Q4	$446.4	49%	$106.1	8%
SEEQ Technology	Sept. 24, Q4	$ 55.1	(10%)	$ 1.1	(87%)

Source: Company Literature

FINANCIAL RESULTS BY COMPANY

Adaptec, Inc.

Results for Adaptec's second fiscal quarter reflected the company's achievement of its second consecutive quarter of record profits and third consecutive quarter of record revenue. Adaptec attributed its strong financial performance to a combination of increasing shipments of SCSI products and expanding international presence.

Advanced Micro Devices (AMD)

Results for AMD's third quarter were essentially flat over the immediately preceding quarter in terms of both revenue and net income. What is noteworthy, however, is the sharp improvement in income over the same period a year ago. The company attributed the increased profits on lower revenue to effective cost-containment measures. In his comments on the company's financial performance, W.J. Sanders, chairman and CEO, said that demand for AMD's iAPX86 microprocessors and programmable logic devices remained strong, permitting the company to "achieve ... flat results in a period of generally weak demand for semiconductors." The Asian market continued to show strength during the quarter. Mr. Sanders noted that the outlook for AMD in a period of moderate industry slowdown that was largely caused by declining DRAM prices bodes better for AMD than for the industry in general because the company does not participate in the DRAM market segment. For the nine-month period ended in September, AMD recorded income of $34 million on sales of $819 million, compared with income of $53 million on revenue of approximately $878 million last year.

Altera Corporation

Altera's third quarter fiscal results marked the company's 21st consecutive quarter of increasing sales and its 11th consecutive quarter of record profits. Rodney Smith, chairman and CEO, said that the company experienced steadily increasing demand for all its product lines of user-configurable components.

California Micro Devices

California Micro Devices' first fiscal quarter revenue reflected a 49 percent increase over the corresponding quarter a year ago, while remaining essentially flat over the immediately preceding quarter. However, income of $425,000 was a significant improvement over losses of $1.2 million and $1.1 million for fiscal first quarter 1989 and fourth quarter 1989, respectively. Chan Desaigoudar, company chairman and CEO, attributed the improved position in the semiconductor side of the business to increased demand for telecommunication products as well as more customer-furnished tooling business. The thin-film division, on the other hand, continued to report sluggish shipments. However, profitability has been restored, and the company looks forward to a promising future and the prospect of new product introductions.

Chips and Technologies (C&T)

Chips and Technologies' first fiscal quarter 1990 revenue reflects an increase of 61 percent over the same quarter a year ago and 15 percent over fourth quarter 1989. Although C&T's reported $9.1 million of income represented a 60 percent improvement over the same quarter last year, it was down 10 percent from the immediately preceding quarter. Gordon Campbell, president and CEO, said that sales growth was due to higher shipments of the company's CHIPSet products, particularly the NEAT and 386/AT product lines. Gross margin for the quarter fell to 47 percent of net sales, caused by "price protection on certain low-end products."

Cirrus Logic

Cirrus Logic reported an increase of 211 percent in revenue and 312 percent in net income over the corresponding period last year. Company president and CEO Michael L. Hackworth attributed the company's strong financial performance to increased demand from PC-compatible OEM systems customers for its VGA products as well as higher levels of acceptance of its hard disk drive controller products, particularly of the company's SCSI products. Moreover, the company's data communications controller is achieving increased rates of design wins.

Cypress Semiconductor

Cypress experienced strong growth in revenue and net income of 40 percent and 45 percent, respectively, over the same quarter a year ago. Growth over the preceding quarter was much slower, in the range of 2 percent in revenue and 4 percent in income. T.J. Rodgers, president and CEO of Cypress, characterized the company's quarterly results as successful and said that they were largely attributable to "the company's entrepreneurial start-up subsidiaries that are contributing positively both to the company's revenue and bottom line." Mr. Rodgers said also that given the uncertain short-term outlook for the industry, Cypress is maintaining a cautious position on new employee hiring and expense control.

Dallas Semiconductor

C. Vincent Prothro, chairman and CEO of Dallas Semiconductor, also has taken over as president of the company, replacing John W. Smith. Mr. Smith, who resigned to pursue other interests, will remain as a consultant. Mr. Prothro said that prospects for the company reflect continued growth.

Integrated Device Technology (IDT)

IDT reported record levels of sales and earnings for its second fiscal quarter. Revenue of $54.1 million represented an increase of 17 percent over the same quarter last year and an increase of 5 percent over the prior quarter. Income, however, while growing 11 percent over the immediately preceding quarter, was only 1 percent over the same quarter a year ago. IDT's chairman and CEO described the company's performance as "solid" and said, "We are cautiously optimistic that we will continue to grow in the third quarter."

Intel Corporation

Intel's third quarter financial results showed a 2 percent decline in revenue and a 50 percent decline in net income, compared with the same quarter a year ago. Compared with the immediately preceding quarter, the company's results registered a 28 percent decrease in income on a 3 percent increase in revenue. However, third quarter results include a $35 million charge associated with the potential sale of BiiN, the computer systems joint venture with Siemens AG. Dr. Andrew S. Grove, president and CEO, commented that "bookings improved as the quarter progressed...bookings were higher than the previous quarter, and our book-to-bill ratio exceeded 1.0." The company's 386SX continued its strong ramp-up while shipments of the 386DX were firm. Intel started first production shipments of the i486, and volume will ramp up in the fourth quarter. Intel's Systems Group is working to increase output of its 386-based OEM PC platforms.

International Microelectronics Products (IMP)

Revenue for the company's second fiscal quarter was $17.1 million, an increase of 15 percent over both the corresponding quarter last year and the immediately preceding quarter. IMP reported net income of $236,000; although a decrease of 87 percent from the like period a year ago, this income represents a return to profitability from losses of $941,000 in the prior quarter. The company views near-term prospects with confidence because bookings were at record levels for the quarter. Barry Carrington, president and CEO, said that IMP is ramping up production to meet strong demand for its products.

Lattice Semiconductor

Results for Lattice's second quarter of fiscal 1990 represent record quarterly revenue and earnings for the company and mark the company's 11th consecutive profitable quarter. Revenue grew 60 percent over the like period last year and 19 percent over the preceding quarter, while income increased 150 percent and 45 percent, respectively. Net proceeds of almost $14 million from a recent IPO of 2.9 million common shares will be deployed for general working capital requirements. Lattice is a supplier of proprietary PLDs called GALs (Generic Array Logic devices).

Linear Technology

Linear Technology reported record sales and income of $17.8 million and $2.5 million, respectively, for its first fiscal quarter. Company revenue grew almost 20 percent over last year but remained flat compared with the prior quarter. Net income increased approximately 12 percent over the corresponding quarter a year ago and 3 percent over the previous quarter. Robert H. Swanson, president and CEO, noted that Linear Technology modestly increased sales and income "despite a business climate that was generally trending downward."

Logic Devices

Logic Devices reported third quarter results showing income increases of 60 percent over the corresponding quarter a year ago and 2 percent over the prior quarter. Although revenue grew 43 percent over last year's like quarter, it declined slightly by 4 percent over second quarter 1989. Company president Bill Volz stated his gratification with these results, particularly in light of the fact that the company is now subject to taxation after using up the tax carry-forwards incurred during its start-up phase. Third quarter results mark the 16th consecutive quarter of profitability for the company, which supplies SRAMs, DSP devices, and math coprocessors.

LSI Logic

LSI reported a net loss of $3.1 million for the third quarter ended October 1, 1989. This loss was realized before taking a one-time, pretax charge of $43 million associated with a restructuring. The restructuring charge includes the write-off of LSI Logic's 5-inch wafer fab in Santa Clara, California—the company's first wafer foundry. LSI plans to put the outdated fab to future use as an R&D facility and pilot line. The company's $3.1 million loss compares with a $7.5 million profit earned during the third quarter of 1988. In addition to the write-off of its 5-inch wafer fab, LSI chairman and CEO Wilfred Corrigan attributes his company's losses to a combination of factors, including excess capacity exacerbated by a slowdown in the company's rate of growth, a slowing in the rate of new orders from the computer sector, a write-off of inventories related to its out-of-date manufacturing line, and discontinued product assets. For the first nine months of fiscal 1989, LSI Logic reported a net loss of $23.2 million on revenue of $408.5 million. This compares with a net profit of $19.4 million on revenue of $259.5 million for the same period last year.

Maxim Integrated Products

Maxim's record first quarter 1990 net income marks the company's 14th consecutive quarter of increasing profitability. During the quarter, Maxim announced 20 new products, including 12 proprietary parts, bringing the company's total analog product offering to 330 devices.

Micron Technology

Micron's fourth quarter earnings reflect a significant decrease from the corresponding quarter a year ago and a slowdown from the prior quarter's results. In the prior quarter, the company had income of approximately $29 million on sales of $119.2 million.

Motorola, Inc.

Motorola's third quarter results include a pretax provision of approximately $43 million to cover the anticipated costs of a voluntary severance program and a decrease in the company's estimated 1989 full-year tax rate. Motorola's third quarter earnings before taxes were $104 million—a 21 percent decrease from third quarter 1988. For the first nine months of fiscal 1989, Motorola reported earnings of $366 million on net sales of $6.97 billion. This compares with earnings of $321 million on net sales of $6.06 billion for the similar period last year. Comparing third quarter 1989 results for the company's Semiconductor Products Sector with those of the previous year, president and CEO George Fisher noted that both sales and orders increased 10 percent, while backlog rose 11 percent. Orders during the period ran slightly lower than sales. Lower average selling prices and higher engineering costs for R&D and product development combined to lower operating profits. Orders in all major regions were higher, with Japan, Asia/Pacific, and Europe providing the greatest boost to growth in orders. Memories, microprocessors, and analog devices were the product areas that saw the greatest order growth. Semiconductor order growth was highest in personal computer and communications end markets, although automotive, consumer, and industrial segments grew as well. Orders from the computer and military end markets declined.

National Semiconductor

National Semiconductors' first quarter results of $397.6 million from continuing operations reflected a decrease of almost 11 percent from the same quarter last year. The company reported a net loss of $21.9 million this year, compared with a loss of $30.5 million last year. However, considered from the point of view of continuing operations, this quarter's loss of $21.9 million compared unfavorably with earnings of $13.6 million for the corresponding period a year ago. Results were an improvement over the company's fourth fiscal quarter, however, when National reported a loss of $97.8 million on sales of $419.1 million from continuing operations, although down from net earnings of $77.1 million (which was generated from the sale of NAS). Charles E. Sporck, president and CEO, claimed to be encouraged by the company's "continued improved performance during a quarter which saw flat semiconductor business conditions, along with pricing pressure in certain areas." He also said that he expects the next fiscal quarter to mark National's return to profitability.

SEEQ Technology

SEEQ reported results for its fourth fiscal quarter and year ended September 24. Annual income fell 87 percent on revenue of $55.1 million. This revenue of $55.1 million was down 10 percent from fiscal 1988 revenue, while revenue for the fourth quarter declined 35 percent from the same quarter a year ago. SEEQ suffered a loss of $2.4 million in the fourth quarter, which compares unfavorably with income of $2.3 million for the same quarter a year ago and income of $1.7 million for the prior quarter. The company attributed its poor revenue and earnings performance to events in manufacturing and marketing. Over the past two years, SEEQ has been trying to convert from a single-product, engineering-oriented facility to a multiple-product, manufacturing-oriented company. Additionally, the company has experienced some price and volume pressures associated with the current business environment. SEEQ had indicated a few weeks earlier that the company would report a loss for the fourth quarter as a result of a "precipitous" decline in orders for its Ethernet product family.

Silicon General

Financial results for Silicon General's first fiscal quarter of 1990 include only the continuing operations of its semiconductor business, because the company is in the process of spinning off its telecommunications business as a separate company. Revenue of $9.1 million represented an increase of 5 percent, and income increased 88 percent over the same quarter last year. Net earnings of $425,000 included an extraordinary tax credit of $73,000. Revenue for the telecommunications business for the quarter were $5.1 million, with income of $12,000. A company spokesperson said that demand for Silicon General's semiconductor products continued to be strong in the areas of defense electronics, industrial power conversion, and automotive electronics.

Texas Instruments (TI)

TI reported a decline in third quarter revenue and net income compared with both the corresponding quarter last year and the immediately preceding quarter. Third quarter revenue of $1,539 million represented a decrease of 2.5 percent over last year's third quarter and a decrease of 1.6 percent over the prior quarter. Income registered a sharper decline of 31 percent and 39 percent over the same quarter a year ago and the previous quarter, respectively. Jerry Junkins, TI chairman, president, and CEO, commented that "electronic end-equipment production in the United States remained sluggish, with pronounced weakness in the computer and defense segments. In Europe... slowing was experienced in consumer products and computers." Mr. Junkins observed that the slowing growth rate of the semiconductor market is particularly evident in memory products. He attributed the decline in net sales billed to lower semiconductor billings, which were down 6 percent. Profits were negatively affected by lower prices, primarily in memories, and by higher depreciation in semiconductors. Third quarter results also include royalty income of $28 million compared with $21 million for the same period a year ago. TI will continue to invest in global deployment of the company's submicron CMOS processing capability, however, and capital spending for 1989 is pegged at $850 million.

Unitrode Corporation

Unitrode announced third quarter results that showed a small increase in income on a lower level of revenue when compared with the immediately preceding quarter. Revenue from continuing operations for the quarter were down 5 percent and 3 percent, respectively, from the same quarter last year and the prior quarter. Income of $244,000 represented a 33 percent decline from the like quarter a year ago but a 4 percent increase over the second quarter. Net income included a modest gain from the sale of the Passive Components Division, and revenue of $37.2 million included $3.3 million in sales from that division, which was sold to AVX Corporation in mid-October. Howard Wasserman, president and CEO of Unitrode, noted that two of the company's divisions, Integrated Circuits and Powercube, posted a record quarter in sales and profits. New orders, particularly in the Semiconductor Products Division, strengthened over the prior quarter.

Weitek Corporation

Revenue of $12.8 million for Weitek's most recent quarter reflects strong growth of 38 percent and 11 percent over the same quarter last year and the prior quarter, respectively. Income of $1.8 million grew 64 percent over last year's similar period and 10 percent over the preceding quarter. For the tenth consecutive quarter, Weitek's revenue and net income have increased substantially. The company's book-to-bill ratio remains above 1.0.

Western Digital (WD)

For its first fiscal quarter, Western Digital reported a loss of $2.7 million on sales of $224.9 million. Compared with the corresponding period last year, sales dropped 9 percent while earnings went from net income of $12.9 million to a loss. Factors contributing to the quarterly loss were primarily a drop of 57 percent in sales of imaging products, mainly to the reseller channel; a loss of production time at WD's board-manufacturing plant in Puerto Rico due to Hurricane Hugo; and currency losses resulting from the strength of the dollar. In terms of the company's communications business, although revenue was flat, that segment remained substantially profitable, while the company's total storage business improved on its already profitable performance. WD expects to break even next quarter in its systems logic business. The company achieved its best level of bookings in five quarters, according to WD chairman, president, and CEO, Roger Johnson.

Xicor, Inc.

Xicor reported third quarter financial results for the quarter ended September 10. Revenue of $21.2 million was essentially flat compared with the same period a year ago, but income declined 77 percent to $863,000 from $3.8 million for the third quarter of 1988. The company attributed the impact on its operating profits to continued declines in selling prices. Xicor president Raphael Klein also said that bookings had not yet recovered from the summer sluggishness and that price erosion continues. He took the opportunity to warn that Xicor may report a loss for the fourth quarter, although he expects the company to be profitable for the year.

VLSI Technology

VLSI Technology reported record revenue and net income for its third fiscal quarter, ended October 1. Company chairman and CEO Alfred J. Stein attributed the strong financial performance for the quarter to both a strong backlog from the preceding quarter and new orders, resulting in record production revenue for ASIC and Logic Product Divisions. Other factors contributing to increased operating profits were improved manufacturing productivity at the San Jose, San Antonio, and Tempe fabs and higher utilization and production at the San Antonio fab. The company expressed cautious optimism about its future prospects.

ZyMOS Corporation

Record third-quarter revenue of more than $10 million for ZyMOS represented a 57 percent increase over third quarter 1988 and an 18 percent increase over the prior quarter. However, the company recorded a loss of $500,000—up from a second quarter loss of $324,000 but substantially down from the $1.6 million loss before an extraordinary gain for the like quarter a year ago. The increase in revenue is attributed primarily to increased standard product sales, while the loss is mainly the result of continued investments in R&D and expenses in new product introductions.

Patricia Galligan

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DSP AND THE WAVE OF NEW RISC PRODUCTS

INTRODUCTION

The major news topic of the last six months in the semiconductor field has been the reduced-instruction-set computer (RISC) processor. Every major semiconductor and computer company now has a stated position on RISC in its product lines. Although much of the news is market posturing, there can be little question that the new RISC microprocessors represent a significant next generation for general-purpose computing. Independent of instruction set size, they embody the latest thinking from both computer science and market demand in today's VLSI technologies. Such opportunities for a completely fresh start on a processor architecture occur only rarely. Some suppliers are taking better advantage of the chance than others.

Any change in the general-purpose microprocessor market is important to digital signal processing (DSP) because it is consistently estimated that half of the volume of the integrated circuits used in DSP are conventional microprocessors. Their low price, wide familiarity, and variety of support tools always make them an attractive alternative to the higher-performance digital signal processor (DSMPU) solution. In addition, many of the mips and mflops performance figures of the new RISC processors are close to those expected only from digital signal processors. Even a casual glance shows RISC's architectural similarities to DSMPUs, such as deep data pipelining, the Harvard-style separation of instruction and data memories, and multiple execution units. RISC processor manufacturers are even talking about the same embedded controller markets that have been the domain of high-performance DSMPUs and about things like real-time operating systems.

What does this mean for the suppliers and users of single-chip DSMPUs in the future? We will explore that question in this newsletter. In addition, we will review some of the basic performance requirements for digital signal processors and see how these are met by the major new RISC processors. Next, we will look at the latest generation of high-performance DSMPUs and see how both are moving to solve some common new systems requirements. Comparing the two types of processors leads to some strategies for DSMPU makers to protect and expand their markets in the face of this potentially strong competition.

DSP REQUIREMENTS AND THE NEW RISC PRODUCTS

Historically, signal processors have been distinct from general-purpose microprocessors because of the following three major requirements:

- Higher precision
- Higher speed
- Special functions operating on large amounts of data

Table 1 lists these requirements with some of the architectural or implementation techniques used to meet them. The first two columns indicate which of these techniques has generally been used in current-generation CISC microprocessors and in the first- or second-generation DSMPUs. The next two columns show the RISC processors and the latest (or third generation) of high-performance DSMPUs. Following the historical requirements are the additional DSP requirements considered to be important today as the result of larger, more complex systems.

Just looking at the relative predominance of the Xs over the Os in Table 1 confirms the general trends: New CISC microprocessors have few attributes other than precision to make them suited for DSP, whereas even the first-generation DSMPUs are a significant improvement. New higher-performance DSMPUs are complete in their use of such techniques, while RISC, for its own performance needs, has used more than even the early DSMPUs. The Xs and Os represent only rough averages across a number of products. Table 2 shows some of the specific features and performance parameters for four representative RISC products. Three high-performance DSMPUs are included for comparison on the same basis.

Table 1

Product Overlap in Meeting DSP Requirements

DSP Requirements	Implementation Technique	Products CISC	DSP-1&2	RISC	DSP-3
Historical DSP Requirements					
High precision	8-bit	X	O	X	X
	16-bit	X	X	X	X
	32-bit	X	O	X	X
	Floating-point	O	O	X	X
High speed	Pipelined data path	O	X	X	X
	Parallel operation				
	Data memories	O	X	X	X
	Instruction memory	O	X	X	X
	I/O controller	O	X	O	X
	Address generators	O	X	O	X
	Fixed and floating point	O	O	X	X
	Loop counters	O	X	O	X
	Full processors paralleled	O	O	X	X
	Memory speed-size hierarchy				
	Instruction caching	O	O	X	X
	I/O buffering	O	O	X	X
Special processing	Complex address generation				
	Vector	O	X	O	X
	2-D	O	O	O	X
	Arithmetic				
	Multiply-accumulate	O	X	X	X
	Saturation	O	X	O	X
Large amounts of data	Large memory space	O	O	X	X
	High-speed I/O	O	O	O	X
	Real-time control	O	X	X	X
New DSP Requirements					
High-level languages		X	O	X	X
Operating systems		X	O	X	X
Industry standard functions		X	O	X	O

Source: Dataquest
March 1989

Table 2

Major New RISC and DSMPU Feature and Performance Summary

	RISC				DSP		
	Motorola 88100	AMD 29000	SPARC 7C601	Intel i860	TI 320C30	AT&T 32C	Motorola 96002
Precision							
Integer	8-32	8-32	8-32	8-32	16, 32	8-24	32, 64
F-P	32, 64	Ext	Ext	32, 64	32, 40	32, 40	32, 96
Speed							
Cycle time (ns)	50	40	30	30	60	80	75
Execution unit data pipelines							
Integer	1	1	1	1	2	1	2
F-P	2	N/A	N/A	2	S	1	S
I/O	1	1/2	1	1	1	2	2
Concurrent data pipelines	3	3/2	2	4	3	3	3
Parallel processors	Y	N	Y	Y	Y	N	Y
Memory hierarchy							
Integer RF	32	192	136	32	16	22	10
F-P RF	S	N/A	N/A	32	S	4	S
Data cache	Ext	Ext	Ext	Y	N	N	N
Inst. cache	Ext	Ext	Ext	Y	Y	N	Y
Special processing							
Address generation	N	Y	N	Y	Y	Y	Y
Multiplier-accumulator							
Integer	N	N	N	N	Y	Y	Y
F-P	Y	N/A	N/A	Y	S	Y	Y
Address space (bits)							
Data 1	30	32	40	32	2x10	2x9	32
Data 2	-	-	-	-	12	10	S
Instruction	30	S	S	S	24 (S)	24 (S)	32
I/O bandwidth (MB/sec)	80	50	66	132	132	50	106
Interrupts	Y	Y	Y	Y	Y	Y	Y
Context switch	Y	Y	Y	Y	Y	N	Y
High-level language	Y	Y	Y	Y	Y	Y	Y
R-T operating system	Y	Y	Y	N	Y	N	N

Ext = External
N/A = Not Applicable
Y = Yes
N = No
S = Shared

Source: Dataquest
March 1989

Precision and Speed

Precisions are at rough parity now. DSMPUs tend to preserve more bits for accumulation, but RISC processors often have greater word length flexibility, which can be useful for DSP image data. RISC meets the precision need. Basic data pipeline cycle times are shorter for RISC processors, and the difference is real for small vectors. Nevertheless, address generation times in the RISC integer ALU and data memory bottlenecks reduce performance for most signal processing operations below that of the DSMPUs. As the number of separate pipelines in the execution units and the concurrency figures show, however, the differences may not be large. Note that the 64-bit data busses of the i860 give it higher large-vector performance than the DSMPUs due to concurrency. Thus, RISC can meet many DSP speed requirements now. So-called vector processors are being considered by RISC suppliers now to provide multiport address generation for large real data memories to increase DSP and vector performance, so the gap may narrow in the future. NEC has even announced such a vector processor for its V-series product line, which employs traditional complex-instruction-set computer (CISC) architectures. RISC processors for the moment seem to lead DSPs in providing for paralleling of complete processors.

Memory Hierarchy

RISC processors have large data register files that, for most functions, equate to the much larger separate data memories on the DSMPUs. Concurrent load/store I/O operations on the RISC processor can reduce this size difference; however, speed may degrade quickly due to I/O bottlenecks. The large number of registers or accumulators on the DSMPUs reflect the desire to support high-level language compilers. Caching of instruction memory is used in both RISC processors and DSMPUs, although the modes of operation are much different. A low-cost, low-complexity solution is possible with a RISC processor that is sufficient to meet signal processing needs. Data caching is handled overtly with partitioned memories and programmed control in DSMPUs rather than "automatically" as in RISC processors. The large on-chip data cache on the i860 with its 128-bit bus is a real performance booster for signal processing operations. Overall the RISC memory hierarchy may seem ill suited for signal processing, but it can be scaled down and be cost and performance effective for large DSP systems.

Special Processing

The addition of vector processors to RISC processors may more nearly even the score, but now DSMPUs clearly excel at the concurrent and complex address generation needed in large data spaces for signal processing. This extends to I/O with DMA controllers as well as for on-chip memory. The concurrent multiply-accumulate arithmetic function so central to DSP is not common in RISC except in the floating-point execution units. This directly affects DSP speed performance on the RISC processors.

Large Amounts of Real-Time Data

The important address space change for RISC is to separate data and instruction spaces for higher performance. DSMPUs have increased the size of both spaces in order to handle the larger programs from high-level languages and the graphics and image data bases. DSMPU memory spaces have become more linear (like RISC) as they have gone off-chip. Thus, RISC processors can meet the separate and large memory space requirements of current signal processing systems. DSMPU I/O bandwidths remain higher than RISC processors and generally can be more fully utilized, but RISC I/O rates exceed many early DSMPUs and can be sufficient in many DSP systems.

RISC processors have interrupts, stacks, and other context-switching hardware assists, but they often lack the deterministic response times necessary for real-time DSP. Cypress Semiconductor is moving to improve this in its implementation of the SPARC architecture, and it seems likely that others will also. RISC processors, likewise, have the more complete high-level language support but not in a real-time operating system environment.

TODAY'S HIGH-PERFORMANCE SYSTEMS AND THEIR MARKETS

This growing similarity between digital signal processors and general-purpose RISC microprocessors results from manufacturers of these products recognizing the needs of an increasingly common high-performance system. Figure 1 is a block representation of such systems. It represents functional blocks of the typical new high-performance systems and their varied CPU processing and software requirements. Typically, some physical process that generates a large amount of data is analyzed or controlled by computations on the data. The computations are altered by operator controls, often interactively, from results that are presented on a display. The display itself often involves much processing, as does the final output result on some peripheral device.

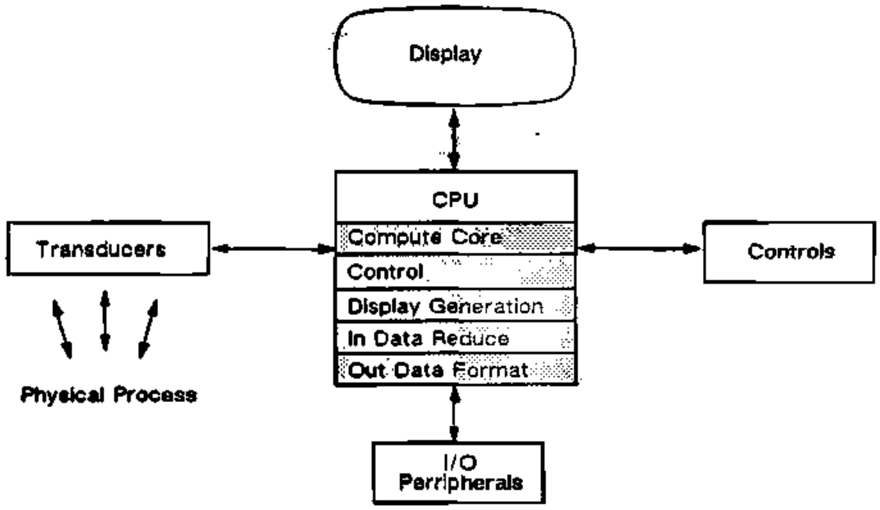
For economic reasons, and because not all processing is simultaneous, a single CPU is desired. Speed is important because of the large amount of data, the fact that the system is interactive, and the fact that it often must be real time in the strictest sense for closed-loop control purposes. The speed must be in I/O as well as arithmetic functions to support displays and the data collection.

Large amounts of high-level language applications code are used, often running under UNIX. This user- and third-party-supplied software accommodates industry standards processing and standard I/O peripherals, drivers, and formats. The high-level language improves maintainability, but often it is used initially because it allows the function to be transported in to get the system operating in a minimum amount of time. Critical time to market is improved.

Typical applications that use these systems are listed in Figure 2. Frequently, they are referred to collectively as high-performance embedded controller systems. Note that high-performance workstations in this context are a subset with less demanding real-time I/O.

Figure 1

New High-Performance Systems and Their Varied CPU Processing and Software Requirements



0003271-1

Source: Dataquest
March 1989

Figure 2

Important High-Performance Markets for RISCs and DSMPUs

- Medical Tomography Imaging
- Ultrasound Imaging
- Communications Instrumentation
- Vibration Testing
- Electrical, Chemical, and Mechanical Design, Simulation, and Analysis Workstations
- Image Scanning and Electronic Publishing

0003271-2

Source: Dataquest
March 1989

THE COMPETITIVE THREAT AND NEW DSP STRATEGIES

Few significant quantity shipments of RISC processors occur today, except for workstation shipments, and it will be two years before the important product families and markets can be confirmed. However, the prudent DSP product strategist cannot wait for market erosion to react.

Dataquest believes that certain DSP performance issues are important ones for DSMPU suppliers trying to maintain their markets. DSMPU suppliers must continued to do the following:

- Accommodate the real-time nature of DSP operations—The first requirement is to continue to accommodate the real-time nature of the processing while adapting to the need for operating system and high-level language benefits. This can be done through integrated hardware assists and real-time software function libraries that support industry standards and device independence yet do not get in the way of the other real-time processing required. Developing a standardized library of real-time functions and a suite of DSP performance measures, like the recent SPEC benchmarks, would help.

- Support greater memory flexibility

  - Even with the larger data bases and programs of DSP systems today, the memory hierarchy needed always will be different from the more general-purpose data processing system. The need for large, multiported nonvirtual memory always will exceed the RISC on-chip register file. Continued attention to this memory distinction will protect DSP markets.

  - Vector processors that provide concurrent address generation for arrays are expected to be added to both CISC and RISC microprocessors, but DSMPUs always should be able to exceed the performance achieved in a linear memory, particularly for 2-D functions and transforms like the FFT.

- Develop workable multiprocessor languages and interprocessor protocols—Paralleling complete processors to increase computing power is everyone's candidate for the next major leap in performance, yet progress has been very slow in systems that can be used today. Because DSP is so amenable to partitioning between parallel processors, it can take the lead in simple, workable languages and interprocessor communications conventions.

- Emphasize high-bandwidth, real-time I/O—A final area of emphasis for DSP should be input/output (I/O). Graphics and imaging have made I/O dataflow an issue for all processors; however, the serial telecommunications interfaces, complex multiplexing/demultiplexing, and high real-time bandwidths should allow important product distinctions.

DATAQUEST ANALYSIS

Dataquest believes that if DSP suppliers are successful in providing this special DSP performance, their growth will continue and they will remain an important portion of the semiconductor processor market. The discussion here has centered only on the high-performance, higher-cost devices, but they represent a major growth area now and the dominant products of the future. Failure to act could bring a repeat of the generation-earlier contest between DSP array processors and general-purpose minisupercomputers. In spite of FORTRAN library support and parallel processors, the array processors lost vital market share to the more general-purpose minisupercomputers when they had the same floating-point multiprocessor parity. The near demise of Floating Point Systems, the leading array processor company, at the hands of Alliant and Convex closed out the first significant generation of DSP high-performance systems. The parallel between those rival minicomputer systems and today's rival microprocessors bears careful attention by suppliers of DSP integrated circuits.

Robert E. Owen

- Encouraging companies with cross-licensing agreements to introduce MCA products quickly and offering assistance to third-party vendors in order to increase the use of MCA

- Squeezing PC-clone vendors by lowering prices to make MCA PCs more attractive

- Seizing every opportunity to discredit the viability of EISA, as members of the EISA group introduce MCA products

However, Dataquest believes that IBM will reduce its licensing fees for MCA technology only as a last resort.

In the near term, we expect sales of MCA-based PCs to increase due to the creditability given to a new bus structure by the PC-clone manufacturers. In our opinion, IBM's influence, EISA's late entry, and fragmentation within the EISA ranks will hinder the acceptance of EISA systems. Compaq's strong influence and determination ensure that MCA systems and EISA systems will coexist in the market, at least in the intermediate term, with MCA products gaining market share as other vendors offer MCA systems. EISA will survive as a bridge, to extend the use of the current installed base of XT and AT machines. In the long term, however, Dataquest believes that EISA will not meet the challenge of future performance and expandability requirements and that this market will become a shrinking niche market, serviced by only a few surviving vendors.

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Ken Pearlman
Robert Charlton

IBM

Dataquest believes that IBM holds the winning hand in this card game. It is in a good position to influence the outcome of the EISA/MCA challenge and can sway the business community to embrace MCA. Our analysis is based on the following factors:

- EISA may not be available from PC manufacturers for 9 to 18 months. This gives IBM time to introduce products that can take advantage of MCA, and to establish a user base. The sooner useful MCA applications hit the market, the greater the market share MCA will capture.

- Although it has stated that the royalty structure will remain in place, IBM always has the option of changing its mind, if it becomes beneficial.

- Companies that have a universal cross-licensing agreement in place with IBM may not be required to pay the same royalty fees as companies that do not. This makes it more attractive for those companies to manufacture MCA-based PCs.

- It is being debated whether EISA or MCA, in the current configurations and environment, is technically superior. We believe that the issue is really which architecture will perform best in the future.

  - An expected requirement is the ability to expand to a 64-bit data path and handle processing speeds above 40 MHz.

  - ESIA will have problems with both the physical accommodation of a 64-bit bus and the electrical noise associated with high-speed processors.

  - IBM has the time and the option to redesign the current MCA to eliminate the debate and to clearly differentiate performance before the first EISA machine is even shipped.

- Most importantly, whereas MCA exists now, EISA is, at present, vaporware.

Compaq

Compaq Computer will hold an estimated 3.4 percent U.S. market share of personal computers shipped in 1988. Compaq is also the leader of the EISA consortium, and we believe that it holds enough market share and following to make EISA a viable product. It was the first company to introduce an 80386 PC and continues to be a leading force in the industry.

Dataquest believes that Compaq will follow through and introduce EISA regardless of how the rest of the PC industry reacts to extended bus architectures. In fact, Compaq has announced that, as of April 21, it will sever its relationship with Businessland. Businessland has stated that it may back only MCA technology; although Compaq denies that this caused the rift, many analysts believe otherwise.

EISA Consortium

Dataquest believes that the EISA Consortium is very serious. It is well organized and well supported by the members. Nevertheless, it faces an uphill battle against MCA with obstacles that IBM will exploit at every opportunity.

The first obstacle is that the EISA standard is being formed by a group of competitors anxious to increase their own market shares in an extremely competitive market. Even with the common interest of EISA, it is hard to believe that any group of competitors with a common goal will stay together. Any fragmentation in the ranks will be quickly noted by IBM.

A second obstacle is one of economics. Members of the EISA consortium will hedge their bets and will develop, or already have developed, MCA PCs, and will actively market them. This is partially due to the effort they have already put into cloning MCA systems and partially due to the fear of being caught without an extended architecture product if EISA stalls. Tandy, for example, is shipping MCA products now. John Roach, president and CEO of Tandy, stated at Dataquest's PCIS Conference that he would be ready to satisfy his customers whether they wanted MCA or EISA product. Dell also has announced that it has MCA systems. Companies with MCA systems that are shipping now, or will be very shortly, are ALR, Dell, Mitac, Olivetti, and Tandy.

The Winners and the Losers

The Winners

Dataquest believes that, provided Apple Computer can capitalize on its stable NuBus platform, it will be a clear winner as a result of the chaos caused by multiple PC bus standards. Corporations vacillating between the Apple and the IBM product will purchase Apple because it has a viable 32-bit bus technology without competitive confusion. Other winners will be the third-party board manufacturers that will sell their products to both buses—MCA and EISA. Board vendors view the two standards as expanded opportunities. They see the MCA and EISA markets as a larger total market that offers increased opportunities for selling their products. Certainly, Microsoft will win as it is hardware independent and will sell products to both MCA and EISA-based PCs.

The Losers

The losers will be the public, which ultimately will pay the price for this confusion, and the manufacturers, which must invest limited funds into both standards. Designing two products is costly due to development time, distribution and revision changes, service, and repair.

DATAQUEST CONCLUSIONS

Dataquest thinks that IBM will react strongly to the introduction of EISA in the following ways:

- Introducing applications—possibly at Fall 1989 Comdex—that use the unique characteristics of the microchannel architecture

Dataquest does not agree that this issue is strong enough to dissuade businesses from purchasing a different bus architecture, for the following reasons:

- Because older systems are passed down intact to areas that were previously devoid of PCs, businesses do not have surplus boards available.

- The new systems probably contain standard features that were options on older systems.

- The third-party board manufacturers have added new features and functions to their products, which makes upgrading attractive.

These factors were amply demonstrated when the PC AT system was introduced. Imagine placing a 10MB, 85ms hard disk drive running on an 8-bit controller into the AT, or doing CAD/CAM with a CGA monitor driven by the original color card in an effort to save money.

Although backward compatibility is feasible with EISA, Dataquest believes that in a business environment, the bus layout will not significantly alter sales—provided support products, third-party boards, and peripherals are competitively priced and readily available. The total system price and the support product availability will ultimately determine which product will sell.

An important underlying issue is the question of who sets the standards for PC compatibility. Until now, IBM has been the standard, the model for the PC clonemakers. IBM has had control over the direction of this industry, even as it loses market share. Will the EISA consortium, led by Compaq, be capable of breaking from this tradition to establish and maintain a new standard? Whose EISA machine will define the compatibility standard for the other consortium members? Will it be Compaq's or will it be the first EISA machine on the market (if it is not Compaq's)? The answer lies in the ability of Compaq to lead and to maintain the support, cooperation, and respect of the consortium members.

EISA Second Sources

Many companies selecting PCs prefer to have multiple sources for the same product. The number of PC manufacturers supporting the EISA bus makes the EISA PC attractive for this reason. Dataquest believes that this is an especially critical area to watch—to ensure that the EISA bus is identical from one PC to another.

The potential exists for one manufacturer to "improve" on features to leverage market share, as in the case, for example, of expanded memory. A prominent group of companies developed an approach to use memory in protected mode to "stretch" real mode memory so that larger spreadsheets could be manipulated. Instead of staying with this scheme, another company developed a similar but different scheme with different features. Now, both Expanded Memory System (EMS) and Enhanced Expanded Memory System (EEMS) memory management techniques exist.

MCA

MCA Delivery Time

IBM has been shipping MCA bus PCs since April 1987. Dataquest estimates that 1.5 million MCA-based systems will be installed by the end of 1988. Thus, companies that expect to have new applications for their PCs do not have to wait for a PC with the MCA bus to be developed.

Dataquest believes that third-party manufacturers of application hardware initially will concentrate their resources on MCA-based PCs, simply because of the large marketplace into which they can sell product. Strong development of products using the MCA bus will place the EISA bus in a catch-up mode.

MCA Backward Compatibility

MCA's disadvantage is that is is not compatible with the nearly 33 million MS-DOS PCs shipped since 1983. However, Dataquest does not view this as a strong justification for not purchasing the MCA PC for the reasons stated earlier. Those reasons are: the requirement to use existing PCs intact, the desire to upgrade to the new features and functions offered by third-party boards, and the fact that certain features are now standard on new PCs.

MCA Second Sources

Several companies have announced plans to ship MCA PCs or have announced that they are already shipping them. These companies, which are members of the EISA consortium, have stated that, one way or another, they will satisfy the customer. The argument that there is only one vendor for MCA has therefore been eliminated.

Apple's success is another illustration that shows the fallacy of the argument that companies are reluctant to purchase products from a sole source. Although it has a completely noncompatible bus and operating system and is the only company producing the product, Apple holds the number two spot behind IBM with an estimated 14.5 percent of the 1988 U.S. market.

MARKET PARTICIPANTS

To examine the success or failure of EISA or MCA, the participants must also be examined.

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NEW DSP PRODUCTS AND TRENDS AT ISSCC '89 AND CICC '88

SUMMARY

Significant new products were shown in all digital signal processing (DSP) segments at the major semiconductor conferences during the last year. Most new DSP products were in the video and image special-function segment. Recent product, architecture, and technology trends continued with programmed, functional block, and application-specific solutions coexisting. Reduced-instruction-set computing (RISC) processors and their floating-point coprocessors invited comparison with high-performance signal processors.

INTRODUCTION

The first public awareness of significant new integrated circuit products usually comes through papers presented at the International Solid State Circuits Conference (ISSCC) in February or the Custom Integrated Circuits Conference (CICC) in May. This certainly has been true for DSP, where whole sessions are usually devoted to the topic. An important part of Dataquest's DSP research is coverage and interpretation of new products and related technologies that are described at these two conferences. We also will be reporting on signal processing technology advances and products introduced at the International Conference on Acoustics, Speech, and Signal Processing (ICASSP) in April.

Of obvious interest are the new DSP microprocessors (DSMPUs), microprogrammable building blocks (MPDSPs), special-function DSPs (SFDSPs) for video and imaging, and application-specific circuits for DSPs (ASDSPs) in fields such as telecommunications. But related products like analog/digital converters, high-performance microprocessors, and coprocessors also affect DSP markets. Both conferences provide a guide to the latest design methodologies that can be important in fitting DSP techniques to new application needs rapidly. New semiconductor technologies described often impact DSP products early because of their need for the highest speeds and high density. Our purpose here is to collect those items that seem important for a thorough understanding of DSP product and technology directions. Completeness of coverage is considered more important than details and comparisons of specific products, due to the preliminary nature of this early information.

DSP Microprocessors

Only one truly general-purpose, single-chip DSMPU was described at either conference; it was an upward-compatible, third-generation enhancement from Mitsubishi. However, Mitsubishi's new product's speed at 40ns per instruction cycle for 24-bit floating-point is noteworthy. The 24-bit (16E8) precision is an increase over the initial 18-bit (12E6). Other differences are a shared on-chip data and instruction cache and shared external memory space, in addition to the normal external instruction-only and data-only memories. Caching is increasingly being seen in DSPs, and here it includes a novel clock-scaling circuit to allow it to be easily loaded from slower external memory.

Although described as video processors, a 24-bit integer unit also from Mitsubishi and a 16-bit integer processor from NEC are really full-function programmable DSMPUs. Both are impressively fast, and as Table 1 shows, they have all the functions of the general-purpose Mitsubishi device except the serial telecommunication interface. The chief distinction between the video processors and the DSMPU is the richness of address generation capability, a welcome addition for most applications on a DSMPU, along with the faster speed. Prices will be higher for these two larger-size chips.

Special-Function DSPs

Video Processors

The special function receiving the most attention this year, as it has for the past several years, was video (see Table 2). This follows from the increased interest in HDTV and the establishment of ISDN video compression standards. The most flexible product is the 24-bit integer processor from Mitsubishi (also shown in Table 1). The three data execution units supported by two large dual-ported memories with three address generators driven by the 48-bit instructions provide very high performance. The data precision is high enough for transforms, yet the instruction set also makes it data byte efficient. Address generation is two-dimensional both on- and off-chip. Performance figures were given for a large number of video functions, but full attention was given to the video codec requirements for transforms, vector quantization, and motion compensation.

Table 1

Significant New DSP Microprocessors (DSMPUs) at ISSCC '89

Features	Mitsubishi	Mitsubishi	NEC
Precision	24-bit FP (16E8) & integer	24-bit integer	16-bit integer
Instruction Cycle	40ns	50ns	25ns
Arithmetic Element Stages			
ALU	1	1	1
MPY	1	1	1
ACC	0	1	1
Address Generators	2	3	4
Memories			
Instruction			
Internal ROM	4Kx32	-	-
Internal RAM	-	512x48	512x32
External	60Kx32	16Kx48	-
Data & Instruction			
Internal RAM	64x32	-	-
External	4Kx32	-	-
Data			
Internal RAM 1	512x24 (DP)	512x24 (DP)	128x16
Internal RAM 2	-	512x24 (DP)	128x16
External 1	60Kx24	64Kx24	1Mx16
External 2	-	-	1Mx16
Input/Output			
Serial	1-bit	-	-
Parallel	24-bit	24-bit	16-bit
Technology			
Process	CMOS	CMOS	CMOS
Feature Size	1u	1u	1.2u
Transistor Count	300K	538K	220K
Pin Count	135	177	176
Die Size (mm)	7.0 x 8.6	13.8 x 15.5	14.0 x 13.4

Notes: FP = Floating-Point, DP = Dual-Port

Source: Dataquest
April 1989

Table 2

Significant New Special-Function DSPs (SFDSPs) at ISSCC '89 and CICC '88

Company	Function	Instruction Cycle Time	Precision	Transistors
Video				
Mitsubishi	Broad, microprogrammable	40ns	24-bit	538K
NEC	Broad, microprogrammable	25ns	16-bit	220K
MicroElectronics Center	2-D FFT	100ns	11-bit	152K
Bellcore	2-D DCT	70ns	12-bit	73K
Toshiba	Codec	41ns	8-bit	288K
Kodak	Color correction	70ns	14-bit	94K
Image				
LSI Logic	FIR filter	50ns	8-bit	240K
	Template match	50ns	1-bit	94K
	Rank value	50ns	12-bit	140K
	Delay line	50ns	8-bit	110K
Siemens	MAC	40ns	18/32-bit	340K
	Correlation	40ns	32-bit (FP)	90K
Sony	16 MAC array, selectable	50ns	12-bit	124K
NEC	MAC (BiCMOS)	5ns	16-bit	20K
Fast Fourier Transform (FFT)				
Plessey	FFT, weighting	25ns	16-bit	500K
Filter				
Fujitsu	Adaptive filter	100ns	16-bit	42K

Notes: DCT = Discrete Cosine Transform, FP = Floating-Point

Source: Dataquest
April 1989

The NEC chip is a 16-bit integer processor (also shown in Table 1) and is correspondingly faster than Mitsubishi's at 25ns. It compares with a simpler three-stage pipeline, 70ns version presented two years ago. The seven stages of the newest chip are in a sequence that is useful for most video tasks. NEC has provided for multiprocessor synchronization, because even with these data rates, more than one processor may be necessary for real-time performance.

These two programmable processors, with their writable control stores for instructions, are contrasted with the video processors from Toshiba and Kodak, which are fixed in function. Toshiba's video codec uses the time-compressed integration format for HDTV conversion in either direction. The link may be either analog, 400-Mbps digital, or video disk. For an established format, it offers functional flexibility in one large but potentially high-volume part. Kodak's processor serves a more narrow function—it provides the digital processing from color filter CCD arrays to create correct three-color video signals. The slower speed is acceptable because of the smaller number of pixels in current CCD arrays.

Image Processors

Video processing generally is seen as a subset of image processing that accommodates in some manner the specific real-time bandwidth requirements of video signals and makes use of the sequential raster nature of data and its storage. For more basic functions like multiply-accumulate, the distinction may not be meaningful. Sony's processor containing 16 multiplier-accumulators (MACs) and adders and NEC's BiCMOS MAC are described as video building blocks, while Siemens' products are aimed at "real-time images." The Siemens two-chip set and the Sony processor are programmed processors but fit together like building blocks. The input MAC is integer for 6-bit neighborhood data, while the arithmetic processing unit is 32-bit floating-point for full image 2-D operations like correlation. There are three concurrent floating-point data execution units and concurrent I/O. Sony's processor's limited functions, all based on the inner product operation, can be combined in systolic arrays to boost the 1.04 Giga-operations per second (GOPS) for a single chip. NEC, in one-fourth the chip area and with 65 percent of the power consumption, achieves 0.2 GOPS or one-fifth the performance—more of a BiCMOS test vehicle than part of any video or imaging product strategy.

Fast Fourier Transform (FFT) Products

With the flurry of new FFT chips recently introduced by Austek, Honeywell, TRW, UTC, and Zoran, interest was high in the new PDSP 16510 from Plessey. Its most notable feature is that it will do a full 1,024-point complex transform using only internal memory and in less than 100us. Most other products use large, fast, and expensive external memories and/or multiple processors to do transforms this large. Plessey's version is also very flexible in transform size, real or complex data type, use of data buffers, and selection of weighting functions. The 13.1 x 13.3mm area will make it not be cost competitive with DSMPUs for small transforms; however, in the many applications requiring midsize transforms, this product will be very attractive in price, size, and complexity of design. Plessey's FFT was the most significant pure DSP product introduced at ISSCC '89.

General–Purpose Microprocessors

Coprocessors

The major public product announcement at ISSCC was of course Intel's i860, and it was of not just a little interest to the DSP community. The hype was about RISC, UNIX, and standalone operation, but competitors' concerns were about a high-performance $750 coprocessor, and that is how we have compared it in Table 3. The significant trends among the coprocessors are toward multiple, fast pipeline stages; multiple execution units including I/O; and wider-than-32-bit data paths. All are moves toward DSP-like performance in a standard microprocessor system. This was particularly evidenced by the concurrent multiply-add and the vector address generation capability of NEC's new coprocessor for the V60, 70, and 80 series.

RISC Processors

RISC processors are the engines that drive coprocessors with high clock rates and wide 64-bit busses. A Digital Equipment Corporation spokesperson said in his session 7.1 presentation that a vector processor was a future part of this (non-VAX) family. The Matsushita chip, with its four parallel execution units, clearly rivals the i860 in power, and it, too, has features for multiprocessing.

Building Blocks

Multipliers are the traditional regular-function, medium-complexity test vehicles for any new technology, so it is not surprising to see some appear now in gallium arsenide (GaAs). Seldom are they significant in commercial DSP markets. However, Honeywell's GaAs multiplier introduced at ISSCC clearly was designed for DSP because it does a full 16-bit complex multiplication (four multiplies and two additions) and does it in only 8ns. Mitsubishi's 32-bit floating-point building block is highly pipelined with five 10ns stages and is self-timed. This technique, where data is passed from stage to stage only when the processing is complete, is bound to see wider use as multiple variable-length data pipelines become common. Mitsubishi does not use this technique in its purest form, but the company has a head start at learning about its use. This product was the most significant DSP circuit/architecture innovation presented at ISSCC '89.

Table 3

Significant New General-Purpose Microprocessors and Building Blocks (MPDSPs) at ISSCC '89

	Functional Unit	Pipeline Delay	Pipeline Depth	Precision
Coprocessors				
Intel i860*	Integer ALU	30ns	1	32-bit
	FP ALU	30ns	3	32/64-bit
	FP MPY	30ns	3	32/64-bit
	I/O	60ns	1-3	64-bit
NEC	FP ALU	50ns	8	32/64/80-bit
	FP MPY	50ns	9/11/12	32/64/80-bit
GE	32-bit Integer or FP ALU or MPY or MAC	25ns	3	32/64-bit
	I/O	25ns	1	32-bit
Digital	FP ALU or MPY	20ns	4/5	32/64-bit
RISC Processors				
Digital (7.1)	Integer ALU	20ns		32/64-bit
Matsushita	Integer ALU	50ns		24-bit
	FP MPY	50ns		64-bit
	FP MPY	50ns		64-bit
	I/O	50ns		64-bit
Digital (7.3)	Integer ALU	28ns		32-bit
	I/O	28ns		64-bit
HP	Integer ALU	33ns		32-bit
Digital (7.5)	Integer ALU	40ns		32-bit
	I/O	40ns		64-bit
Building Blocks				
Honeywell (GaAs)	Integer MPY (complex)	2ns	3	16-bit
Mitsubishi	Integer & FP ALU	10ns	5	32-bit
	Integer & FP MAC	10ns	5	32-bit

Notes: ALU = Arithmetic Logic Unit, FP = Floating-Point, MAC = Multiplier-Accumulator, MPY = Multiplier

*Intel's i860 processor is considered a standalone RISC processor with integrated floating-point and 3-D graphics. For purposes of this comparison, we will focus only on the floating-point portion of the i860.

Source: Dataquest
April 1989

Applications

It is always interesting to check on the migration of DSP techniques into chips for complete applications. There is a concern that all of the high-volume applications will be met this way and that there will be no lasting market for the general-purpose programmable solutions. Oki's modem chip showed that this high-volume application's requirements can be met with a DSMPU core and specialized on-chip A/D and D/A peripheral circuits.

Panel Discussions

The regular "Future of DSP" panel session was less partisan and more penetrating than usual. A major topic was questioning the need of the latest large, full-featured DSMPUs. Is there a place for other than "lean and mean" (simple and fast) processors? As part of that topic, the usual floating-point versus integer discussion ensued, but this time it ended differently than usual. AT&T virtually acknowledged that floating-point had been put in its DSP-32 because it was the next step and not because it was clearly justified. And sure enough, AT&T said, the most successful application had been graphics transformations, not a traditional DSP function at all.

CICC '88

Products

At last year's Custom Integrated Circuits Conference, the DSP products were all special-function products, as one might expect, and there was more information about DSP-specific design methodologies. Video and imaging dominated again. For example, Bellcore's discrete cosine transform chip does 16 x 16 pixels in real-time for video coding. It is a multiplierless design using only additions and ROM lookup tables for compactness.

The MicroElectronics Center (MEC) 2-D FFT array of chips processes 256 x 256 pixels in real-time at a 30Hz rate. It uses the long-forgotten shift register method of FFT data sequencing to advantage.

Two papers by LSI Logic introduced a family of 20-MHz image-processing chips that has since grown to six and increased in speed. They were the most significant DSP papers presented at CICC '88 because in one short span of time LSI has made available a complete processor and memory building block set for imaging. This came from a thorough product line plan, fast turnaround design tools, and a commitment to provide what was needed even if it resulted in large chips. The FIR filter, for example, has 64 MACs and is 1.4cm on a side. Rarely is there such a complete product thrust into a market that is in an early development stage. The commercial battle line is clearly drawn now between programmable processors and functional blocks in this DSP application area.

Fujitsu described an adaptive filter that offers improved I/O and multichannel processing over a DSMPU. It is unusually well supported with design software and documentation.

Design Methods

CICC papers have more discussion of design tools than circuit design details, and the silicon compiler session always includes DSP because DSP data processing is more regular and amenable to description and synthesis. The University of California at Berkeley and IMEC in Belgium are both centers of much of this compiler work, and their progress is steady, with effects being seen in commercial products at Philips and LSI Logic. No company is visible yet that has made silicon compilation a cornerstone of its DSP product strategy.

DATAQUEST CONCLUSIONS

What did these two important conferences say about the major DSP issues being watched today? They confirmed first that general-purpose microprocessors in the form of RISC and their coprocessors are getting function and performance levels close to high-end DSMPUs. Secondly, in the growing area of video/image processing, a special-function DSP segment, there are still new product examples of programmable, functional block, and application-specific implementations. These three forms may continue to coexist with no clear indication of a single product "best" strategy.

The product trends for each of the segments were as follows:

- DSMPU—Little new; the third generation is still being digested.
- SFDSP—Video/image is the function getting the most attention recently.
- MPDSP—No major products except at new technology frontiers.
- ASDSP—Core DSP processors are expanding into this area more than compilers/design tools are adapting to DSP.

The architectural trend is to separate highly pipelined data execution units for higher performance and more run-time assists to control them. One micron is the new technology norm, and BiCMOS' impact, if any, is yet to be felt in DSP.

Generally, DSP integrated circuit progress is strong and healthy, but one feels a little cautious when all of the excitement is about general-purpose processors with speeds and precisions that were only so recently the sole domain of DSP.

Robert E. Owen

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Research Newsletter

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DSP
0003826

THE INVISIBLE DSP IC MARKET: GATE ARRAY, CELL-BASED, CUSTOM, AND SILICON COMPILER DESIGNS

SUMMARY

Application-specific digital signal processors (ASDSPs) constitute a large and rapidly growing segment of the general application-specific integrated circuit (ASIC) market. The major suppliers are broad-based ASIC firms that provide little DSP support, rather than the traditional DSP IC companies. By supporting the DSP designer better, DSP-focused suppliers can secure some of this market, which is nearly equal in size to the DSP microprocessor (DSMPU) market.

INTRODUCTION

DSMPUs, building blocks, and special-function DSP chips (SFDSPs) constitute a very visible market because of the large marketing promotions for these devices. Suppliers and users alike advertise the successful incorporation of these ICs into end products. Almost totally invisible are the custom ASDSPs developed by product manufacturers for their special DSP needs.

ASDSPs are a portion of the broad ASIC market and include all of the same techniques in their design: gate array; cell based—standard cell, as well as extensions to a microprocessor core; full-custom; or silicon compilation. However, they are distinct within DSP IC markets from the SFDSPs such as modems and FFT chips, which are designed and marketed broadly for specific functions rather than specific "applications."

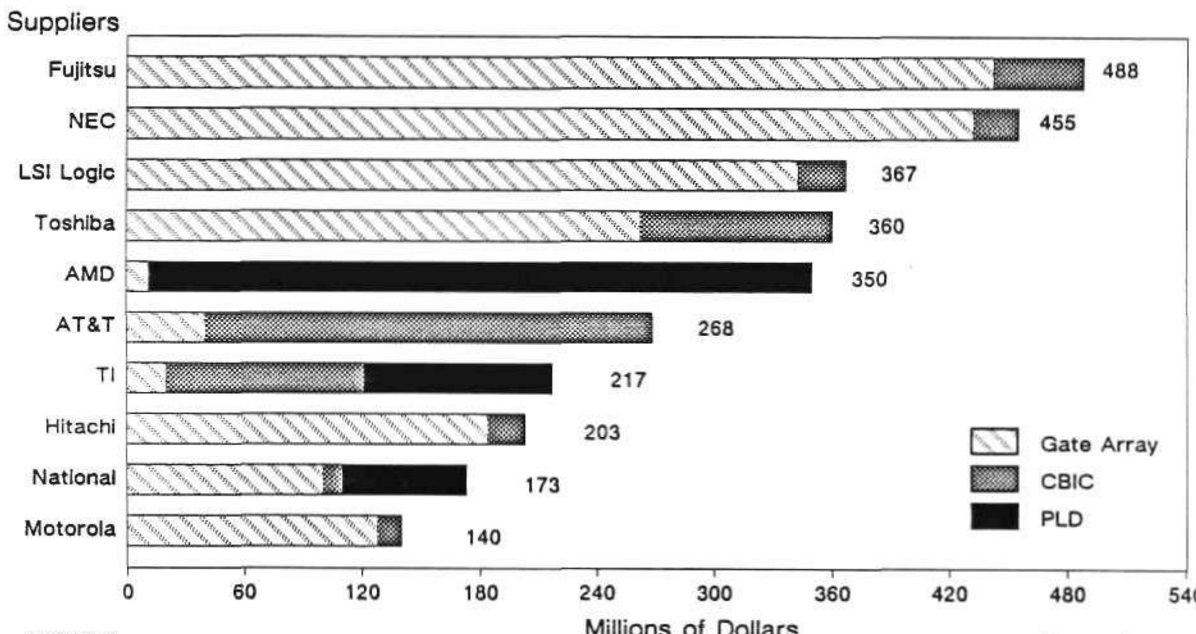
These invisible ASDSP chip sales are very substantial, estimated at $131 million in 1988, or roughly the same as the $158 million for the highly visible DSMPUs. For many domestic ASIC suppliers, 20 to 30 percent of their output is DSP related, with some companies approaching 50 percent. The invisibility comes from the proprietary nature of the business, not its lack of market importance. This newsletter looks at what is happening in this market with the thought that its invisibility may be hiding DSP business opportunities and important trends. We first review the major general ASIC suppliers and their marketing positions toward DSP. Then we examine the major DSP suppliers and their involvement with ASDSPs.

PRODUCTS AND DSP MARKETING POSITIONS OF MAJOR ASIC SUPPLIERS

The general ASIC market was $7.4 billion in 1988, nearly 20 percent of the total IC market, with a compound annual growth rate (CAGR) of 16 percent. Figure 1 shows the worldwide sales for the major suppliers in all technologies (MOS, bipolar, and BiCMOS) and design types (gate array, cell-based, etc.). Estimated North American ASIC consumption by application market is shown in Figure 2. Note the prominence of the communications and military areas, major DSP markets.

Figure 1

Estimated 1988 Worldwide ASIC Ranking



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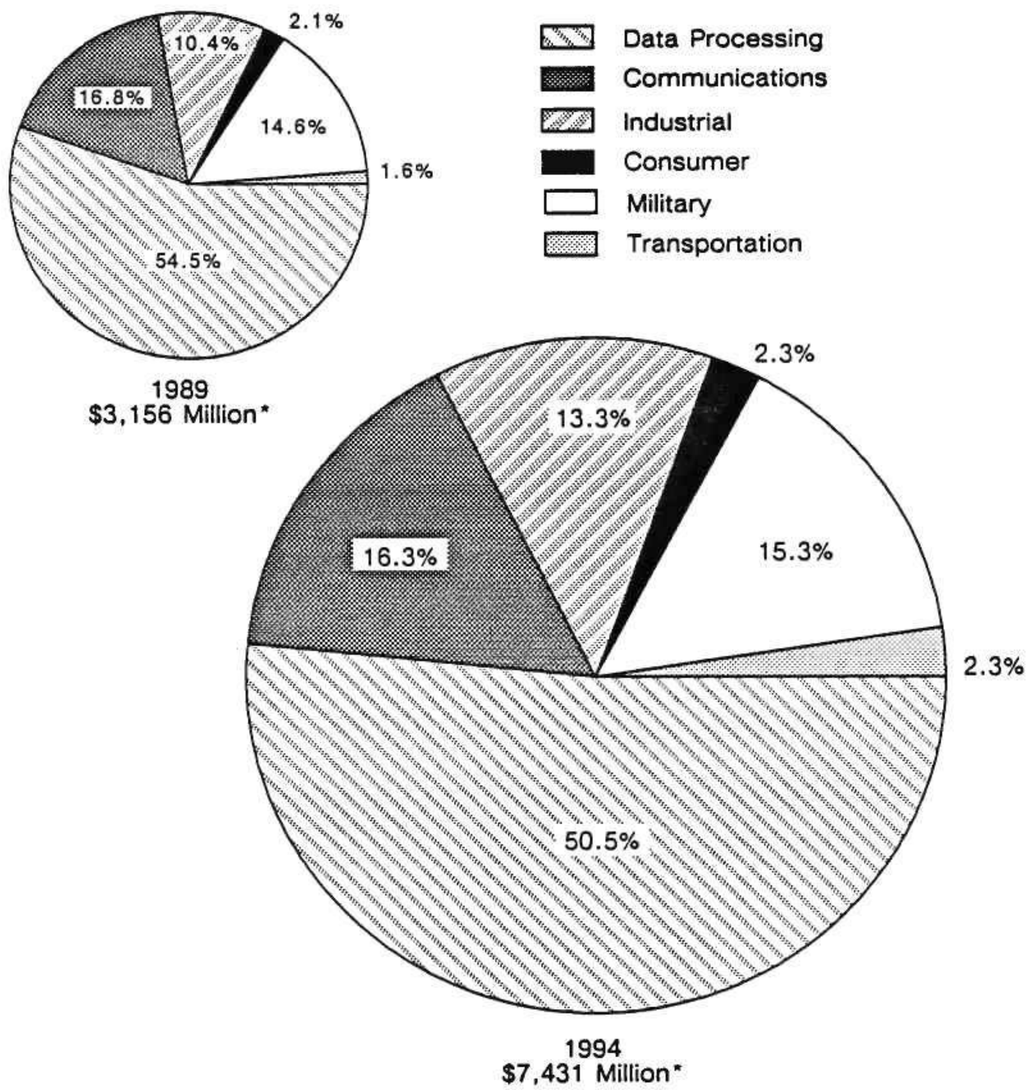
Source: Dataquest May 1989

Figure 2

Estimated North American ASIC Consumption by Application Market—Total (1989 and 1994)



*Excludes Full-Custom ICs

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Source: Dataquest May 1989

Gate Arrays

The largest ASIC segment is gate array designs, at $2.9 billion in 1988. The ranking five suppliers are the top four overall ASIC companies—Fujitsu, NEC, LSI Logic, and Toshiba—plus Hitachi. None, with the exception of LSI Logic, have significant design aids for DSP users. The closest thing is macrofunctions of the AMD Am2900 series building blocks, which are popular in DSP. LSI Logic, the top CMOS gate array supplier with an estimated 25 percent DSP business, has the MACGEN compiler for generating multiplier-accumulators of varying precision and arithmetic formats. Although backed up with a full arithmetic and functional simulator, it still lacks specific DSP features like overflow saturation and coverage of the often complex address generation and microprogramming functions needed for a full processor.

Cell-Based Designs

The smallest but fastest growing segment of the ASIC market is the so-called standard cells segment. In 1988, revenue was $1.3 billion, with AT&T, Texas Instruments, Toshiba, NCR, and VLSI Technology as the top-ranked suppliers. Growth was 43 percent last year. Here again, DSP support has been limited mostly to Am2900 series building blocks.

Full-Custom and Silicon Compilers

The second largest ($2.5 billion) portion of the ASIC market in 1988 was still the full-custom segment, but it is declining at a 3 percent annual rate. Silicon compilation, however, counters the overall figure with strong growth. DSP accounts for nearly half of all silicon compiler applications because of its acceptance by large communications and military systems companies. DSP support is a natural fit for silicon compilation, with its emphasis on high-level functional design, but even leader Silicon Compiler Systems, Inc., provides no specific DSP support.

The motivation for a full-custom design is often proprietary design protection and cost, but it also can be the high performance that DSP requires. The largest custom suppliers are NEC, Matsushita, Sharp, and Toshiba. Although much of their output is for consumer products (e.g., ultrasonic autofocus controllers for cameras), the companies are often solving DSP problems. That trend should continue as consumer products become smarter. Philips, the large European consumer products firm, estimates that half of its custom silicon output is for DSP functions.

MAJOR DSP SUPPLIERS' ROLES WITH ASDSPs

Dominant DSP supplier Texas Instruments has surely leveraged its position with application-specific designs, but these designs have been mostly full-custom done with internal design resources. One that became visible is the TMS 320C20, now a standard product, which grew from specific speech processing requirements at ITT. But Texas Instruments does not actively encourage ASDSPs, particularly those that involve users in any active role in their design. The new TMS 320C30 has a modular layout and a future as a processing core, but it is not a major thrust at this time.

Number two DSP supplier NEC has produced a myriad of DSP designs in most DSP applications, such as speech recognition, signal encoding and image processing, as well as in more experimental areas like data-flow processors. Most have been cell-based designs to keep development costs low and design times short. However, these devices have been mostly for internal telecommunications requirements, with no public attempt to secure ASDSP business using the cell libraries.

Similarly, Fujitsu has supplied a large internal telecommunications need with cell-based designs. It has had less commercial success with standard products. Perhaps because of this, Fujitsu has now made available its processing cores and cell-based peripherals and memory configurations in the MB8220/232 product line.

AT&T, a major internal ASIC and DSP supplier, has not used its limited commercial success with standard parts to expand its ASDSP business. Motorola and Analog Devices have no ASIC programs in DSP, even though Motorola's 56200 was a silicon compiler design that could presumably have been the start of an application-specific filter business.

TRW LSI Products is understood to have replaced much of its loss of merchant market share with custom DSP designs using its own design teams. There are no tools for public use. AMD's lack of participation in the general ASIC market has kept the company from capitalizing on the Am2900 series building blocks.

DATAQUEST CONCLUSIONS

The distinction between DSP and general-purpose data processing is becoming blurred, but clearly a large portion of the fastest growing segment of the IC business, ASICs, is DSP related. Dataquest expects ASDSP to be a $181 million market in 1989 (see Table 1). The major participants in this business are the traditional ASIC suppliers rather than the DSP IC firms. Business is being secured in spite of not having device libraries or support tailored to DSP designer needs. At this time, users are limited to sophisticated users who do not require much support.

The major DSP suppliers, although they do high-volume, full-custom, application-specific designs, have not pursued this business either. Because their own standard products have usually been custom designed, they have not internally developed the libraries or tools that would assist them in the public ASDSP market. They also might view an aggressive ASDSP program as eroding the programmable solutions with their standard products in which they have made such an extended investment. This explains their cautious approach of expanding from a programmable core processor for ASDSPs. Within large IC companies, DSP and ASIC are often separate divisions, with many organizational forces working to impede cooperation on a workable strategy. Even in a narrowly focused company like LSI Logic, the DSP effort has been an attempt to establish a viable standard product line (something new for the company) rather than to strengthen its position in the ASDSP market.

Table 1

Application-Specific DSP (ASDSP) Market (Millions of Dollars)

Estimated		
1986	1987	1988
$68	$98	$131

CAGR 1986-1992
37.6%

Forecast			
1989	1990	1991	1992
$181	$250	$340	$461

Source: Dataquest
May 1989

The ASDSP market is understandably undersupported at this time. Because both general ASIC suppliers and DSP firms have been growing rapidly, they have had other more important tasks. Each type of company would have to master a new set of skills to solidify a position, but as competition increases, some company will likely move to claim ASDSPs as its own. ASIC houses would seem to have a head start, but DSP manufacturers may have the strongest motivation.

As DSP increasingly becomes possible on general-purpose, particularly RISC, processors, a quick-response, application-specific approach to the remaining diversified DSP market will be necessary. Cell-based designs seem the best design approach today, besides being a good basis for any long-term plan for DSMPUs, or special-function or building block DSP standard products.

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Semiconductor Industry Service
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Research Newsletter

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THE ANALOG IC MARKET: A BAROMETER FOR THE SEMICONDUCTOR INDUSTRY

SUMMARY

It is well known that the analog IC market neither grows as fast nor suffers the same severe downturns as the digital market. Less well known is that the difference in growth rates between the total monolithic IC market and the analog market 1) is periodic and tracks the IC industry ups and downs, and 2) has provided a leading indicator for every downturn over the past 16 years.

Over the past 16 years, most IC market forecasts have predicted the decline of the analog segment of the semiconductor market. In reality, the analog IC market not only has kept pace with the semiconductor market in general, but it has offered a stable benchmark by which the state of the IC industry can be measured.

This newsletter provides a new look at analog IC market growth and how it relates to the total market.

THE ANALOG BENCHMARK

The line graph in Figure 1 shows both total monolithic IC consumption and analog IC consumption over the past 16 years. The curves are similar in shape, differing mainly in magnitude, which suggests that the analog market tracks the total IC market. By using the World Semiconductor Trade Statistics (WSTS) data shown in Figure 1, a bar chart can be constructed (see Figure 2) that shows monolithic analog IC sales as a percentage of the total monolithic IC sales. The important point shown by this bar chart is that analog sales have consistently remained at about 20 percent of the total monolithic IC market. This is a surprising result because, despite significant changes in both analog and digital products, the analog proportion of 20 percent has remained virtually unchanged over the 16-year period. Using the fact that the analog portion of the market has remained at approximately one-fifth of total sales suggests that the consumption curve of Figure 1 can be redrawn, multiplying analog sales five times for comparison. This has been done in Figure 3.

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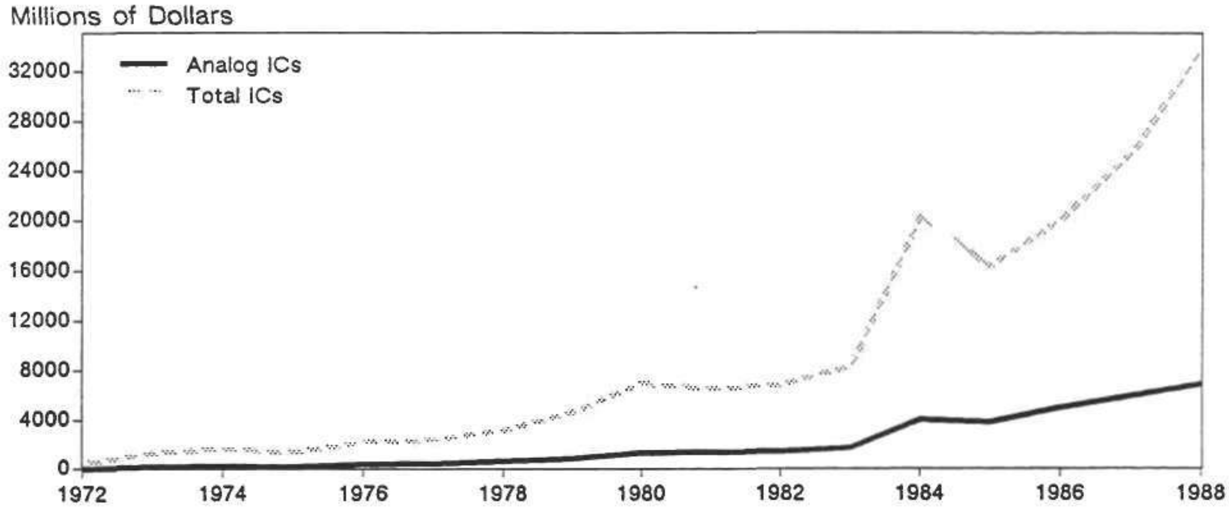
Figure 1

Analog IC Sales versus Total Monolithic IC Sales



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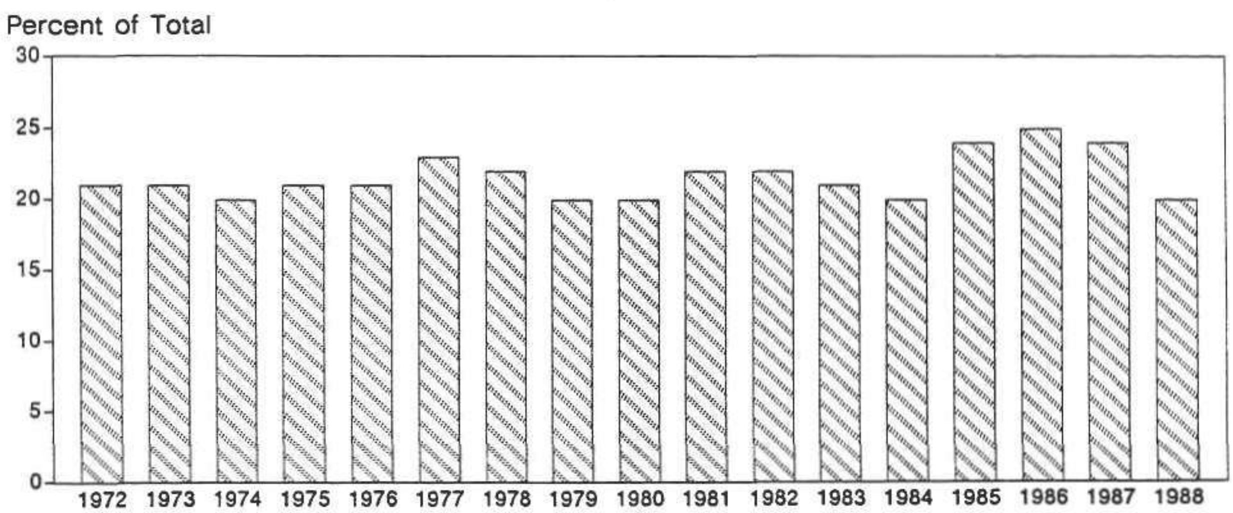
Source: Dataquest
January 1989

Figure 2

Analog IC Sales As a Percentage of Total Monolithic ICs



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Source: Dataquest
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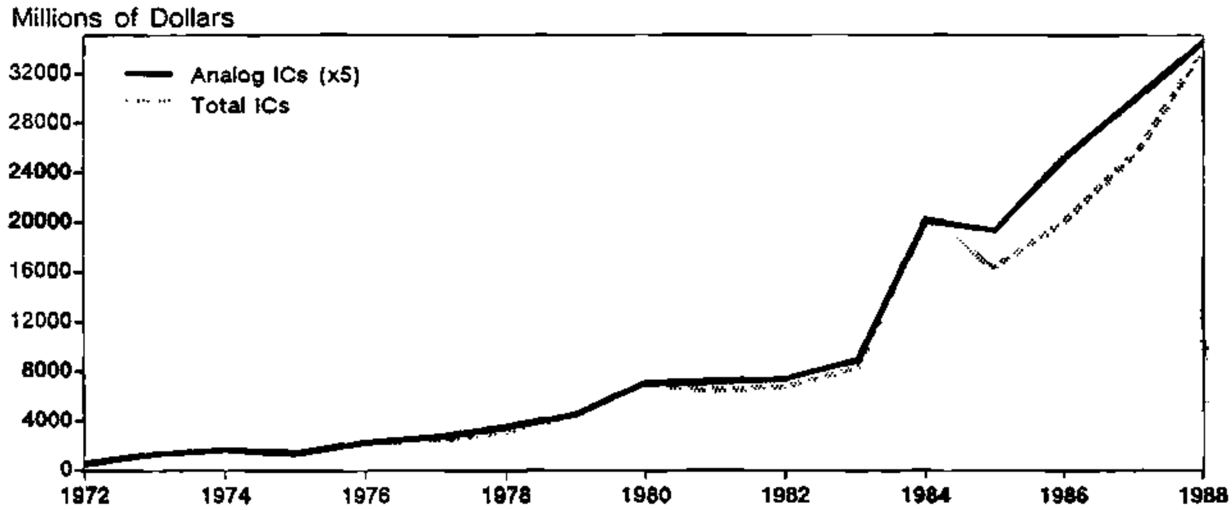
Figure 3

Total IC Sales versus Five Times Analog Sales



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Source: Dataquest
January 1989

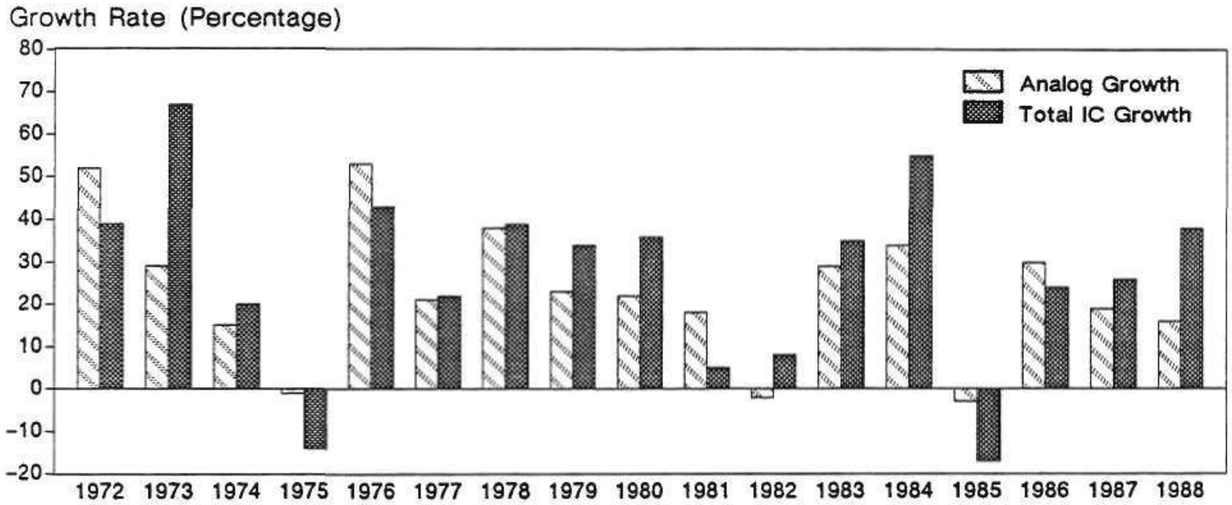
Figure 3 shows how closely the analog market tracks the total IC market. The analog curve is not only similar in shape, but it is a smoother curve that more closely defines the long-term market trends. These curves diverge greatly at two important periods—strong growth (boom) periods and weak market (bust) periods.

Please note that Figures 1, 2, and 3 use WSTS data to isolate monolithic ICs. This WSTS data represents only the reported sales of SIA participants, so the year-to-year growth rates can be distorted. Japanese companies joined this trade association in 1984, which is why the growth is so large in this year (although it was an exceptional year). WSTS data is used to establish the relationship of analog to total ICs in monolithic form only and not for absolute numbers or growth rates.

Taking sales data and plotting it as growth rates over 16 years, as illustrated in Figure 4, shows these growth characteristics more graphically. While it is well understood that the analog market shows smaller growth rates and declines than the total market, the less obvious long-term result of this pattern is that the analog market growth during the bust period compensates for the lower growth during the boom period. This is why analog IC sales remain at a nearly constant 20 percent of total IC sales.

Figure 4

Growth Rate Comparison
(Total ICs versus Analog ICs)



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Source: Dataquest
January 1989

GROWTH RATES COMPARED

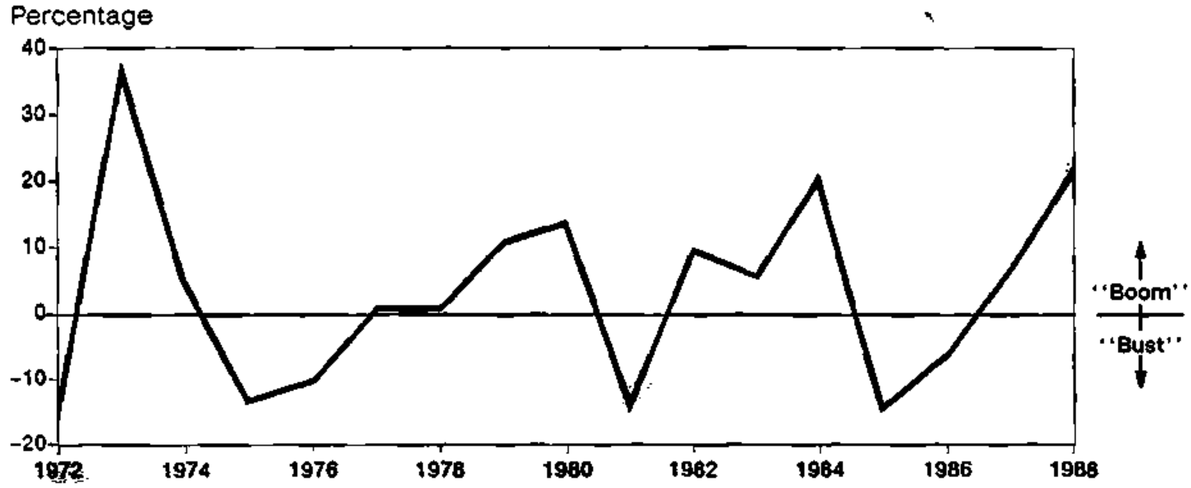
The fact that analog IC growth lags the total growth in periods of strong growth and leads in periods of slow (or negative) growth suggests a periodic nature to these comparative growth rates. By plotting the total IC sales growth minus the analog growth by year over the same 16 years, the periodic nature of their relative growth is dramatically illustrated (Figure 5). This graph defines normal boom periods as being above the zero axis and bust periods as being below. The slow markets of 1975, 1981, and 1985 are clearly defined, as are the strong years of 1973, 1979, and 1984.

This graph may lead to the conclusion that an industry downturn can be predicted when the total-to-analog growth rates get too far apart. An analog lag of more than 10 percent seems to signal an approaching downturn as it did in 1974, 1980, and 1984 (and again in 1988).

Note that Figures 4 and 5 are derived from Dataquest information that includes worldwide data but does not identify monolithic ICs separately from total ICs. These curves are essentially the same as those derived from the WSTS data used in Figures 1 through 3 but are used to prevent concern about the growth rate distortions that could result from the WSTS data.

Figure 5

Growth Rate Difference by Year
(Total IC Growth Minus Analog IC Growth)



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Source: Dataquest
January 1989

How can the different growth rates forecast a change? By showing when the total IC market is growing faster than the analog market, the graph defines a period of an imbalance in market demand (a boom period) and the following adjustment (a downturn). Analog components do not exist in a vacuum. They provide interface, conversion, and signal-processing functions found in all electronic equipment. Even products considered to be digital can contain analog ICs in the power supply and output functions. Any product handling electronic signals such as audio, radio, TV, and telephone equipment must have analog ICs. In addition to this broad market application, analog ICs have shorter lead times, less pricing volatility, many suppliers, and few high-demand glamour circuits.

In an ideal IC market, one in which supply equals demand, prices remain relatively constant, and end-product markets have little variability, both the total and analog growth curves should track. However, distorted buying patterns caused by chip shortages, long lead times, and "hot" electronic products can lead to the total-to-analog growth rate difference shown in Figure 5. Past occurrences of this large growth rate difference have led industry observers to conclude that the analog IC market was declining. In fact, as we have seen, the large difference in growth rates was not signaling the decline of analog as much as it was indicating a forthcoming market downturn.

FORECAST

Dataquest has forecast a slowdown in the second half of 1989, using other forecasting techniques. The same conclusion may be drawn by interpreting the growth rate difference curve of Figure 5 as a leading industry indicator. The fundamental assumption for this interpretation is that analog will remain at a constant 20 percent of IC sales (as it has over the past 16 years). This leads to the conclusion that the average value of the difference curve of Figure 5 must remain constant (at zero) over time. When a demand difference as large as we saw in 1988 occurs, a correction (total industry slowdown) can be expected within the next one to two years to maintain this zero value.

DATAQUEST CONCLUSIONS

The movement of the analog IC market should be of interest to more than the suppliers and users of analog ICs. Analog IC products are important to all areas of electronics. It is this broad functional utility that ties analog so significantly to the whole IC market. But it is the analog market's unique pattern of stability that makes it a suitable benchmark to measure the changes in the total IC market. While the periodic pattern that shows up in Figure 5 may not always remain a viable forecasting method, it does fit the past patterns of industry changes. The analysis of analog IC growth patterns can provide a useful leading indicator of the general health of the IC market.

Gary Grandbois

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Research Newsletter

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Analog
0003120

SEMICONDUCTOR SENSORS: KEY COMPONENTS IN SMART PRODUCTS

INTRODUCTION

Senses provide a window to the world outside ourselves. Without sensory input, not only humans, but also powerful logic elements such as microprocessors are not in control of "real-world" processes and events. This newsletter describes electronic sensors and their markets, focusing particularly on semiconductor sensors, their advantages, and their potential for growth.

Sensor Defined

An electrical sensor is a device that creates an electrical signal (an analog) proportional to the intensity of a particular physical phenomenon. Some of these phenomena are light, force, pressure, displacement, temperature, moisture, acidity/alkalinity (pH), chemical concentrations, electrical fields, magnetic fields, and sound. The term transducer, from the Latin "to lead across" (in this case, to transfer energy from any form to an electrical form), is sometimes used interchangeably with sensor. Using Dataquest's definition, sensor covers all sensing elements and ICs that provide electrical signals in response to nonelectronic physical phenomena.

SENSOR INDUSTRY

The sensor industry is very fragmented. More than 200 U.S. sensor companies alone vie for equally broad markets. The result is that most sensor companies are relatively small, with niche-oriented products and diverse sensor design technologies. The wide range of sensor types, technologies, packages, interfaces, and suppliers makes the sensor marketplace a very amorphous one. In fact, the term sensor has been applied to products ranging from the basic sensor element (a slug of silicon, for example) to complex sensor modules or systems. Market-size estimates can vary greatly due to this latitude in product definition.

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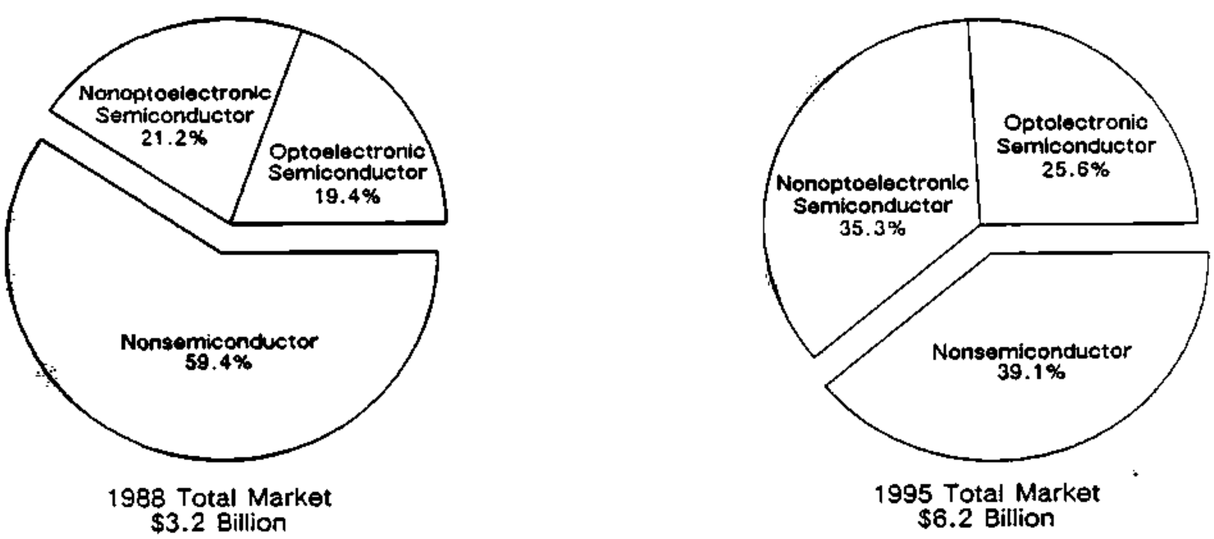
SENSOR MARKET

Dataquest defines a semiconductor sensor as a component-level product, either a chip or an IC (monolithic or hybrid) composed of a semiconductor material (silicon or gallium arsenide). For nonsemiconductor sensors, only the sensing element and any mechanical interface and packaging are considered to comprise the sensor. Dataquest estimates the total 1988 worldwide sensor market to be $3.2 billion. Figure 1 shows the breakdown of this market by sensor technology. In 1988, about 60 percent of the sensor market was supplied by nonsemiconductor sensors. These products include thin-film strain gauges, ceramic infrared sensors, thermocouples, and linear voltage-differential transformers (LVDTs). By 1995, it is expected that 60 percent of the market will be supplied by semiconductor sensors. The semiconductor segment of the market can be further split into optical and nonoptical sensors. Figure 2 shows sensor consumption by region.

Figure 1

Sensor Market by Technology
(Captive and Merchant Suppliers)



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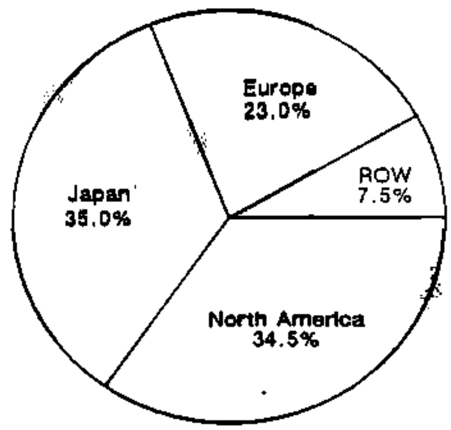
Source: Dataquest February 1989

Figure 2

Sensor Consumption by Region



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Source: Dataquest
February 1989

Microprocessors, Automobiles Drive Sensor Market

Microprocessor-based electronics promise efficiency, automation, comfort, and safety as programmed logic replaces human interface in everyday products. Electrical sensors are the key to having "perception" capabilities in these automated systems. But electrical sensors and controls can do more than merely automate products and processes. They provide the sensory input essential to improved performance, efficiency, and safety. Automobile engines, suspensions, and braking systems, as well as electric motors and air-conditioning systems, are examples of products that have been improved by sensor technology. These high-volume consumer and automotive products demand inexpensive yet rugged sensors. Semiconductor sensors can meet these stringent requirements.

The automotive market is the largest single market for sensor products. Automobiles now use 2 to 7 sensors per automobile (33 million automobiles manufactured per year). At present, sensors are found in automobile engine control applications. Comfort and safety applications will be the next growth areas for automotive sensors. The average number of sensors per vehicle is expected to increase to 12 by 1995, with semiconductor sensors dominating these new applications.

SEMICONDUCTOR SENSORS

Silicon has become an important sensor material because of its impressive advantages over other materials. These advantages include the following:

- Excellent mechanical properties
- Excellent electrical sensing properties
- Extensive semiconductor R&D "coattails"
- Ability to integrate signal conditioning on sensor

The nature of silicon is well suited to sensing. Silicon has a resistance that varies with strain, a property that is used in force, pressure, and acceleration sensors. Magnetic fields can create voltage differences in semiconductor material that has a current flow (Hall effect).

Semiconductor junctions are sensitive to light, strain, and temperature. In addition, MOS devices are sensitive to electric fields and the presence of ions. Although rugged, silicon sensors have a limited upper temperature of about 125° Celsius. Although gallium arsenide (GaAs) devices have the potential to extend this upper limit to 400° Celsius, processing and cost constraints have limited GaAs sensor developments.

Besides having excellent physical properties, semiconductor sensors borrow and build on the extensive R&D efforts made by IC manufacturers. This "free ride" on IC R&D developments gives semiconductor sensors substantial advantage over other sensor types. The learning-curve expectations for IC prices and developments can be applied to semiconductor sensors as well.

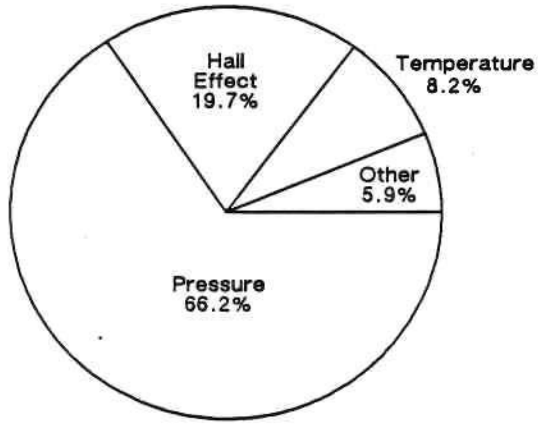
Since the sensor is fabricated on semiconductor material using standard IC processes, additional circuitry can be fabricated on the same chip. The additional circuitry can include other sensors, amplifiers, or linearization functions. A sensor combined with active circuitry can overcome environmental problems, such as noise, temperature, and power-supply variations as well as correcting any deficiencies of the sensor element itself.

SENSOR CONSUMPTION BY SENSED PHENOMENON

Figure 3 shows the semiconductor sensor consumption by type (excluding optoelectronic sensors for simplicity's sake). Pressure sensors are very much the dominant type of semiconductor sensor. The reason can be seen in Figure 4. Semiconductor pressure sensors have penetrated their market much more effectively than have other semiconductor sensors.

Figure 3

Nonoptoelectronic Semiconductor Sensor Consumption by Type



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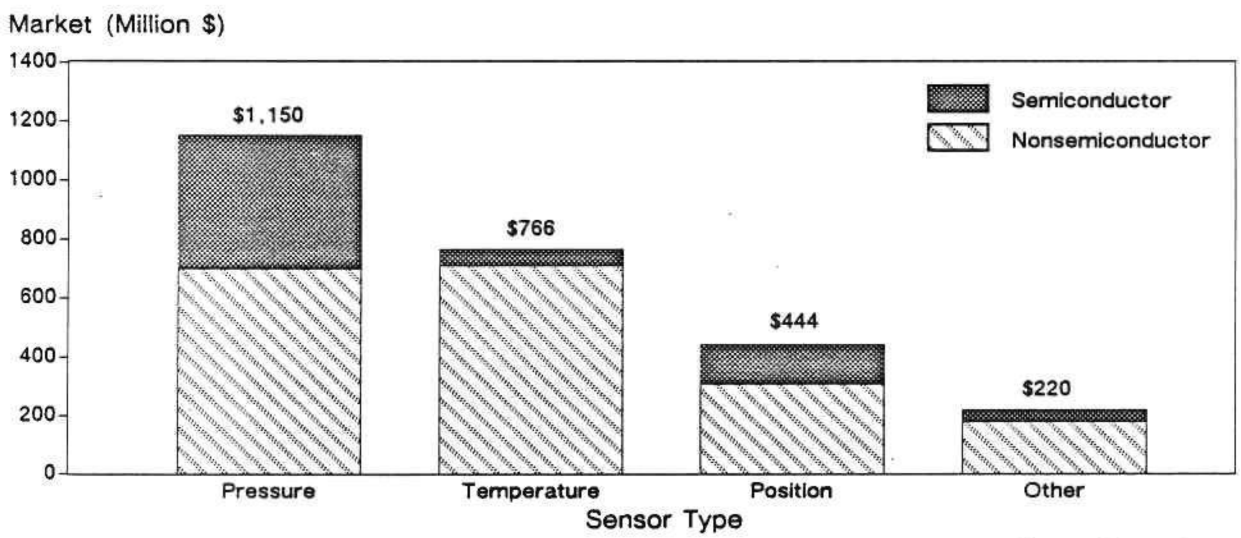
Source: Dataquest February 1989

Figure 4

Nonoptoelectronic Semiconductor Sensor Market Penetration



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Source: Dataquest February 1989

NONCAPTIVE U.S. SUPPLIERS

Table 1 lists U.S semiconductor suppliers that supply nonoptoelectronic sensor ICs into the merchant market. The total merchant market for nonoptoelectronic semiconductor sensors exceeds $300 million.

Table 1

Estimated Nonoptoelectronic Sensor Shipments by U.S. Semiconductor Sensor Suppliers

Company	1988 Sales ($M)
Kulite Semiconductor	$ 27
Sprague Semiconductor	18
Honeywell	16
Motorola	12
Sensym	9
IC Sensors	7
NovaSensor	7
National Semiconductor	4
Analog Devices	4
Others	41
Total	$145

Source: Dataquest
February 1989

HALL-EFFECT SENSORS

Twenty percent of the nonoptoelectronic semiconductor sensor market is for Hall-effect sensors, which develop a voltage output relative to the magnetic field sensed. Hall-effect sensors determine position or displacement by sensing the variation in a magnetic field. Brushless DC motors depend on Hall-effect position sensing for operation.

Hall-effect devices have been available for many years, being based on a century-old sensing concept. They have become important for a number of reasons. By being both noncontact and a nonoptical, they are largely immune to the effects of dirt and corrosive materials. They also share the low cost of manufacturing and the ease of integration common to all semiconductor products. Hall-effect ICs combine the basic Hall-effect sensor with signal-conditioning circuitry, such as amplifiers and comparators. Although a Hall-effect device normally provides analog output, the comparator function makes the device a switch by providing only a two-state output. These "digital" Hall-effect sensors are found in keyboards, motor controllers, and tachometers.

SEMICONDUCTOR PRESSURE SENSORS

The traditional thin-film strain gauges have been successfully challenged by silicon, micromachined, piezoresistive strain gauges. Piezoresistive means simply that resistance changes in relation to strain.

These products use IC diffusion and etching developments in the fabrication of pressure sensors that offer new levels of performance, repeatability, and cost-effectiveness. Micromachining is the technique of selectively etching a silicon wafer in three dimensions to create thin silicon diaphragms. Silicon diaphragms exhibit near-ideal mechanical elasticity with an absence of hysteresis (mechanical memory). Thousands of pressure sensors, along with signal-conditioning circuitry, can be fabricated on a silicon wafer using standard IC equipment and processing.

TEMPERATURE SENSORS

Silicon temperature sensors make use of the temperature sensitivity of the PN junction. This simple sensing element has a predictable characteristic that can be linearized and conditioned right on the sensing chip.

IC temperature sensors have had limited success in displacing other temperature-sensing devices. This is due to the limited operating temperature range of silicon. Silicon devices, at best, operate over the temperature range of -55° to +125° Celsius. The upper range is simply too low for the monitoring of most thermal processes, including the temperatures found in automobile engines.

OPTOELECTRONIC SENSORS

Light sensing is used in control applications, fiber-optic communications, image detection, machine vision, and video. Semiconductor optical sensors include discrete photodetector products, such as photodiodes and transistors, and IC image sensors, such as charge-coupled devices (CCDs) combined with photodiode arrays. CCD image sensors are available in linear and area arrays and are vital to imaging and machine vision applications. Silicon photodetectors are widely used in fiber-optic data transmission and fiber-optic sensors, optical encoding/decoding, and position sensing. This $620 million market will have strong growth in consumer and communications applications.

CHEMICAL AND BIOLOGICAL SENSORS

Semiconductor chemical sensors are emerging only now. One application of a transistor as a chemical sensor has been dubbed the chemFET. This device is similar to the standard MOSFET except that modulation of channel conductivity is provided by chemical ion concentrations rather an applied voltage. A semipermeable membrane selectively passes the ions being measured into the gate oxide position of the chemFET. Channel resistance of the FET device is altered by their presence.

Biological sensors generate voltage or resistance changes in silicon in response to the presence of biological agents. Semiconductor chemical and biological sensor applications accounted for an insignificant portion of the sensor market in 1988. This market will develop in the early 1990s as reliable and inexpensive sensors are introduced.

DATAQUEST CONCLUSIONS

Sensors are the missing link in the next decade of electronics development. The sensor market is poised for standardization, consolidation, and growth. Automotive and consumer applications will provide the impetus for sensor standardization, which will result in lower-cost devices that will, in turn, develop the market further.

Upcoming newsletters will focus on specific semiconductor sensors. Micromachined silicon pressure sensors, Hall-effect sensors, and optoelectronic sensors will each be the subject of an individual newsletter in the months to come.

Gary Grandbois

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Research Newsletter

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ANALOG AT ISSCC '89
ISSUES, PRODUCTS, AND PROCESSES

INTRODUCTION

The International Solid-State Circuit Conference (ISSCC) was held in New York City on February 15 through 17 this year. Although the sessions covered all IC types, this newsletter focuses on analog IC design trends, with highlights of selected sessions. These are followed by tables showing process technology by product type, by presenting company, and by leading analog suppliers.

SESSION HIGHLIGHTS

Data Converters

The Data Converter Papers

Five of the six papers were devoted to new designs for A/D converters (ADCs). The sixth described a D/A converter. Of these six presentations, five were devoted to CMOS converters and the other to a bipolar design. This preponderance of CMOS ADCs is a remarkable change from a decade ago. In 1979, only 23 percent of the converter papers described CMOS devices; the rest were divided into 46 percent bipolar, 23 percent NMOS, and 8 percent PMOS. A less dramatic fact is that 60 percent of the data converter papers this year were from U.S. sources, down only slightly from 77 percent in 1979. This is one of the few areas where U.S. suppliers seemingly have maintained a strong position.

None of the ADC papers was on fully parallel flash converters. The complexity, chip size, power requirements, and resolution limitations of flash converters as well as the limited speed capability of the successive approximation technique have pressed the multistep, subranging technique to the forefront of new designs. Four different papers on this technique were presented.

The first two papers (by NTT and Sony) were remarkably similar in describing 40-MHz, 8-bit, CMOS subranging ADCs that incorporate on-chip sample-and-hold (S/H) circuits. These circuits were fabricated in 1.0- and 1.4-micron CMOS processes, respectively.

The third paper (from National Semiconductor) also covered a 40-MHz 8- to 10-bit CMOS ADC. This design used a recycled remainder technique to time-multiplex a single 4-bit flash converter in successive conversion steps. This ADC did not incorporate the S/H function on the chip. The device was fabricated with a 2.0-micron CMOS process.

Signetics presented a paper on a 12-bit bipolar subranging ADC with fuse trimming. This device uses a complex four-step quantizer that successively determines the least significant bits (LSBs) while correcting errors that may have been created in preceding steps. Conversion time is stated to be 500ns.

A 13-bit, 160ns ADC was presented by SGS-Thomson. This device uses a combined resistor string and capacitive array in a successive-approximation converter to obtain the 13-bit resolution. The resistor string provides the 4 most significant bits (MSBs) while the capacitor array provides the 9 LSBs. This structure normally leads to a converter with good differential linearity and poor integral nonlinearity. To combat this, a multitapped single resistor element was incorporated to improve the integral nonlinearity of the device. The part was processed in 1.2-micron double-metal CMOS process.

In the last converter presentation, Philips laboratories presented a design technique that can be used to provide multiple matched current sources for CMOS A/D converters.

Standardization on the CMOS process for A/D converters is apparent from these papers. BiCMOS, as a data converter process, was conspicuously absent from the presentations. Dataquest believes that, along with CMOS, BiCMOS will be a significant process for data converter designs.

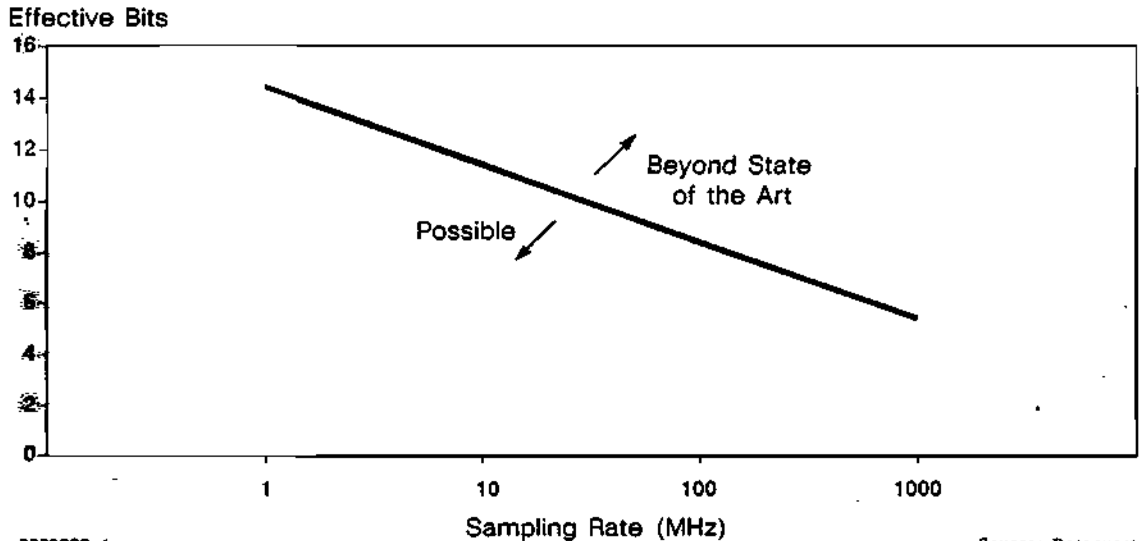
BiCMOS was more evident in the amplifier session. National Semiconductor presented a paper on a sample-and-hold amplifier that settles to 10 bits in 15ns. Video speeds were maintained from the combination of bipolar amplifiers and fast MOS switches despite the fact that a closed loop configuration was used for increased accuracy.

The Limits of Data Converters

One of the panel discussions focused on the performance limitations of data converters. Conversion rate limitations were the main focus. The relationship between sampling rate and resolution was also discussed. Factors that can limit sampling rate include package capacitance and inductance, time delay of silicon interconnects, comparator delay, input capacitance, rise/fall time uncertainty, finite bandwidth, induced noise, and inherent noise. The point was made that high sampling rates (>1 GHz) and high accuracy (>6 bits) are mutually exclusive parameters. Although sample-and-hold circuits can solve many of the time-dependent problems, 250 MHz seems to be the fastest rate that can be achieved presently with an S/H ADC system. Figure 1 illustrates the present frontier of A/D converter performance.

Figure 1

A/D Converter Performance Limit



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Source: Dataquest
March 1989

Resolution to 20 bits and beyond are predicted as oversampling and digital correction techniques are used. Resolution beyond 20 bits and usable bandwidths beyond 500 MHz both seem beyond the present state of the art.

Amplifiers

One of the product highlights of the amplifier session was an op amp with a 10-GHz unity gain bandwidth. This device, presented by Hughes Research Laboratories and offering a fourfold improvement over previous designs, was fabricated in a GaAs MESFET process that created an insulated backgate. Previously, backgating effects had hampered the performance of other MESFET amplifier implementations considerably.

Analog Standard Cells

A panel discussion important to analog observers was titled "Analog Standard Cells . . . A Powerful Tool Whose Time Has Come?". The presence of the question mark in the title gave emphasis to the many concerns and questions involving analog ASIC technology. No one on the panel or in the audience questioned the usefulness of the analog standard cell concept; implementation is the problem. Implementation of analog standard cells is hampered by the availability of CAD tools and by the fundamental nature of analog circuits and their markets. Although some panelists believed that available digital layout tools and analog simulation tools can be used, no one suggested that true integrated tools are available at this time.

Additional discussion developed around the point that even if the design tools existed, analog standard cell libraries would not be viable. Some of the concerns expressed about analog cells were as follows:

- Process dependency of parameters
- Process/library inflexibility required to be truly "standard"
- Variation in performance demanded by fragmented markets (This requires many similar cells or constant modification.)
- Number of analog functions needed (The market may be limited for a limited library.)
- Sensitivity to physical layout
- Cumulative performance degradation of interconnected cells
- External passives needed
- Testability

Although no concerns developed on whether or not the time will come eventually for analog standard cells, a common opinion seemed to be that we do not yet have true libraries of analog standard cells. The present libraries are not truly standard because the cells are constantly being "tweaked" and new cells are constantly being added.

Imagers and Sensors

This session was largely devoted to CCD imaging sensors designed for color video, HDTV, and imaging applications. These products are key to many of the high-volume consumer, medical, and industrial applications of the future.

A number of papers indicated that the standard CCD imagers are being refined in resolution and performance. A 1.3-million-pixel imager was presented by Matsushita. One problem in reducing pixel size is that noise and image smear increase; however, an advanced technique, the BAsed-Stored-Image-Sensor (BASIS), provides a means to combat the degradation that occurs when pixel size is reduced. Canon, Inc. presented a paper on a 310,000-pixel BASIS Imager that has an amplification function within each pixel. Noise and smear can be reduced and dynamic range increased by this technique. Processed in BiCMOS, this imager shows great potential for highly integrated image-sensor systems in the future.

Despite the importance of these products to the future of electronics, the session was rather poorly attended. Although 60 percent of the papers presented were of U.S. origin, we can expect imaging technology, along with most optoelectronic technology, to be dominated by the Far East.

Telecommunications

A complete telephone circuit on a single chip was presented by SGS–Thomson. This IC was able to combine line interface, power supply, ringer, audio driver, and dialing functions as a result of the capabilities of the bipolar–CMOS–DMOS (BCD) process used. The audio portions of the circuit use 30V bipolar circuitry, the logic uses 12V CMOS, and the ringer/driver circuits use 60V DMOS drivers.

STATISTICS ON PRESENTATIONS

The geographic origin of the papers presented in the analog and digital sessions differed. The analog sessions contained 26 papers, 14 of which (54 percent) were of U.S. origin. The digital sessions saw the reverse trend where 57 percent of the papers were of non–U.S. origin. At the 1979 conference, 75 percent of the analog papers were of U.S. origin. The United States has not lost market share in analog circuits as rapidly as in digital, and this fact is reflected in the paper origins.

Table 1 lists the number of papers presented at each session and the process technology used. This table displays the preferences in process technology relative to product type.

Table 2 lists the number of papers presented by each participating company or organization and the process technology used.

Table 1

Number of Papers by Product Type and Process

	Process						
	Bipolar	CMOS	BiCMOS	BCD	DMOS	GaAs	Other
Analog Sessions							
Data Converters	1	5					
Amplifiers	2		1			1	
Imagers and Sensors		1	1				3
Analog Processors	1	3	1		2		
Telecommunications ICs		7		1			
Digital Sessions							
Static RAM	1	3	4				
Floating-Point Processors		6					
Microprocessors		4					1 NMOS
High-Speed BiCMOS ICs			7				
Nonvolatile Memories		7					
Data Communication ICs	1	4				1	
Digital Video Processors		7	1				
Gate Arrays	2	2	1			2	
High-Speed Digital ICs	4	1				1	
Dynamic RAM	7						
Total	12	57	16	1	2	5	4

Source: ISSCC Proceedings

Table 2

Number of Papers by Company and Process

	Number of Papers		Process				
Organization	Total	Analog	Bipolar	CMOS	BiCMOS	BCD	GaAs
Alcatel Telephone	1	0		1			
AT&T Bell Labs	4	1		4			
Canon Inc.	1	1			1		
Carnegie/Mellon Univ.	1	1		1			
Cypress Semiconductor	1	0		1			
Delft Univ. (Netherlands)	1	1	1				
Digital Equipment Corp.	4	0		4			
Eastman Kodak	2	1		1			
Elec. & Telecom Inst. (Korea)	1	0					1
Fujitsu	2	0	1	1			
General Electric	1	0		1			
Hewlett-Packard	2*	1	1	NMOS			
Hitachi	9	0	1	3	4		
Honeywell SPT	1	0					1
Hughes	1	0					1
IBM	5*	0	2	2			2
Intel	2	0		2			
Krysalis	1*	0		1			
Magnavox	1	1	1				
M.I.T.	2	2		1			
Matsushita	2	1		1			
Mitel Semiconductor	1	1		1			
Mitsubishi	7	0	1	6			
National Semiconductor	4*	2		3	1		
NEC	5	1		4	1		
NTT	4	1		2	1		1
Oki Electric	1	1		1			
Philips/Signetics	8*	5	2	2	3	DMOS	
Plessey Semiconductor	1	0		1			
Rockwell Corp.	1*	0					1
Ruhr University	1	0		1			
SEEQ Inc.	1*	0		1			
SGS-Thomson	3	3		1		2	
Siemens	4	1	1	2	1		
Silicon Systems	2	2		2			
Sony Corp.	3	1		3			
Texas Instruments	4	0		2	2		
Toshiba	5	0		4	1		
Univ. of California	2	2		2			
Western Digital	1*	0		1			

*Some papers were jointly developed by two or more organizations; therefore, totals from this table will not match Table 1.

Source: ISSCC Proceedings

Table 3 takes the data from Table 2 and orders the companies using Dataquest's 1988 ranking by analog IC market share. These are the top 15 analog suppliers in descending order of rank.

Table 3

Presenting Companies by Market Share

	Number of Papers		Process*				
Organization	Total	Analog	Bipolar	CMOS	BiCMOS	BCD	GaAs
Toshiba	5	0		4	1		
National Semiconductor	4	2		3	1		
Sanyo	0	0					
NEC	5	1		4	1		
Philips/Signetics	8	5	2	2	3	DMOS	
Texas Instruments	4	0		2	2		
Motorola	0	0					
Matsushita	2	1		1			
Mitsubishi	7	0	1	6			
SGS-Thomson	3	3		1		2	
Sony Corp.	3	1		3			
Hitachi	9	0	1	3	4		
Analog Devices**	0	0					
Rohm	0	0					
AT&T Bell Labs	4	1		4			

*An important result of this ordering is the fact that five of the top six analog suppliers presented BiCMOS papers (and only one of the following nine did).
**A paper on BiCMOS sample/hold amplifiers was deleted from the conference.

Source: ISSCC Proceedings

DATAQUEST CONCLUSIONS

The most notable occurrence at this conference was the widespread presence of BiCMOS technology. Although CMOS has become a dominant technology in the IC world, its rapid move into the digital marketplace has not been mirrored in the analog marketplace. Bipolar has held a good share of the market and will continue to do so for some time. New analog products will be increasingly developed in MOS technologies, however. As this conference has demonstrated, BiCMOS has particular value in combining the performance of bipolar analog with CMOS switching and logic elements.

The variations in BiCMOS feature size presented at the conference ranged from 0.5 micron (Hitachi SRAM) to 1.5 microns (Siemens). CMOS feature size ranged from 0.5 micron (Sony DRAM) to 3.0 microns (UCLA linear).

Many of the analog product types for which BiCMOS is especially attractive were absent from the conference papers. These products include power ICs, interface ICs, and mixed-mode ASIC. CMOS/BiCMOS penetration of analog designs may be considerably greater than the presentations at the ISSCC indicate.

Gary Grandbois

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BiCMOS: A HIGH-PERFORMANCE COMPLEMENT TO CMOS

INTRODUCTION

The BiCMOS process technology has become one of the hottest topics in the IC arena. It was the dominant theme of this year's International Solid-State Circuit Conference (ISSCC) for both analog and digital ICs. BiCMOS has been most often discussed in terms of digital products, especially gate arrays and static RAMs. In fact, BiCMOS is a crucial technology for three of the highest growth areas in analog ICs: mixed-signal ASICs, smartpower ICs, and data converters. This newsletter will focus on the analog BiCMOS process, its present state, and its potential.

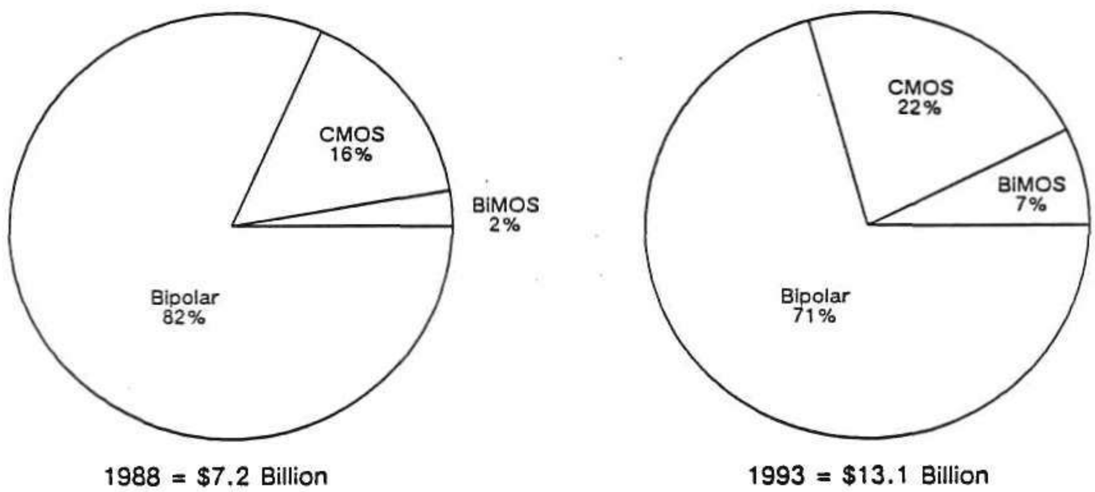
BiCMOS FORECAST

Analog ICs and the BiCMOS process are intertwined. BiCMOS has been around the analog IC world for more than a decade. Although the 1988 analog BiMOS, including BiCMOS, IC sales exceeded $148 million, the major BiCMOS developments and growth are only beginning.

Figure 1 illustrates Dataquest's estimates of analog revenue by process for 1988 and 1993. These numbers represent the percentage of total revenue provided by ICs fabricated with these processes. In this and all the following figures, BiCMOS is used to represent all BiMOS products (bipolar PMOS, bipolar CMOS, and BCD products). As Figure 1 shows, revenue from products using BiCMOS processing are expected to increase sixfold over the next five years. Bipolar-processed ICs will show growth in revenue during the five-year period, but this growth will drop by 10 percent of the total, losing substantial ground to MOS-processed ICs.

Figure 1

Sales by Process Type



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Source: Dataquest
March 1989

Why BiCMOS?

Although many analog products are still simple functional blocks that can use a single process technology, most new designs are for larger-scale devices that require multiple analog functions or mixed analog-digital subsystems. The needs of these complex subsystem chips are not well served by either a bipolar or a CMOS process. Table 1 lists some important functions and the preferred process.

Table 1

Bipolar and CMOS Compared

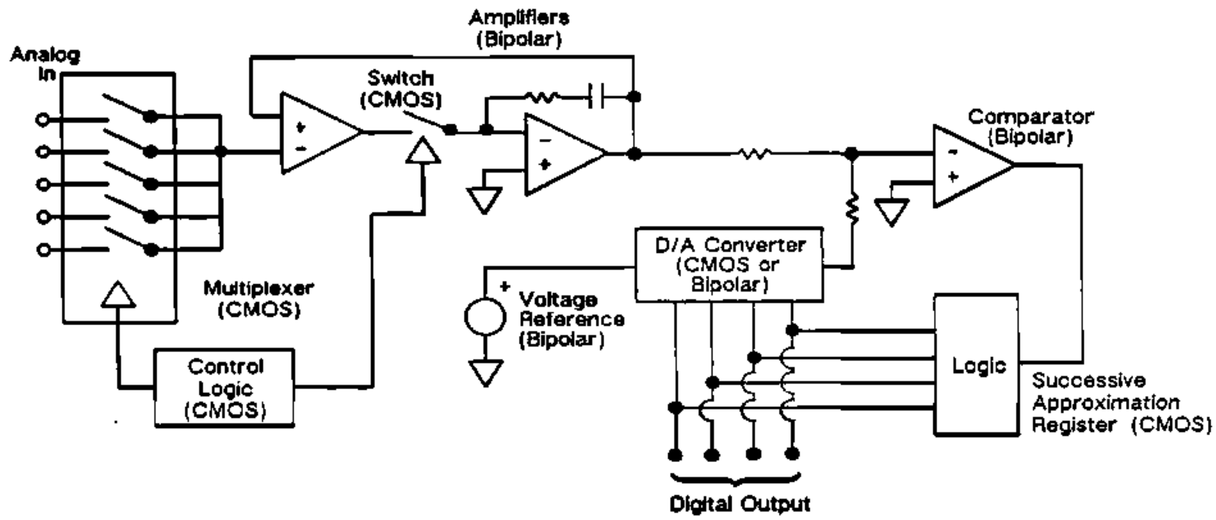
Functions	Bipolar	CMOS
Precision Amps	X	
Fast Amps	X	
High Impedance		X
Voltage References	X	
Analog Switches		X
High-Current Outputs	X	
High-Voltage Outputs	X	
Dense Logic		X
Low-Power Logic		X
Memory		X
ECL Interface	X	

Source: Dataquest
March 1989

Although complex ICs can and have been made with either of these technologies, performance compromises can be very severe. Bipolar cannot provide a useful analog switch nor CMOS a stable reference. As an example, Figure 2 shows the functional blocks comprising a data acquisition circuit. Note that an optimal circuit, designed around discrete function blocks, would require both bipolar and CMOS devices. To minimize performance trade-offs, integration of this system would best be done with a process that combined both bipolar and CMOS devices.

Figure 2

Data Acquisition System



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Source: Dataquest March 1989

Not only data acquisition, but mixed analog/digital ASICs, telecommunications ICs, and smartpower ICs would benefit from BiCMOS capabilities. Smartpower ICs especially require the current, voltage, and interface capabilities offered by bipolar devices. The extreme voltage requirements of some smartpower devices have pressed development beyond the BiCMOS process into bipolar-CMOS-DMOS (BCD), a process that combines high-voltage DMOS transistors with bipolar and CMOS devices.

Although the value of BiCMOS in power and interface circuits is largely accepted, its value in signal-handling and data-conversion circuits is questioned by a number of linear CMOS advocates. Although linear functions implemented in CMOS have improved greatly over the last decade, there is still a significant performance gap between bipolar amplifiers and references and the CMOS equivalents. BiCMOS provides a means to generate state-of-the-art circuits without requiring design "breakthroughs" in CMOS, and high-performance circuits can be implemented rapidly and easily with BiCMOS by less skilled designers. This is not a trivial consideration. The pool of highly skilled analog IC designers (often pegged at 200 worldwide) is a limited resource that cannot be stretched to accommodate the needs of growing markets.

BiCMOS Suppliers

A list of suppliers of ICs using BiCMOS processing is presented in Table 2.

Table 2

BiCMOS Suppliers

Supplier	ASIC	Smartpower	Converter
Analog Devices	X	X	X
AMCC	X		
AT&T	X		
Barvon	X		
Fujitsu	X	X	
Harris	X	X	
Hitachi	X	X	
Honeywell SPT			X
International Rectifier		X	
IXYS		X	
LSI Logic	X		
MIETEC	X		
Motorola	X	X	
National	X	X	X
NEC	X		
Philips	X	X	X
Sony		X	
SGS-Thomson		X	
Siemens	X	X	
Sprague		X	
Toshiba	X	X	
Ricoh		X	X
Telefunken		X	
Texas Instruments	X	X	X

Source: Dataquest
March 1989

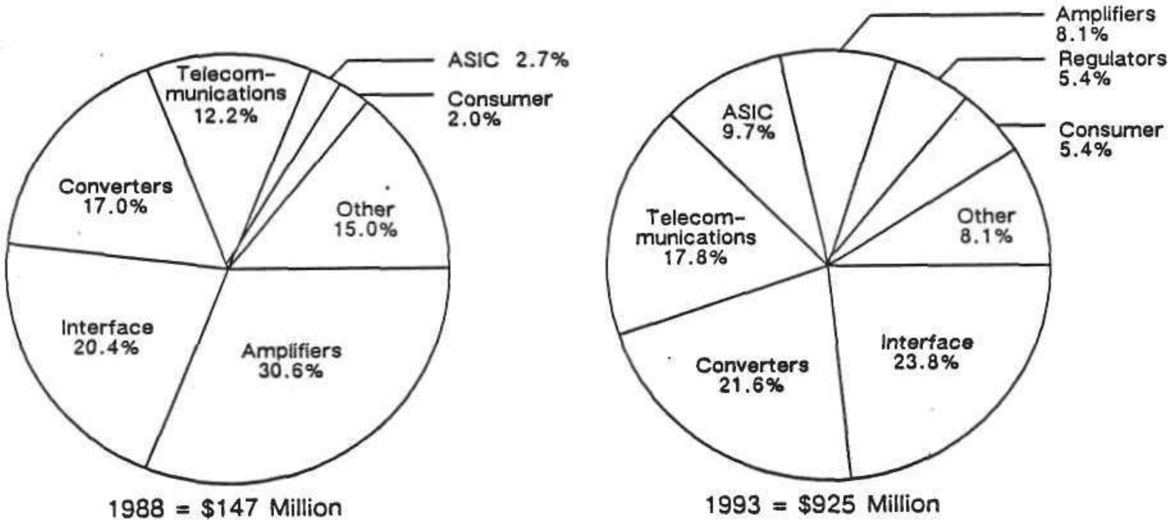
BiCMOS by Product

Figure 3 shows the BiCMOS sales by product type in 1988 and Dataquest's estimate of the sales in five years. We expect the major gainers to be the converter, interface, analog ASIC, and telecommunications IC markets.

Each of the three main product types is displayed by process type in Figure 4. This is done to illustrate the present state of the process technology (1988) and to contrast with the forecast changes by product as depicted in Figure 5 (1993).

Figure 3

BiCMOS Sales by Product



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Source: Dataquest
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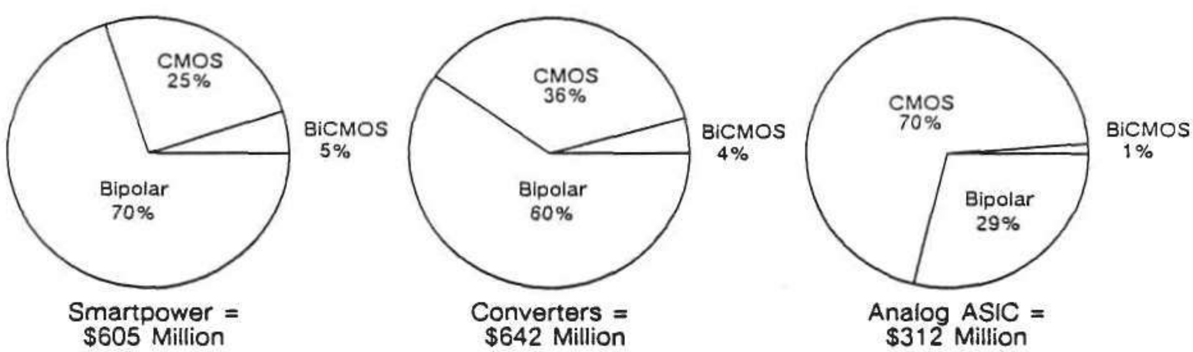
Figure 4

Product by Process in 1988



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Source: Dataquest
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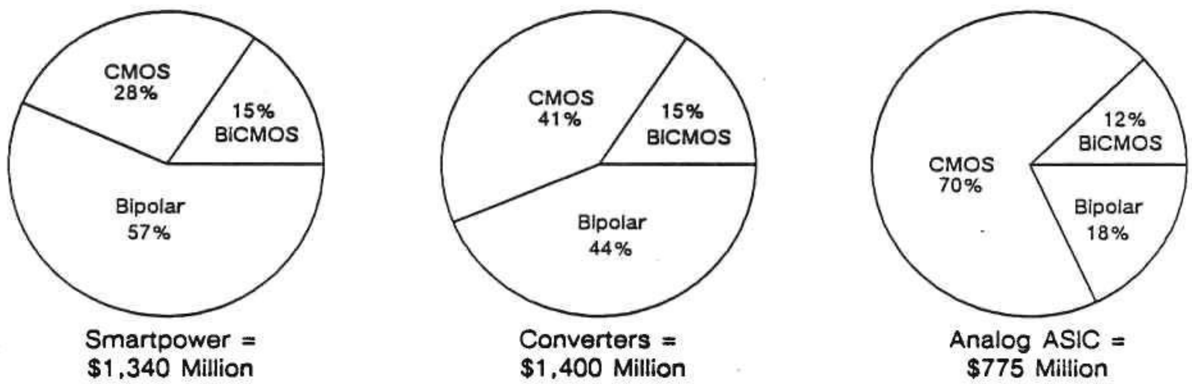
Figure 5

Product by Process Forecast for 1993



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Source: Dataquest
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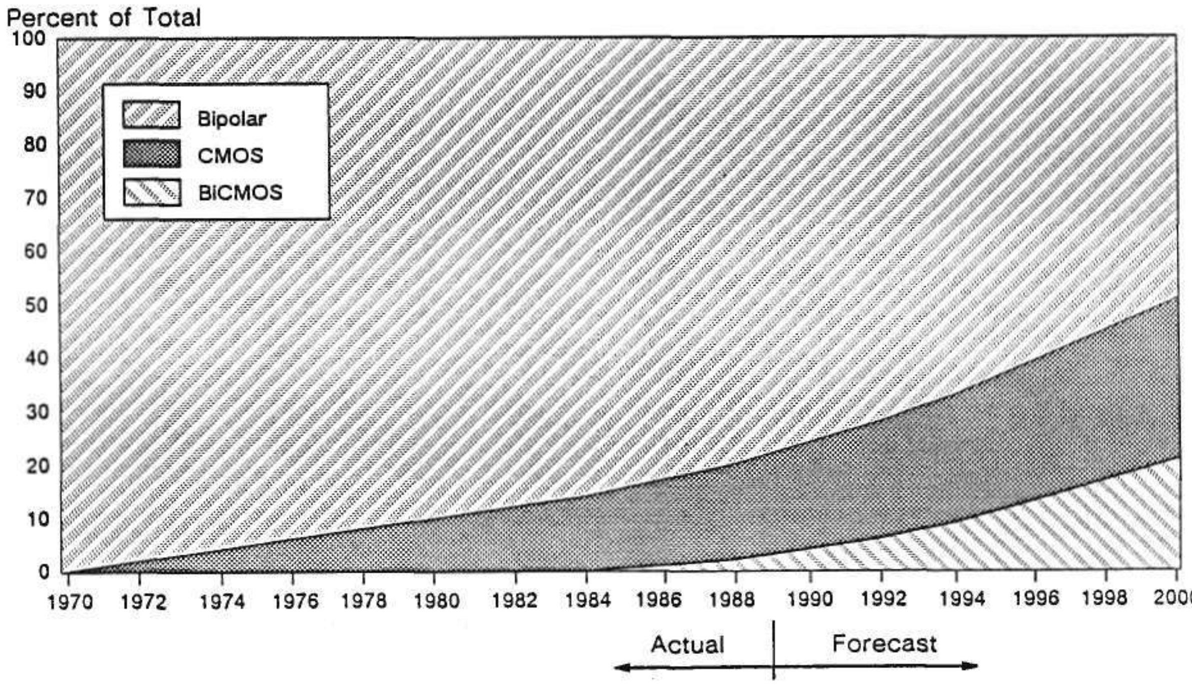
THE FUTURE OF BIPOLAR

Dataquest believes that CMOS and BiCMOS will continue to take market share from bipolar processing technology for analog ICs. Figure 6 shows this trend over a 30-year span, including the expected changes through the coming decade. Although bipolar will be dropping as a percentage of total analog IC revenue, its future is hardly bleak. Bipolar processing is in a very dominant position in the analog world. Dataquest estimates that it will lose approximately 3 percent per year in share of market to the MOS processes in the coming decade. As the analog market growth is expected to average 15 percent over the next five years, this still leaves the revenue for the bipolar segment increasing at a 12 percent compound annual growth rate.

Figure 6

Analog Process Changes over Time



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Source: Dataquest
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DATAQUEST CONCLUSIONS

BiCMOS is at the frontier of new high-performance products in the analog and mixed-mode markets. Dataquest believes that the opportunities represented by this process lie in high-performance analog systems, telecommunications ICs, ASICs, and power ICs. Although BiCMOS will take its place alongside CMOS as an important analog process, it is not likely to overwhelm either the CMOS or bipolar process within the next decade. Some of the limiting factors include the availability of CAD tools, increased costs, and demonstrated reliability.

The importance of BiCMOS over the next decade is twofold. First, it can provide new levels of performance and integration for analog ICs. This is the reason it is being developed and offered. The second important point is that BiCMOS will greatly reduce the dominance of the bipolar process in the 1990s. We predict that the emergence of BiCMOS, combined with the continued growth of CMOS, will drop the analog bipolar process to a minority role (less than 50 percent of the market) by the turn of the century.

Gary Grandbois

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AMPLIFIER IC FORECAST: CLOUDS ON THE HORIZON

INTRODUCTION

Operational amplifiers (op amps) represent one of the earliest and most substantial portions of the analog IC market. This venerable product seems to have reached a mature state in its product life cycle, which is reflected not so much in decreasing revenue as in decreasing importance. Amplifier sales will not decline in volume in the foreseeable future. On the contrary, amplifier revenue will continue to increase, although at a lower rate than that of the analog market in general.

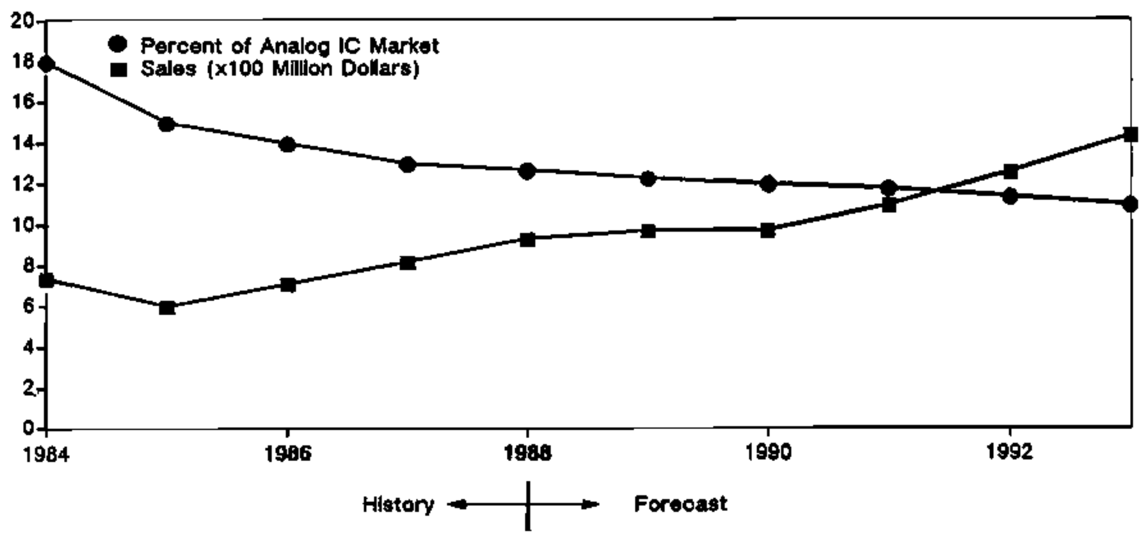
With regard to product families such as amplifiers, the concept of a complete life cycle (birth to death) is not always applicable. Products, like people, have limited life spans. Families, whether of the human or product variety, have widely differing aging profiles that may or may not include a stage of decline. Dataquest sees no period of decline for amplifiers within its forecast period.

TRENDS

Figure 1 shows the state of the amplifier market during the past five years and the forecast growth for the next five years. Note that two recent trends are continued into the forecast. First is the fact that amplifier sales will continue growing. Second, because this growth is not expected to be as fast as that of the general market, amplifiers will account for a decreasing portion of the total analog IC market.

Figure 1

Amplifier Historical Trends and Forecast



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Source: Dataquest April 1989

In the past, amplifiers grew at about the same rate as the total analog IC market because of their broad end-market distribution. The recent decline in market share has been caused by several factors, including the following:

- Digital signal processing (DSP) reducing the need for analog signal processing
- Higher levels of integration in market-specific products
- Mixed-mode ASICs

The demand for specialty products and higher levels of amplifier performance in video, telecommunications, industrial, and military applications is helping to counter this decline in analog market share.

DATAQUEST'S AMPLIFIER FORECAST

Dataquest expects the world amplifier market to increase from $935 million in 1988 to $1,440 million in 1993, a compound annual growth rate (CAGR) of 9.0 percent over the five-year period (see Table 1). This is approximately 3.4 percent less than the total analog market growth predicted for the same period.

Table 1

World Amplifier Forecast

Year	Revenue ($M)	Units	ASP*
1988 (Actual)	$ 935	2,180	$0.43
1989	$ 975	2,270	$0.43
1990	$ 975	2,320	$0.42
1991	$1,100	2,550	$0.43
1992	$1,260	2,900	$0.43
1993	$1,440	3,400	$0.42
1988-1993 CAGR:	9.0%	9.2%	(0.5%)

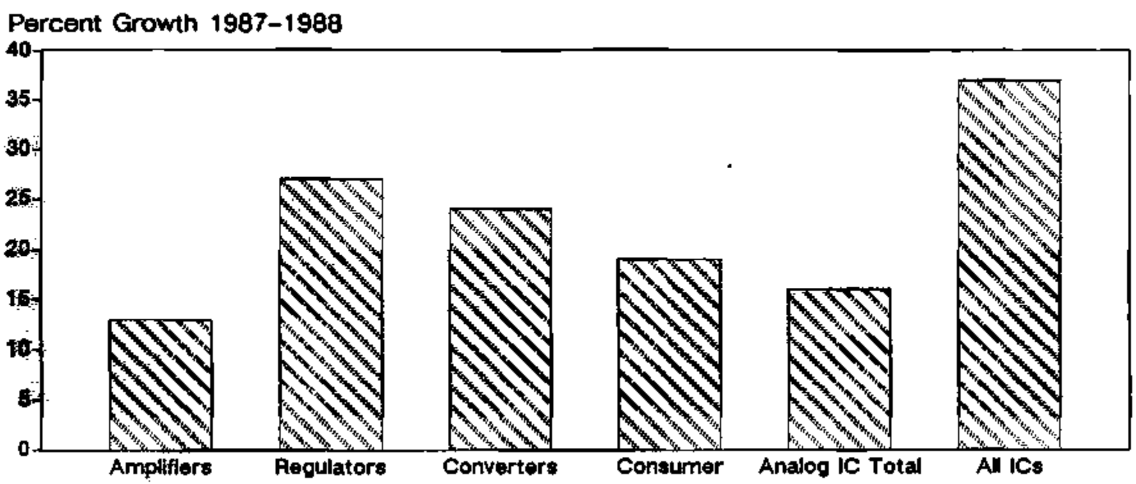
*ASP = Average Selling Price

Source: Dataquest
April 1989

The 1988 amplifier growth rate is contrasted with that of other analog products in Figure 2. Although the analog IC market increased 16 percent in 1988 over 1987, amplifiers grew only 13 percent. The CAGR of amplifier sales over the past five years (shown in Figure 3) was less than 6 percent. This CAGR was deflated largely by the 19 percent decline in revenue that occurred in 1985. The present trajectory of the amplifier market indicates projected growth from 2 to 5 percent less than that of the total analog IC market.

Figure 2

1988 Growth of Amplifiers versus Other Analog Products



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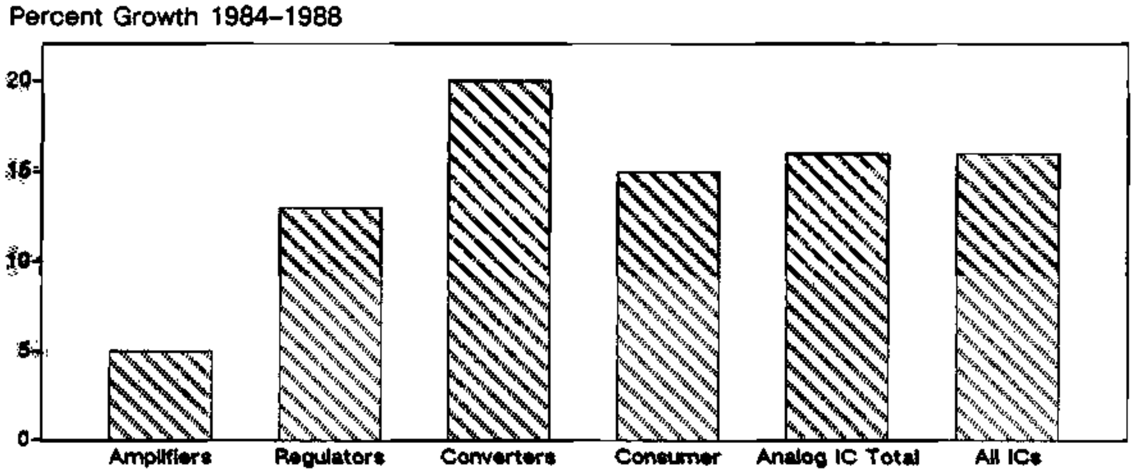
Source: Dataquest
April 1989

Figure 3

1984–1988 CAGR of Amplifiers versus Other Analog Products



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Source: Dataquest April 1989

THE SILVER LINING—PERFORMANCE

Not all segments of the amplifier market are lagging the industry. Specialized product areas, particularly the performance niches of speed, power, and precision, represent growth areas.

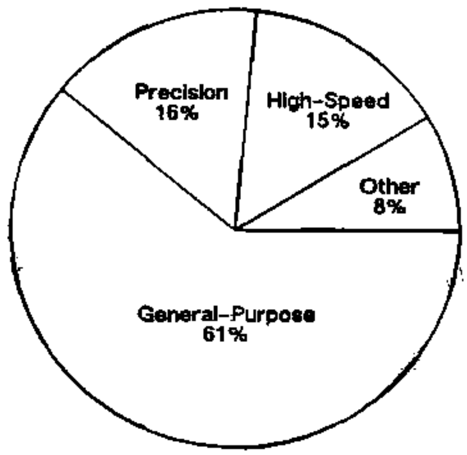
Dataquest divides amplifier performance into three categories—general-purpose, precision, and high-speed devices—as follows:

- High-Speed—Gain-bandwidth product >5 MHz; Slew rate > 10V/microsecond
- Precision—Vos <1mV; Gain >100,000; I_b <50nA
- General-Purpose—Everything else

Figure 4 shows 1988 amplifier sales by these performance categories. The amplifier market is dominated by the general-purpose type product, which constitutes approximately $565 million or 61 percent of the total world amplifier market. Precision and high-speed amplifiers meet more demanding and specialized application needs. The precision market for highly accurate ICs is the next largest; these amplifiers account for $150 million in sales or 16 percent of the total market. In general, there has been some movement from this category into the general-purpose sector as technology has improved. The high-speed category amounts to approximately $140 million or 15 percent of the world market.

Figure 4

1988 World Amplifier Market Share by Performance Category



0003521-4

Source: Dataquest
April 1989

Of the three types of amplifiers illustrated, the fastest growth is occurring in the high-speed sector. Dataquest believes that high-speed amplifiers are growing at an approximate 18 percent rate, with sales that will increase from $140 million in 1988 to $320 million in 1993. Gallium arsenide amplifiers represent the ultimate in speed; recent improvements in performance should open this market greatly during the next decade. Precision amplifiers also should realize a relatively higher growth rate than general-purpose products. We expect precision amplifiers to grow at a 14 percent CAGR from $150 million in 1988 to $276 million in 1993. In total, we expect the amplifier market to grow about 9 percent between 1988 and 1993. This lower overall growth is due to the lower market demand for the larger, slower-growing general-purpose category, which is growing in the 7 percent range.

DATAQUEST CONCLUSIONS

The amplifier market represents a diminishing horizon for finding either new or growing markets. Specialty suppliers such as Linear Technology and Maxim Integrated Circuits have demonstrated that opportunities exist in high-performance and specialty products. GaAs amplifiers are at the high-speed frontier, whereas MOS technologies offer new capabilities in "smart" amplifiers.

The ubiquitous general-purpose op amp may be a product past its prime. Besides the market encroachment of mixed-mode ASICs and more highly integrated standard ICs, the "jelly bean" nature of general-purpose op amps, including fairly low-tech fab and process demands, large markets, large distributor sales, and commonly known part numbers, could make them an attractive target for emerging Rest of World companies that want to grab market share and tap a source of foreign currency in the 1990s. In the coming decade, the suppliers of specialty and high-performance amplifiers may have the more secure long-term position.

Gary Grandbois
Barbara Van

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Research Newsletter

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HDTV
ANALOG ICs ARE MORE IMPORTANT THAN EVER

SUMMARY

The hottest topic in trade literature today is high-definition television (HDTV). Invariably, the articles imply that digital circuitry will replace analog signal processing, and that consequently, the analog content of TV will decline. Dataquest believes that neither analog IC content nor analog technology will be pushed into the background by the race to develop and market HDTV.

ANALOG OPPORTUNITY

TV development is following two paths at this time. The first is to develop new broadcast and TV standards for HDTV. The second is to use digital techniques to improve display resolution and visual impact while still using today's standard video transmissions (NTSC, PAL, SECAM). Products such as improved definition TV (IDTV) or enhanced definition TV (EDTV) are examples of this direction. Either path toward picture improvement will involve digital signal processing, which will increase the use of data converters, as well as memory and DSP functions. The types of IC products used in these TVs can be anticipated, regardless of the broadcast format of the signal received.

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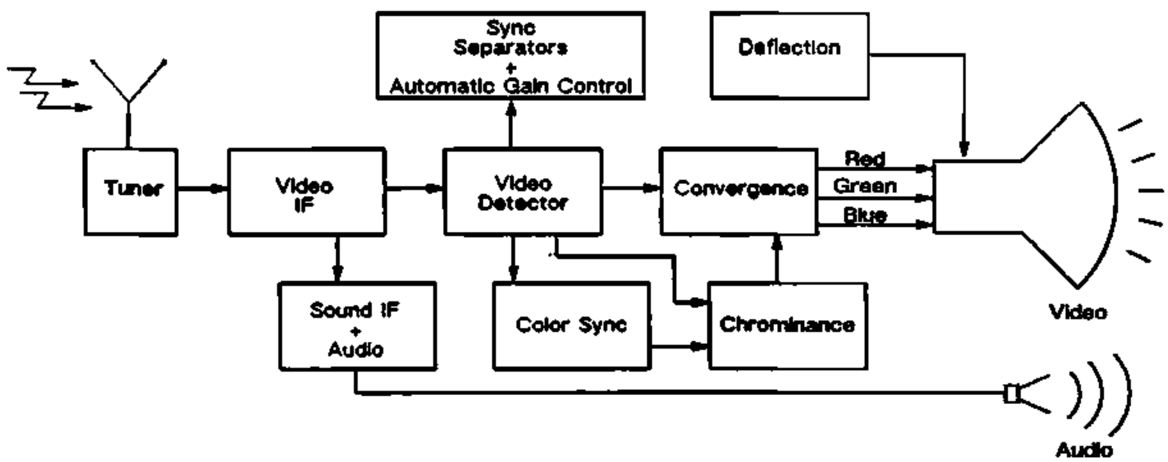
THE ANALOG IC MARKET FOR TVs

Figure 1 is a block diagram of a typical analog TV of today. There are approximately 61 million color TVs manufactured worldwide per year. On average, each of these TVs uses $30 worth of semiconductors, $11 of which are analog ICs.

Figure 1

Analog
NTSC Color TV Block Diagram



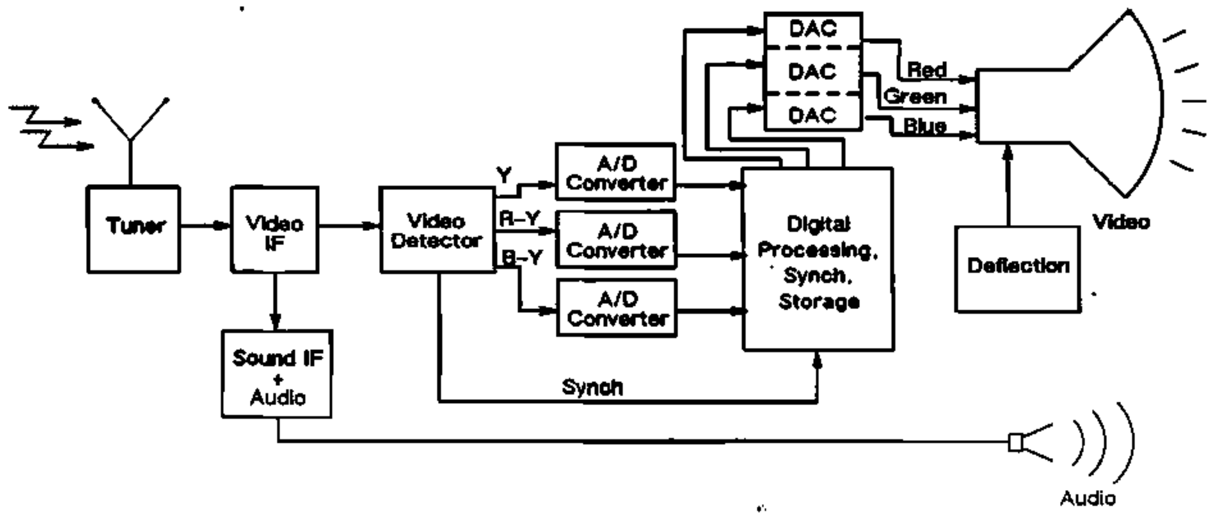
0003621–1

Source: Dataquest
April 1989

An IDTV or HDTV will have a block diagram similar to that of Figure 2. Analog ICs will still be found in the tuner, audio amplifier, and video intermediate frequency (IF) sections. More importantly, four to six critical data converters also are needed. From one to three A/D converters (ADCs) are required to convert the baseband video into the digital data for processing within the digital system. On the output side of digital processing, a high-speed, triple 8-bit video D/A converter (DAC) would be needed to drive the video display.

Figure 2

Digital HDTV Block Diagram



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Source: Dataquest April 1989

Despite all the conflicting standards being proposed, HDTV systems are being implemented already. In addition to this move to HDTV, digital enhancement techniques will continue to be used to improve picture performance on upscale, compatible TVs. Both of these product offerings will increase the IC dollar content (both digital and analog) within the total television market. Table 1 and Figure 3 show the forecast sales of analog ICs into the TV market and the estimated value of the analog ICs per set. All IDTV, EDTV, and HDTV sets have been grouped together due to similar needs in ICs.

Table 1

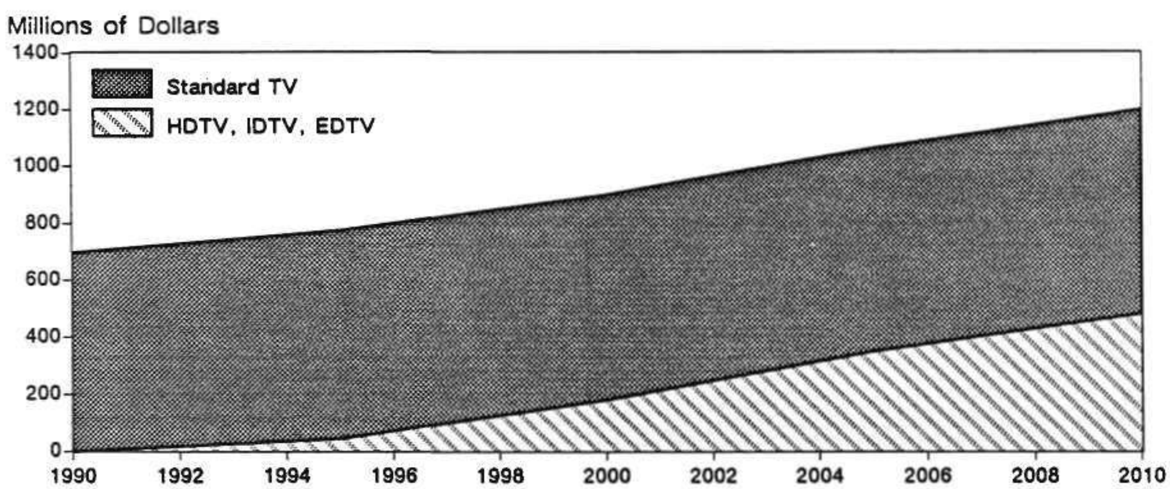
Forecast Sales of Analog ICs for Color TV
(In Constant 1988 Dollars)

	Analog Content per Set		Analog IC Revenue ($M)		
Year	Standard	IDTV, HDTV, EDTV	Standard	IDTV, HDTV, EDTV	Total
1988	$11.00	-	$670	-	$ 670
1990	$10.50	$100	$699	$ 1	$ 700
1995	$10.00	$ 45	$730	$ 45	$ 775
2000	$ 9.00	$ 30	$720	$180	$ 900
2005	$ 8.50	$ 25	$714	$350	$1,064
2010	$ 8.00	$ 23	$720	$483	$1,203

Source: Dataquest
April 1989

Figure 3

Forecast Analog Content of TVs



0003621-3

Source: Dataquest
April 1989

The forecast assumes that a major limitation to HDTV acceptance will be price and perceived value. Increased definition demands increased screen size and digital processing. Both of these factors will combine to drive the price of these sets into a range of two to five times the price of a conventional big screen (25- to 27-inch), CRT-type TV.

Data Converters for Improved Definition

Truly high definition will require D/A converters with 8-bit resolution for each of the three colors of the display. This represents a capability of 16 million colors.

The high-definition, high-speed triple 8-bit DACs are available today. These products will see a significant price decline—to $12 by the time HDTV becomes significant.

Philips recently has lowered the price for 8-bit, 40-MHz flash ADCs to less than $10 for large quantities. The March 1989 announcement speeds up the race for the digital TV market. The announced product (TDA8703) is specified to deliver 48.5dB signal-to-noise performance at 4.43 MHz (European TV color carrier).

U.S. suppliers have long dominated the data conversion IC market. The race to HDTV presents an opportunity for U.S. suppliers to leverage this position to regain market share in consumer products. The flip side is the danger that the loss of the consumer data converter market may lead to lost market share for present suppliers in nonconsumer markets as these low-cost, high-performance converters become available for broad applications. High-definition video is more than just TV. Military, medical, and computer markets (all strong markets for U.S. suppliers) have tremendous need for high-definition video products and represent a greater market than that of HDTV. Losses in any of these markets could be disastrous for U.S. suppliers.

DATAQUEST CONCLUSIONS

Whether HDTV is the next big IC market or the next over-hyped improvement (like "quadraphonic sound"), the news is generally good for analog IC suppliers. Any or all of the HDTV, IDTV, and EDTV possibilities represent sophisticated products that will increase analog dollar content per product rather than decrease it. The interesting paradox of the "digital revolution" is that it expands markets for specialty analog suppliers, especially those in the data converter area. As an example, the analog content of a CD player (DAC, amplifiers, motor controller) is significantly higher than that of the turntable it replaced. For those not yet positioned in the video data converter market, time and opportunity to develop these high-speed products still exist. These products reach beyond the consumer market for digital TV. They are key to all high-definition graphical information display markets.

Beyond the signal processing itself, further analog opportunities may develop in high-resolution, flat panel displays. These products will require complex analog driver ICs to interface to the video processor.

Gary Grandbois

Dataquest

Conference Schedule

1989

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Research Newsletter

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UPDATE ON ANALOG IC ALLIANCES

SUMMARY

The pattern of alliances continues, with factors such as trade, vertical integration, and technology facilitating the unions. The webs are tightly woven, and many of the unions in the analog world are not reported. This newsletter draws attention to some of the important unions that have taken place in 1988 and early 1989 (see Table 1). It also reports on some of the factors driving these alliances.

Table 1

Analog IC Alliances—1988 and 1989

Date	Company A	Company B	Type	Products
1988	Motorola	Seagate	Tech. exchange	Analog tech.
2/88	Thomson	Sipex	Joint venture	Power hybrids
2/88	Brooktree	National	Second source	Video DACs
2/88	Brooktree	Analog Devices	Joint development, second source	Video DACs
4/88	TI	Sony	Joint development	Audio filter
5/88	Comlinear	TRW LSI Products	Tech. exchange	Op Amps, data converters
6/88	AMD	Siemens	Second source	ISDN ICs
7/88	AT&T	GTE	Joint venture	Communications

(Continued)

Table 1 (Continued)

Analog IC Alliances—1988 and 1989

Date	Company A	Company B	Type	Products
8/88	PMI	SSM	Acquisition	Audio IC market
8/88	VTC	Grass Valley Group	Joint development	Video line drivers
8/88	Teledyne	Omnirel	Joint development and marketing	Smartpower ICs
9/88	Sil. Systems	Hayes	Tech. exchange	Design tools
9/88	Sharp	Hycom	Acquisition	Telecom manufacturing
10/88	Harris	Kawasaki Steel	Joint development	CMOS technology
10/88	Siliconix	Teledyne	Second source	Smartpower ICs
11/88	Harris	GE Solid State	Acquisition	General
12/88	Motorola	Cherry Semi.	Second source	Bipolar analog
1/89	AT&T	Intel	Joint development	ISDN, LAN ICs
1/89	Unitrode	ADDACON	Equity investment	Hybrids
3/89	Maxim	Supertex	Joint marketing	Power supply ICs

Source: Dataquest
April 1989

THE ALLIANCES

The alliances listed chronologically in Table 1 involve the following arrangements:

- Motorola and Seagate Technology—The agreement relates to internal use of Motorola's technology by Seagate, a major manufacturer of hard disk drives. (1988)

- Thomson and Sipex—Power Hybrid Systems, a newly formed subsidiary of Thomson-CSF and American Tractebel, began manufacturing a line of power hybrids in a plant belonging to Sipex, a Tractebel subsidiary. (2/88)

- Brooktree and National Semiconductor—Brooktree and National negotiated an agreement previously made between Brooktree and Fairchild; National will second-source four of Brooktree's video DACs. (2/88)

- Brooktree and Analog Devices—Brooktree and Analog Devices announced an agreement to provide customers with an alternate source for the video DACs. Also, the two companies will independently develop, manufacture, and market their own devices based on the Brooktree architecture. (2/88)

- TI and Sony—The companies agree to jointly develop an IC filter for digital audio. (4/88)

- Comlinear and TRW LSI Products—This is a technology exchange pact whereby Comlinear brings its design know-how in high-speed operational amplifiers and track/hold circuits to the party and TRW contributes its expertise in high-speed A/D and D/A converters. The companies are planning to combine a converter with an amplifier on a chip. (5/88)

- AMD and Siemens—This agreement involves the second-sourcing of 15 ISDN circuits. (6/88)

- AMD and Siemens—This is a technology agreement under which the companies will jointly develop, manufacture, and market microchips for data communications and telecommunications, with emphasis on ISDN. (6/88)

- AT&T and GTE—These two major suppliers of telecommunications have agreed to merge their manufacturing and R&D efforts in a joint venture in order to unify the marketing strengths of both companies against foreign competition in the United States.

  - The agreement also ensures that AT&T will continue as the dominant supplier of switches and future ISDN technology in the U.S. market.

  - The venture agreement provides for periodic control of the enterprise.

  - The manufacturing and research activities initially will be controlled by GTE, but the new enterprise will shift to AT&T in 1994. (7/88)

- VTC and Grass Valley Group—The Grass Valley Group is a manufacturer of professional audio equipment. The two companies are involved in the joint development of two 10-bit video line drivers meeting standards established by the Society of Motion Picture and Television Engineers (SMPTE). (8/88)

- Teledyne and Omnirel—This agreement involves the joint development and marketing of CMOS smartpower devices for military markets. The joint development will team Omnirel's high-density military power packages and discrete power MOSFETs with Teledyne's CMOS ICs, MOSFET drivers, and switch-mode power supply controllers. (8/88)

- PMI and SSM—PMI acquired SSM Audio Products of Santa Clara, California, a company that manufacturers analog ICs for audio and music applications. Through the acquisition, PMI gains entry into the professional audio IC market, while SSM gains financial and manufacturing resources. (8/88)

- Silicon Systems and Hayes—This agreement involves the exchange of internal design tools to support respective core businesses. Hayes expects to speed the development of semicustom and standard silicon designs for future products, and Silicon Systems gets insight from a market leader in telecommunications regarding what systems to implement in silicon. (9/88)

- Sharp Microelectronics Technology and Hycom—Sharp acquired Hycom in the fall of 1988. Hycom, a developer of communications and modem products, display systems, and advanced application-specific LSI and VLSI computer chips, now operates as a subsidiary of Sharp Microelectronics. (9/88)

- Siliconix and Teledyne—The companies are involved in a second-source agreement for switch-mode Smartpower ICs. Teledyne gets immediate manufacturing rights to ICs, and the agreement allows for future second-sourcing of parts developed by either company. (10/88)

- Harris and Kawasaki Steel—This is a joint development agreement in which Harris will provide CMOS technology to Kawasaki in exchange for financial and marketing support to Harris.

  - Some of the first parts were to be ASICs for digital signal processing, telecommunications, and industrial control applications.

  - Over the long term, the companies are expected to act as foundries for each other. (10/88)

- Harris and GE Solid State—Harris' acquisition of GE Solid State was finalized in November. The acquisition included GE, RCA, and Intersil facilities. All of these facilities included analog product and add to Harris' overall volume in analog. (11/88)

- Motorola and Cherry Semiconductor—The companies will become partners in technology (bipolar) and act as second sources for each other's devices. This agreement covers both custom and standard circuits and calls for establishing compatible manufacturing processes. (12/88)

- AT&T Microelectronics and Intel—This is a broad technology and product-development agreement covering ISDN and LAN ICs. AT&T will gain Intel's merchant market leverage, and Intel will gain network technology from AT&T. (1/89)

- Unitrode and ADDACON—Unitrode made a 50 percent equity investment in ADDACON, a manufacturer of high-speed, board-level, and hybrid circuit data converters for military and high-end industrial markets. (1/89)

- Maxim and Supertex—This agreement relates to the joint marketing of four devices in the 690 family of MPU supervisory circuits.
  - These chips perform supervisory functions including assurance of a constant power supply and protection against hardware and software malfunction.
  - The agreement is a continuation of a joint chip agreement that goes back to the conception of Maxim.

THE ISSUES

There are some underlying currents today that are fostering analog alliances. These include the pressure on Japan to buy American, the U.S. companies' need or desire to vertically integrate, and the natural alliance of large diversified houses with niche-oriented start-ups.

Japanese/U.S. Trade

Recent concerns over the inequity of trade between the United States and Japan have brought a new emphasis to doing business in Japan. Japanese companies are feeling pressured to purchase U.S. goods and are making steps to do just this. Recently, the EIAJ hosted a session for American companies wishing to do business in Japan. The meetings stressed that Japanese markets require different products than those destined for American markets and emphasized that the criterion for success in Japan would be to design and tailor products to specific Japanese market applications. Japanese companies now are examining U.S. products seriously and increasing their purchases of U.S. goods. This fact bodes well for analog suppliers, which have a significant opportunity in this market, if they offer the right products.

One of the easiest ways to establish long-term relationships, important to doing business in Japan, is through alliances. These alliances typically bring value to both parties. U.S. companies have impressive technology in the analog area, some of which is not available in Japan. With Japanese alliances, U.S. companies gain access to the Japanese market and internal company markets or financial backing.

Vertical Integration: Equipment/Supplier Alliances

More interaction is occurring between the circuit manufacturer and the equipment supplier. Alliances are being formed to offer insights from both sides of the business—component and equipment. These alliances often concern tools for semicustom circuit development. It is evident that the semicustom approach to circuitry offers many benefits to the equipment supplier. Semicustom products offer cost reduction and quicker entry to the market, especially valuable in highly competitive markets.

Established Company/Start-Up Company Alliances

An existing pattern that continues in the market, is the alliance of the broadly focused analog supplier with the very focused niche supplier or start-up company. This type of arrangement has been very successful because it allows the two companies to share their resources. Large companies gain expertise in fast-growth niche market areas. Small companies gain credibility from the alliance with the large supplier, financial backing, and, perhaps, access to foreign markets.

DATAQUEST CONCLUSIONS

It is obvious that company alliances benefit many parties. Through alliances, technology is advanced and marketing and financial assets may be shared. It behooves companies to investigate opportunities on an ongoing basis and to consider taking advantage of the many types of alliances discussed in this newsletter.

Barbara Van

Dataquest

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Research Newsletter

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THE PRECISION MOTOR MARKET: ANALOG ICs TAKE CONTROL

SUMMARY

Motors are energy converters. They use the property of magnetic attraction or repulsion to convert electrical energy to mechanical energy. As motors are one of the most common electrical devices in everyday life, one often forgets about their presence. Because motors are quite obvious in supplying the mechanical power in items such as drills, saws, washers, dryers, garbage disposals, refrigerators, and air conditioners, one often fails to recognize their presence in electronic products. For instance, the average personal computer setup probably has more than a half-dozen motors (two for each disk drive, one cooling fan, and two or more stepper motors in the printer). The playback of any type of recorded information, analog or digital, also requires motors.

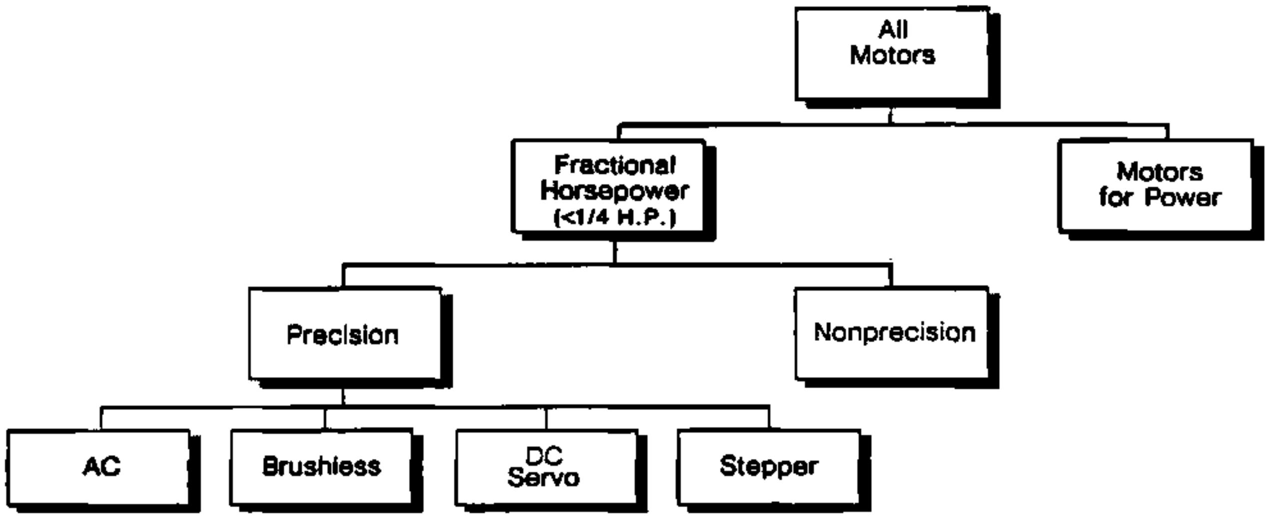
PRECISION MOTORS

The family tree shown in Figure 1 illustrates some of the main branches of motor categories in terms of power output, power source, and controllability. Although motor control runs the gamut from precision motors to massive motors (e.g., those used for controlling elevator position), the most significant market for IC motor control ICs is in the precision motor area.

Precision motors very often are found in consumer and office automation (OA) equipment. Table 1 shows some estimates, by motor type, of the consumption of electronically controlled precision motors.

Figure 1

Motor Categories



0004696-1

Source: Dataquest
May 1989

Table 1

1988 Estimated Unit Consumption of Electronically Controlled Motors

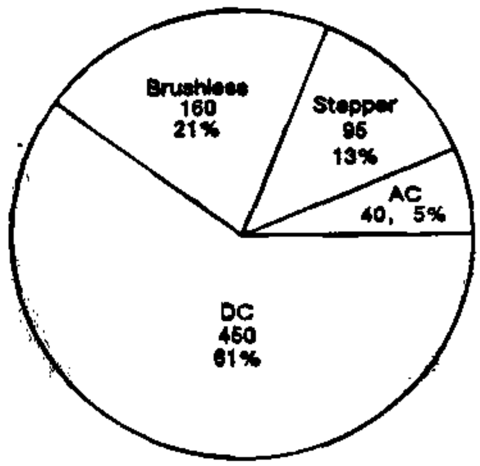
Motor Type	Number of Units (Millions)
Stepper Motors	
Printers	50
Fixed Disk Drives	9
Floppy Drives	30
Other	6
Brushless Motors	
Fixed Disk Drives	15
Floppy Drives	35
VCRs	50
Audio	25
Other	35
Servo DC Motors	
Disk Drives	11
Audio	60
VCRs	50
Other	54

Source: Dataquest
May 1989

Sales totals of "controlled" precision motors are plotted in Figure 2.

Figure 2

Precision Motor Market
(Millions of Units)



0004696-2

Source: Dataquest
May 1989

A motion that is controlled by motor design as well as the nature of the power supply and load is caused by simply connecting a motor to a power source. This imprecise electromechanical operation is acceptable for general motorized products, such as blowers and shavers, but not for precision products. Motor control devices provide a means of optimizing motor performance, precise positioning of mechanical functions (such as robot arms), precise speed control, or new control techniques that create improved types of motors (such as brushless motors). The type of motor used often is dictated by the application. Stepper motors are used for position control, brushless motors for speed control, and the DC Servomotor for either one, if the noise of the brush commutation does not affect the application.

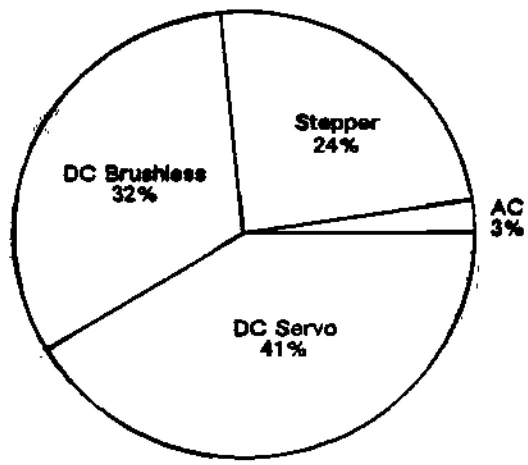
Accurate position control can be achieved by incrementing a stepper motor. Position control of a continuous-motion motor calls for complex control algorithms, such as PID (Proportional Integral Derivative), that use both position and speed information. These devices use this information to determine the motor trajectory for tighter control without positional overshoot and oscillation.

MOTOR CONTROL MARKET

The portion of the motor control market supplied by dedicated motor control ICs is estimated to be $134 million. At present, this represents about one-third of the potential market of $400 million. Control solutions implemented with discrete amplifiers, phase-locked loops (PLLs), logic, and other standard ICs supply the rest of the market. The sales of control ICs by motor category are shown in Figure 3.

Figure 3

IC Controller Sales by Motor Category

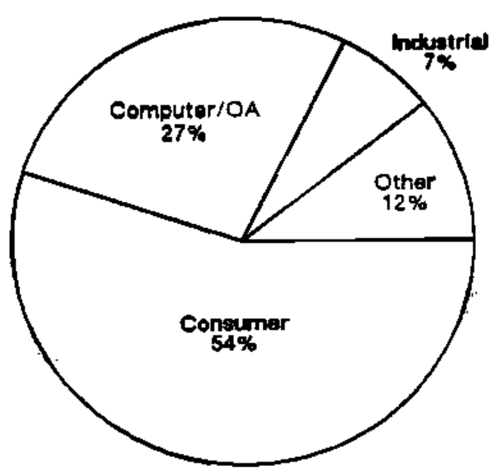


0004696-3 Source: Dataquest May 1989

The application markets for the controllers and motors are illustrated in Figure 4.

Figure 4

Estimated Controller Consumption by Market



0004696-4 Source: Dataquest May 1989

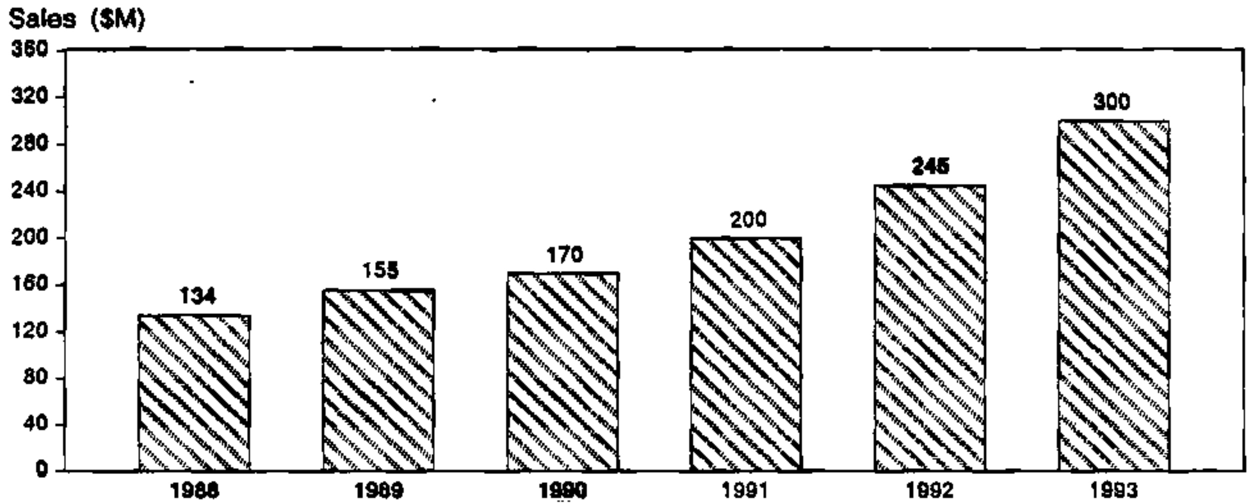
MOTOR CONTROL FORECAST

As shown in Figure 4, the motor control market is strongly linked to both the consumer market and the electronic data processing (EDP) market, and growth is strongly related to segments of these markets. Although the PC peripherals market is expected to slow somewhat over the next few years, the consumer market should continue to be strong. The new applications that motor controllers are being designed into are enhancing the growth of these markets.

Dataquest expects the motor control IC market to grow at 18 percent compound annual growth rate (CAGR) over the next five years. The forecast, shown in Figure 5, defines market growth by year over the next five years.

Figure 5

Motor Control IC Forecast
1988 to 1993



0004696-6

Source: Dataquest
May 1989

MOTOR CONTROL SUPPLIERS

Table 2 shows a listing of motor controller/driver manufacturers and their participation in the different categories of motor control ICs.

Table 2

Motor Control IC Suppliers

Company	Motor Control ICs: Brushless	H-Bridge	Servo	AC	Stepper
Cherry Semiconductor			X		
Elantec			X		
Exar			X		
GE Solid State					X
Gold Star			X		
Hitachi	X				X
International Rectifier		X			X
LSI Computer	X				
Lambda Semiconductor		X			
Mitsubishi	X	X	X		
Motorola	X		X	X	X
National Semiconductor	X	X	X		
NEC			X		X
New Japan Radio			X		
Oki Semiconductor			X		
Philips			X		X
Plessey			X		
RIFA					X
ROHM	X		X		
SGS-Thomson	X		X	X	X
Sanyo	X		X		X
Siemens			X		X
Signetics			X		X
Silicon General			X		
Silicon Systems	X				
Solitron	X				
Sprague	X	X	X		X
Texas Instrument		X			X
Toshiba	X	X	X		
Unitrode	X	X	X		X

Source: Dataquest
May 1989

REGIONAL NATURE OF MANUFACTURERS

A review of the motors, markets, and manufacturers reveals four important points, as follows:

- The two major markets are consumer and computer peripherals (both dominated by Japanese manufacturers).
- The suppliers of precision motors are largely Japanese.

- Japanese suppliers dominate in motor control IC sales.

- The manufacturers of the end equipment are highly vertically integrated.

SILICON SYSTEMS/TDK

The recent acquisition of Silicon Systems by TDK Corp. can be viewed as a means for TDK to become further integrated in the disk-drive market. TDK supplies ferrite read/write heads, ferrite magnets for motors, and other components for disk drives (as well as the media). Silicon Systems supplies read/write amplifier ICs and motor control ICs for disk drives.

DATAQUEST CONCLUSIONS

Data storage, embedded control, consumer entertainment, and home automation products all depend on the control of precision motors. Because of the strong presence in this market of vertically integrated companies, participation in the precision motor control market may be difficult unless strong alliances are made with an original equipment manufacturer (OEM) and/or motor suppliers.

A less developed motor control market is that of high-power, low-precision motors (AC Induction Motors). This type of motor speed control has very important applications in home and industrial equipment. Large savings in power can be made by varying the speed of constantly running motors, rather than duty cycle (on-off) operation of motors. High-volume air conditioning systems are one important example of where power savings of up to 50 percent can be achieved.

From a technology standpoint, Dataquest believes that mixed-mode ASIC and Smartpower ASIC technologies will emerge as the best approaches for developing market, motor, and application-specific motor controller products for the coming decade.

Gary Grandbois

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Research Newsletter

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Analog
0003809

ANALOG ICs: OPPORTUNITY KNOCKS IN THE ASIA/PACIFIC MARKET

SUMMARY

Changes in the regional consumption and manufacture of integrated circuits are part of the dynamics of the semiconductor industry. Dataquest's 1988 sales data show that one region of the world, the Asia/Pacific area, was experiencing furiously paced growth in consumption. This growth is bringing it into parity with two of the three other major consumer areas, North America and Europe. This growth in consumption is not coupled to a corresponding growth in locally produced ICs and therefore represents a major opportunity for nonindigenous foreign suppliers.

CHANGES IN CONSUMPTION

Consumption patterns for analog ICs have changed dramatically during the past few years. The two areas that have undergone fastest change, North America and the Asia/Pacific region, are shown in Figure 1. The curves show the percentage of total analog ICs and the percentage of all ICs consumed in each of these two areas. As Figure 1 shows, North America is notable in that the sales of ICs are dropping at a rapid rate. More important to analog suppliers is the fact that the North American analog IC market appears to be declining at a faster rate than the market in general. Just the opposite is occurring in the Asia/Pacific market, where analog ICs have had a compound annual growth rate (CAGR) of more than 50 percent since 1985 (see Figure 1). This analog IC growth is outstripping the general IC growth rate considerably in the Asia/Pacific marketplace. In 1988, sales of analog ICs to the Asia/Pacific market were \$1.26 billion, 17.4 percent of all monolithic analog ICs sold worldwide.

The effect of the North American decline and Asia/Pacific growth in analog consumption is that they are becoming comparably sized markets. The trend in both of the curves is toward a 20 percent portion of the total analog market by the early 1990s. Plotting the four major sales regions by year, as is done in Figure 2, illustrates that three of them are converging on this 20 percent value, whereas the Japanese market remains flat at about 40 percent of the total.

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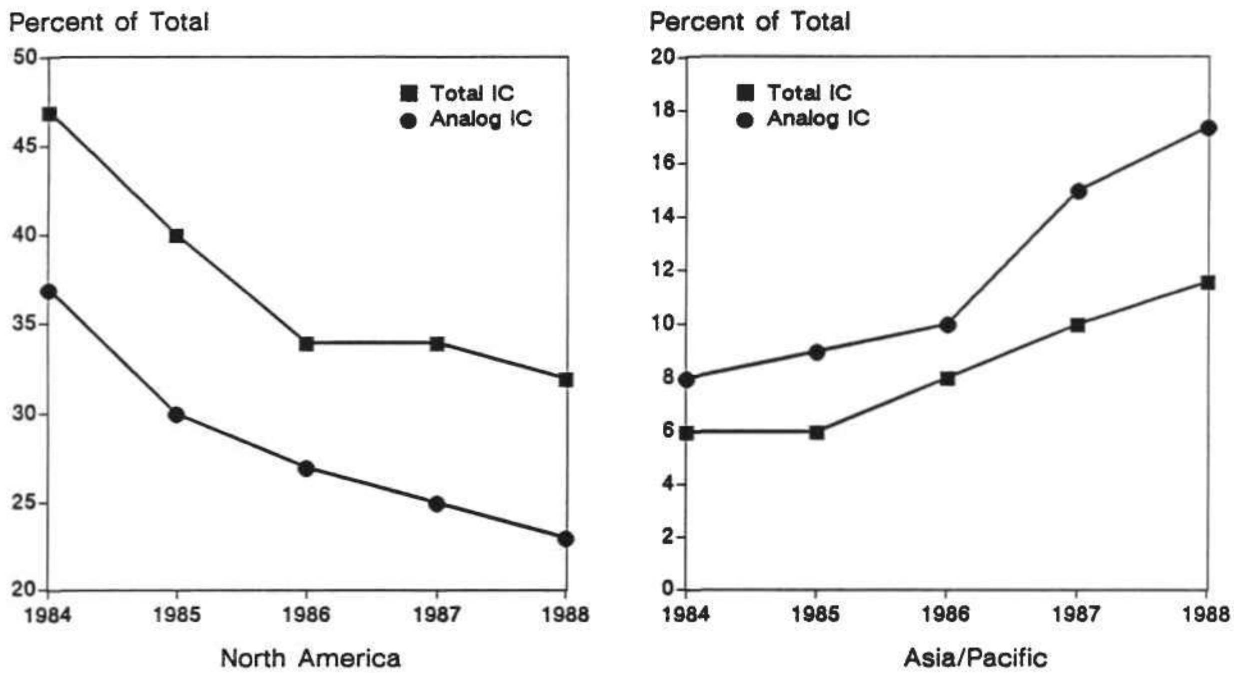
Figure 1

Regional Consumption by Year



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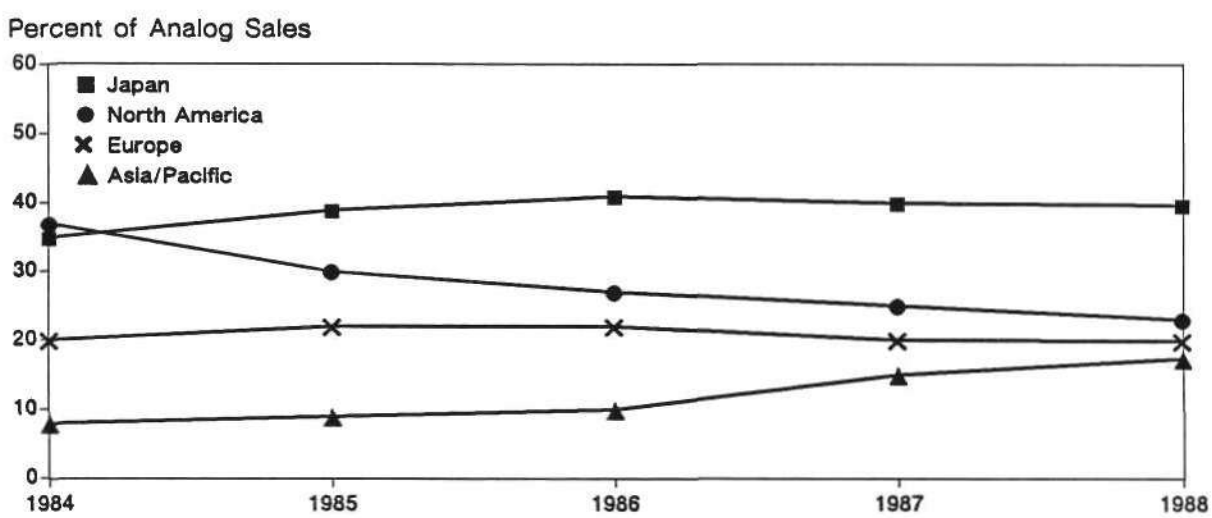
Source: Dataquest
May 1989

Figure 2

Analog IC Sales by Region



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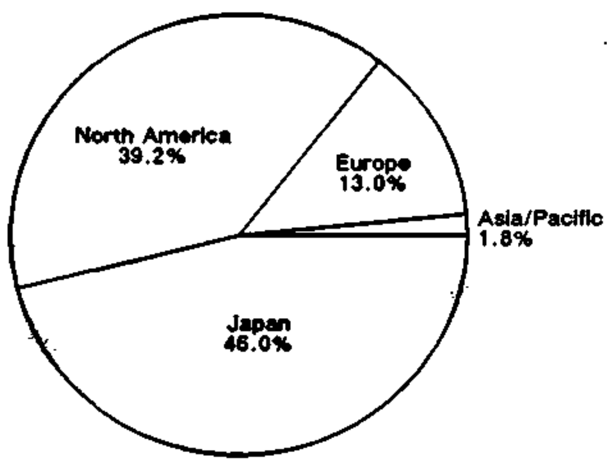
Source: Dataquest
May 1989

ASIA/PACIFIC PRODUCTION

Although the Asia/Pacific market accounted for more than 17.0 percent of analog IC sales, the region's production of analog ICs amounted to only 1.8 percent, as shown in Figure 3. An important characteristic to outside suppliers is that cultural pressure to buy locally produced products is not as formidable as in other world markets. Because the difference in the size of analog IC production and consumption in North America is widening, penetration of the Asia/Pacific market is crucial to counter the production decline that otherwise will follow the decline in consumption.

Figure 3

Analog IC Supply by Region of Origin



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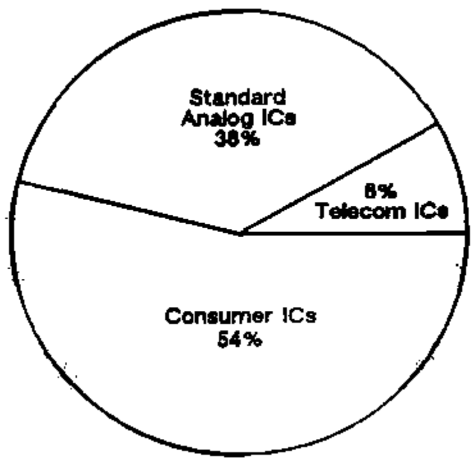
Source: Dataquest
May 1989

PRODUCTS

Figure 4 shows the Asia/Pacific market by product type. Although the market is strongly consumer-specific IC oriented, the broad spectrum of standard analog ICs is also consumed.

Figure 4

Asia/Pacific Markets by Product Type



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Source: Dataquest May 1989

DATAQUEST CONCLUSIONS/RECOMMENDATIONS

Although the Asia/Pacific market is moving into parity with those of Europe and North America, this does not necessarily mean that purchasing is done in the region. Because many nonindigenous companies have manufacturing facilities only within this region, shipments may result from sales agreements made in other market areas. Nonetheless, the rapidly changing nature of analog IC consumption requires informed decisions on where sales and support efforts should be focused. The Asia/Pacific market deserves attention.

Gary Grandbois

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Research Newsletter

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THE COLOR OF MONEY: ONE OF MANY HUES PROVIDED BY PALETTE DACs

OVERVIEW

A specialized digital-to-analog converter (DAC) that has become prominent in the graphics product market is known as the video DAC. Video DACs encompass a variety of products variously called RAM-DACs, palette DACs, and RGB DACs in addition to the more general term, video DAC. These products originated as high-speed, low-resolution DACs designed for creating images from computer-generated graphics data. As high-resolution computer graphics became more commonplace, the original hybrid triple DACs gave way to monolithic video DACs. More recently, these have been combined with RAM to create on-chip color lookup tables (CLUTs). This is the so-called color palette DAC, or RAMDAC. The introduction by IBM of the VGA graphics standard for PS/2 PCs, as well as the growth in graphics workstations, has greatly expanded interest in analog color graphics generation. As any color is created by combining the red, green and blue primary colors, analog signals are needed to modulate the intensity of the primary colors to create the wide range of hues needed for realistic graphics. Figure 1 shows a typical application of a triple DAC in a graphics application.

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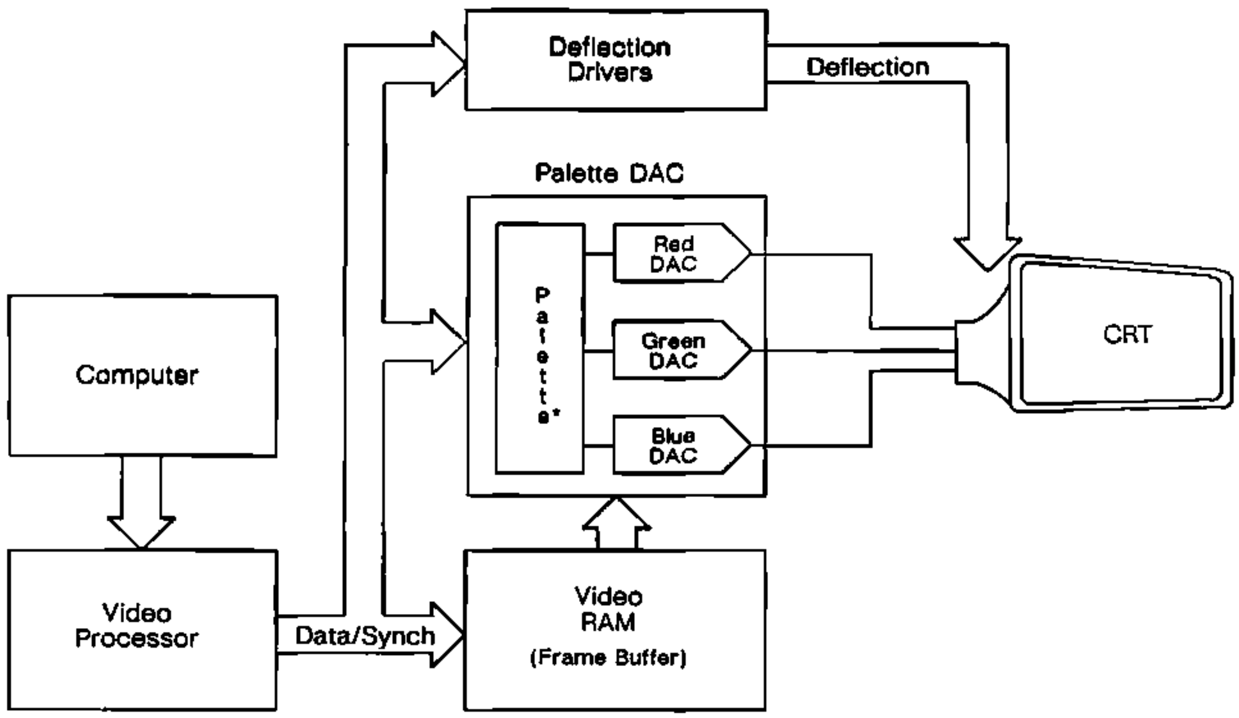
Figure 1

Palette DAC Application



*Also known as Color Look-Up Table

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Source: Dataquest June 1989

THE MARKET

The video DAC product market has exploded in the past year with rapid growth of workstation graphics products and the VGA standard in the PC arena. Video DACs have grown to a substantial portion of the monolithic DAC market, as shown in Figure 2. Presently, video DACs represent one-third of the market, and they are expected to grow to more than 41 percent of the monolithic DAC market by 1993.

Figure 3 shows unit sales breakdown by conversion speed. In 1988, the bulk of the video DACs consisted of lower-resolution applications such as VGA (640 x 480). This mix will change dramatically during the next five years, as the faster products needed for improved resolution become more available and at a lower cost. Super VGA (800 x 600) and other higher-resolution PC standards, such as IBM's 8514/A adapter and Compaq's noninterleaved graphics (both at 1,024 x 768 resolution), as well as the high-performance graphics used in workstations, will drive this resolution race. Figure 4 relates the conversion rate to the screen resolution in pixels (number of pixels per line times number of lines).

Figure 2

DAC Market by Segment

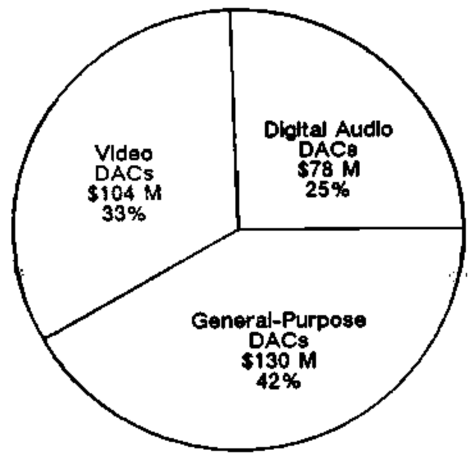

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Figure 3

1988 Video DAC Unit Sales by Conversion Rate

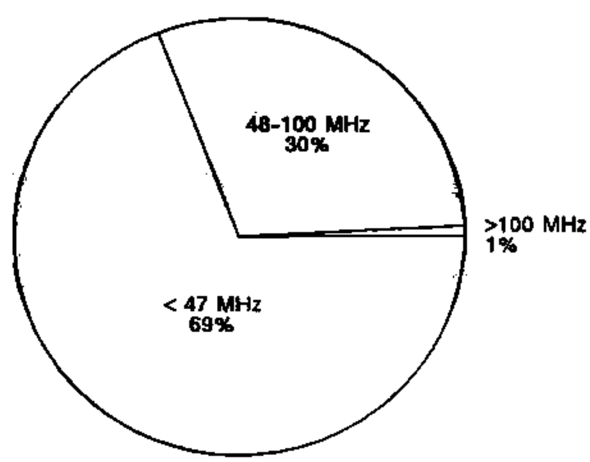

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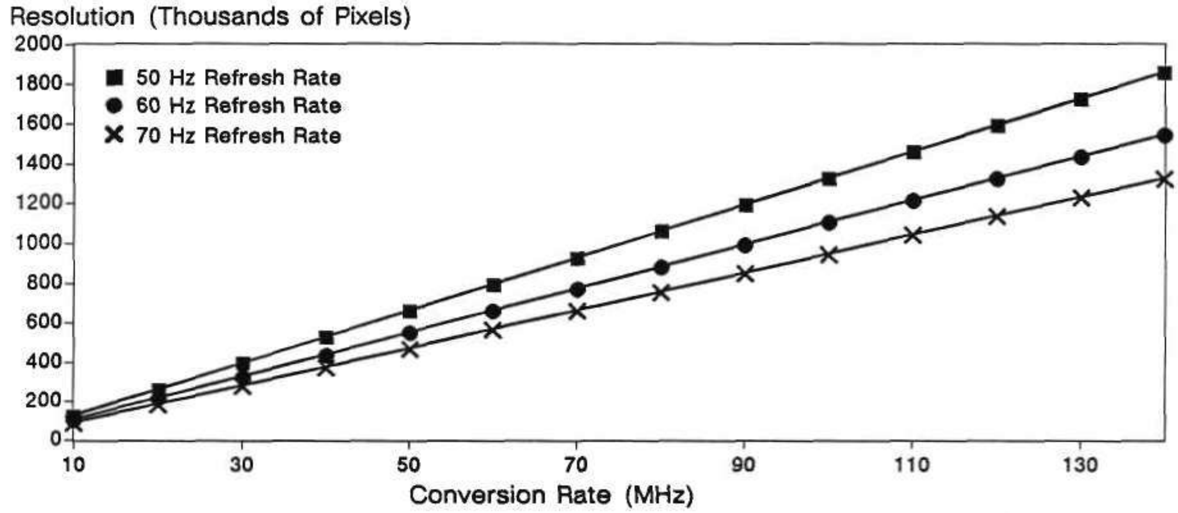
Figure 4

Video DAC Resolution versus Conversion Rate



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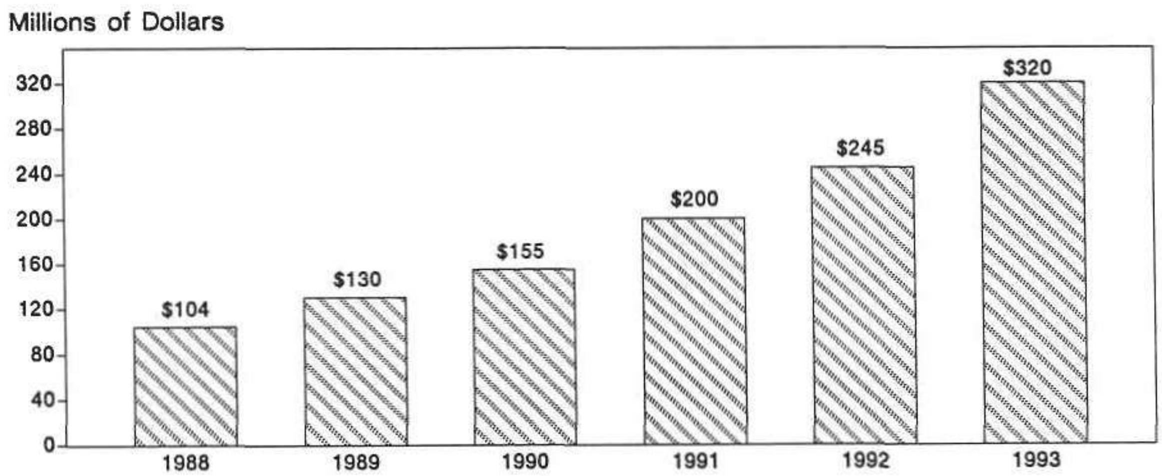
FORECAST

Growth in graphics workstations and greater graphics emphasis both in PCs and PC applications is widening the application of these products while pressing conversion speed higher. Figure 5 shows the anticipated growth in video DAC revenue from 1988 through 1993.

Although we forecast revenue to increase by a compound annual growth rate (CAGR) of 25 percent during this five-year period, we expect the number of units to grow even faster, by more than 41 percent CAGR (see Figure 6). Such growth may be a signal that significant price erosion can be expected.

Figure 5

Video DAC Revenue Forecast 1988–1993



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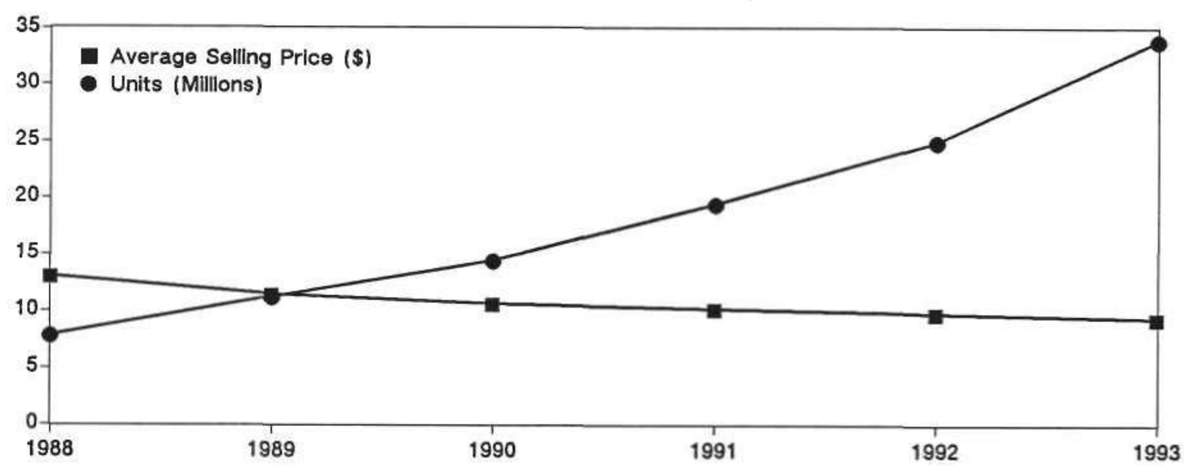
Source: Dataquest June 1989

Figure 6

Palette DAC Unit and ASP Forecast



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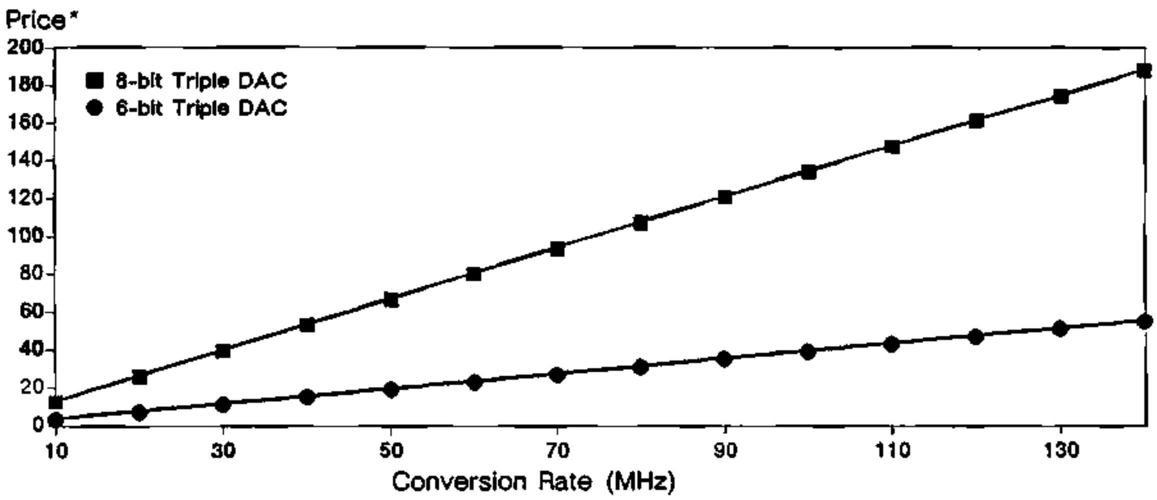
Source: Dataquest June 1989

PRICING

Video DAC pricing varies widely. Although pricing is related to the conversion rate, the product features, and the size of the lookup RAM (the palette), the conversion rate appears to be the dominant pricing factor. Figure 7 shows an approximate pricing curve for 8-bit and 6-bit triple palette DACs by conversion rate (1988 prices, 100 pieces). The 8-bit pricing curve can be described as approximating a price line of $1.35 per megahertz—at 100 pieces, large-quantity pricing is approximately one-half of this. The 6-bit palette DACs follow a similar trend line, but at approximately 40 cents per megahertz, also at 100 pieces.

Figure 7

Palette DAC Pricing versus Conversion Rate
(8-Bit Triple-Palette DAC, 100-Piece Price)
Approximate Trend Lines



*100-piece price
0004257-7

Source: Dataquest June 1989

Palette DACs have seen considerable price erosion in the first half of 1989 as new suppliers have entered the market. Price erosion will occur for all of these products, but the 8-bit triples are expected to show the most dramatic changes as 8 bits becomes the graphics standard. Dataquest believes that the 8-bit products will show more than a 50 percent price decline during the next five years. This price erosion could be accelerated if high-definition video appears in the consumer market. These changes in product resolution will effectively mask the ASP erosion that would otherwise be expected if resolutions and product mixes (PC graphics to workstation graphics) remained constant.

SUPPLIERS

Suppliers presently in the video DAC market include the following: AMD, Analog Devices, Brooktree, Cirrus Logic, Harris, IDT, Inmos, Intech, Motorola, National Semiconductor, Philips, Signal Processing Technologies, Inc., Silicon Systems, Triad Semiconductor, and VLSI Design.

SUMMARY

This product is in one of the fastest lanes of IC growth. Being involved in computer graphics, CAD/CAM, high-definition TV, medical imaging, and other leading-edge product areas makes the future for these products bright indeed. With a large number of traditional DAC suppliers and many mixed-mode ASIC suppliers entering the market, however, the outlook is for fierce competition, eroding prices, and the palette DAC product's rapid evolution. Higher conversion rates and lower glitch energies will give improved definition, while larger palettes, overlay palettes, and other interface and control enhancements will add features to the product. Vendors not willing to invest in developing high-performance, highly integrated video products will find tough going in the market.

Gary Grandbois

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Research Newsletter

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0004447

POWER ICs: NONSMART POWER STILL DOMINANT

The power IC category offers a cross-section of analog ICs with high power or voltage output capabilities from many different product segments. Power ICs include amplifiers, pulse-width modulators, peripheral drivers, display drivers, voltage regulators, and consumer-specific ICs. Although power ICs have been available for decades, the relatively recent combination of logic with power drivers, labeled "smart power" (or "intelligent power"), is seen as one of the major new opportunities for analog ICs. Few IC segments have been as difficult to define and quantify as smart power. In order to shed some light on smart power products, we must restate the power IC definition and compare smart ICs with nonsmart ICs.

POWER ICs—A DATAQUEST DEFINITION

Dataquest defines a power IC as any IC that meets both functional and electrical output criteria.

Functional Requirement

A power IC either provides a power supply function to other electrical/electronic circuits or acts as an interface driver circuit for cables, optoelectronic, electromechanical, or electrochemical devices. Essentially, a power IC provides the activation energy for any electrical function. It is not a signal-processing element that happens to handle higher-than-normal voltages.

Output Requirement

A power IC must be capable of meeting or exceeding one of the following three requirements:

- Dissipate 2 watts
- Handle 1 amp of current
- Control voltages of 100 volts or more

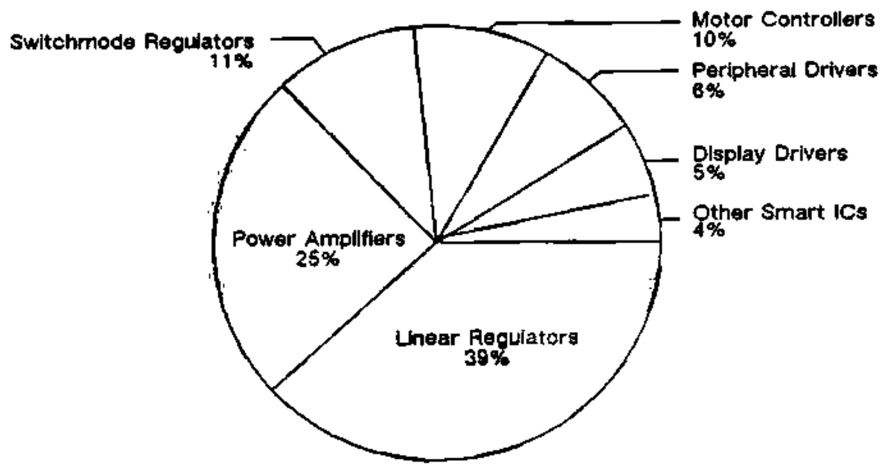
Although this definition includes most of the products promoted as power ICs in the past, it eliminates others. These include high-voltage versions of standard small-signal analog IC functions such as amplifiers, switches, multiplexers, references, and many telecommunications products.

POWER IC MARKET

Figure 1 shows the 1988 power IC market based on some of its major product types. The largest segments are the power portions of the linear voltage regulator market and the combined power amplifier segments of op amps and consumer ICs (audio power amps).

Figure 1

Power IC Market by Product Type



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Source: Dataquest July 1989

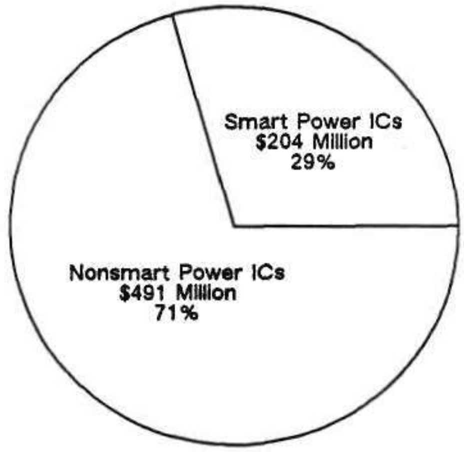
In order to conform with modern power IC segmentation, these products are considered old or new, analog or mixed analog/digital, and nonsmart or smart, based on their logic content, application specificity, and processing technology. Traditional power ICs generally are bipolar devices; are standard products that have a broad application; are inexpensive; and are largely analog in architecture. Newer smart products use a variety of MOS processes, are much more application specific, are somewhat more expensive, and incorporate digital logic. These divisions are listed as follows:

- Analog (nonsmart)
  - Linear regulators
  - Servoamplifiers
  - Audio amplifiers
  - Peripheral drivers
- Mixed (smart)
  - Switching regulators
  - Display drivers
  - Motor controllers
  - Automotive drivers

Based on the analog/mixed or smart/nonsmart partitioning, the market can be broken down into the two major segments shown in Figure 2. Note that the nonsmart segment retains a sizable portion of the market.

Figure 2

Power ICs: Smart versus Nonsmart



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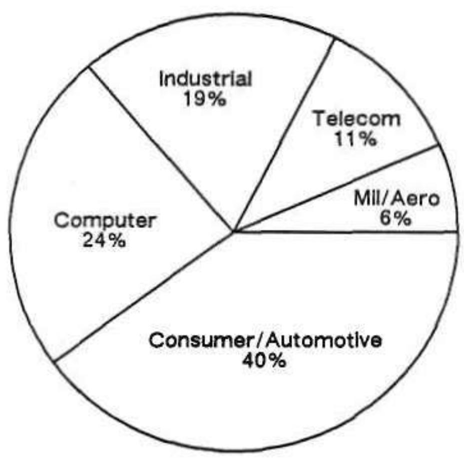
Source: Dataquest
July 1989

Power ICs, smart or nonsmart, are consumed in all electronics markets. Smart power products are targeted largely at the emerging automotive market but find applications in all markets. Figure 3 shows some of the application markets for power ICs in 1988.

Figure 3

Power IC Market by Application



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Source: Dataquest
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POWER IC SUPPLIERS

The major suppliers of power ICs are listed in Table 1. The top rankings are dominated by traditional voltage regulator and power amplifier suppliers.

Table 1

Market Shares for Power ICs
1988 Revenue

Rank	Company	Market Share (%)	Millions $
1	SGS-Thomson	22.8%	$159
2	National Semiconductor	14.8	103
3	Motorola	12.5	87
4	Texas Instruments	11.3	79
5	Matsushita	7.5	52
6	Sprague	5.6	39
7	Philips	5.4	38
8	Toshiba	4.5	31
9	NEC	2.6	18
10	Hitachi	2.4	17
11	Unitrode	2.1	15
12	Silicon General	1.6	11
13	Linear Technology	1.6	11
14	Cherry Semiconductor	1.3	9
	Other	3.7	26
	Total	100.0%	$695

Note: Columns may not add to totals shown because of rounding.

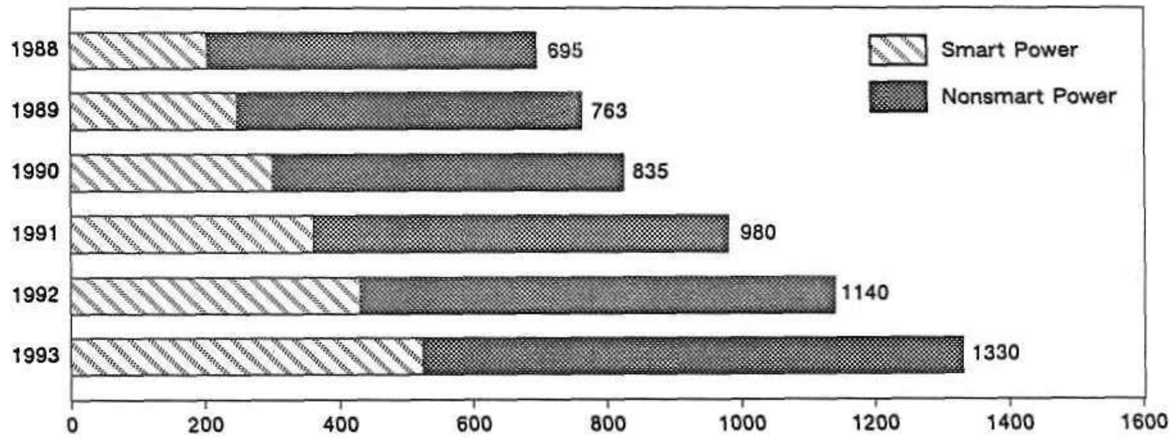
Source: Dataquest
July 1989

POWER IC FORECAST

Although power IC growth will be stunted somewhat by the expected general industry slowdown in 1989 and 1990, we anticipate both the smart and nonsmart segments to continue to grow at substantial rates. Figure 4 shows the anticipated growth in power ICs over the next five-year period. The smart power segment is forecast to show a 20.7 percent compound annual growth rate (CAGR) despite the slowdown, while the more standard products should show approximately a 10.5 percent CAGR. The combined result of these two segments is a 13.9 percent CAGR over the next five years—a growth rate that is strong compared with the lower growth anticipated for other analog segments during this period.

Figure 4

Power ICs Five-Year Forecast



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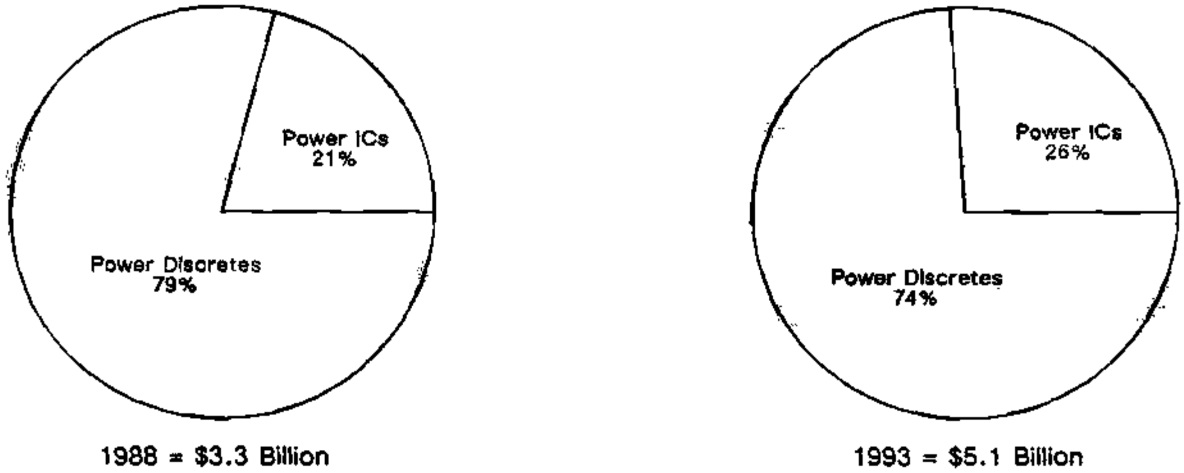
Source: Dataquest July 1989

POWER SEMICONDUCTORS—DISCRETE DEVICES VERSUS POWER ICs

The forecast growth in power ICs comes at some loss of market for discrete power devices. Figure 5 shows that the discrete power transistor market will lose 5 percent of the total power semiconductor market over the next five-year period. This is not so much a loss for discrete solutions as much as it is an emergence of new applications geared to integrated power ICs. Electroluminescent display drivers are but one example of applications that are not really addressable with discrete solutions. However, the cost, availability, and reliability advantages of combining discrete power devices with IC controllers will help the strong discrete presence continue in the market.

Figure 5

Power Semiconductor Market
Discretes versus ICs



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Source: Dataquest
July 1989

DATAQUEST CONCLUSIONS

Power ICs of all types showed strong growth in 1988, paced by switchmode power supply ICs and other smart power devices. Standard linear power regulators made impressive gains as well, showing that these devices are far from a decline. Linear regulator growth was aided by the low dropout (LDO) regulators that offered improved efficiency and lower power dissipation. LDO regulators often are used in conjunction with switching regulators to improve power supply performance.

Dataquest believes that power ICs will continue to be important to growing smart power applications in consumer, computer, automotive, and industrial products, as well as to provide regulated DC power. Smart power ICs provide more custom-oriented or application-specific products that exhibit different requirements in terms of customer relationships, process technology, product life cycle, and price. They are not yet showing the capability of displacing either discrete power devices or the more flexible and less specific nonsmart power ICs. The power semiconductor market needs all three of these alternative solutions.

Gary Grandbois

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Research Newsletter

SMART POWER DEMANDS SMART MARKETING

SUMMARY

Although smart-power ICs may not be particularly smarter than standard power ICs, they *are* different. The many processes, markets, product applications, and user needs present a potential quagmire for suppliers. A slower-than-expected market acceptance and the resulting lowered vendor expectations point out difficulties in defining and marketing smart-power products.

Although it missed the initial predictions of explosive growth, the smart-power segment of the power IC market still is substantial. This segment is estimated to be $204 million, or approximately 29 percent of the total power IC market (see companion power IC newsletter, *Power ICs: Nonsmart Power Still Dominant*, Analog, July 1989). The smart-power segment is expected to grow to $534 million by 1993, a noteworthy 20.7 percent compound annual growth rate (CAGR). Tied to this growth are a number of risk factors, which are the subject of this newsletter.

SMART POWER IS A TECHNOLOGY/METHODOLOGY

Neither fish nor fowl, smart power is neither a market nor an application; rather, it is an IC technology that combines logic circuits with high-current or high-voltage drivers. As with the power discretes they are meant to replace, the markets for smart power ICs fall into every conceivable category. These parts are more than mere arrays of discrete power transistors, however; they definitely are application-specific driver ICs. The logic behind the development of these ICs is the fact that discrete power transistors generally are combined with some IC control circuitry (logic or linear), thus creating the power control function. Integration of the power device and logic was made possible by the development of high-voltage MOS and mixed MOS technologies.

Although they share the electromechanical or electro-optical interface functions of other power ICs, smart-power devices differ from standard power devices in that they are more digital, more application specific, and more expensive. Some of the market segments that smart power addresses include: motor driver/motor control; display drivers; printhead drivers; power supplies; and automotive drivers for instrumentation, engine control, active suspensions, braking systems, and other automobile safety and convenience options.

SMART-POWER RISKS

The risks in developing and marketing smart-power ICs can be greater than for other analog ICs. Risk factors include product definition, technology, packaging, and the nature of the end markets.

Applications and Product Definition

Unlike most other IC products, many smart-power devices are used to interface to an external nonsemiconductor device (e.g., electromechanical, electro-optical, and magnetic). In this way, they are like interface ICs. The electrical and mechanical properties of the external device can determine the electrical and mechanical configuration of the smart-power IC. This is in marked contrast to almost every other semiconductor product offered, (except perhaps for sensors), and it provides a high degree of uncertainty and risk for the semiconductor manufacturer. In addition, much of the emerging smart-power market is tied into developing technologies in the information-display areas such as electroluminescent, PLZT, and plasma. Smart-power product needs can vary immensely as these

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emerging display and other physical interface technologies (such as motors) go through a shakeout period.

Life cycles for application-specific smart-power products will show the shorter life-cycles characteristic of digital products. This shorter life cycle, combined with the lower volumes inherent in most application-specific products, can make learning-curve cost reductions unlikely.

Technology

DMOS, CMOS and DMOS, BiCMOS, BCD, and other technologies are vying in the smart-power market. Which one is the best technology is arguable, as each has advantages for particular applications. The voltage, current, cost, and architecture requirements of the user applications each will drive the technology selection. Although exotic DMOS and CMOS processes can be used at the limits of drive requirements, they would not be cost competitive with standard CMOS and bipolar processes in products that were less state of the art.

Packaging

As previously stated, one aspect of smart-power IC products is that the package may be partially defined by the physical system to be interfaced. Display drivers for flat-panel displays must interconnect with what can be hundreds of thousands of pixels. High pin counts, new addressing and drive schemes, and other concerns in packaging and interconnect work against the standard product concept because each display will require a driver that corresponds to its display drive requirements, pixel demands, and addressing configurations. Smart-power ICs that embody electromechanical drivers may require a package configuration linked to the mechanical and heat-dissipation properties of the motor or module.

Markets

Many diverse applications and markets are united in that they use power or high-voltage devices. Two general market categories are important to the growth of these products. The first is the replacement market for discrete power device implementations in present applications, and the second is the market for new applications.

The power semiconductor market presently is dominated by discrete power devices rather than power ICs. Chasing cost-effective combined discrete/IC solutions with expensive smart-power IC solutions will result in limited penetration. This is because the more specific smart-power ICs each will tend to fragment the market into a myriad of smaller, more specific unit volumes, which in turn will slow advancement down the learning curve.

Smart power is more viable as a technology that is useful to new applications rather than a replacement of discrete power transistors in present applications. Only the automotive, consumer, and computer markets can provide the production volumes that can help make smart-power a cost-competitive alternative. In other emerging applications, pin counts, reliability, and space requirements may make smart power the only reasonable alternative.

Vendor/User Relationship

Although the vendor/user relationship has been more distant in the fragmented standard linear IC market, the application-specific nature of power IC products requires a closer relationship.

In new applications such as drivers for new display technologies, the display and driver IC must be developed in close conjunction. For non-captive suppliers, this requires a close working relationship with the display supplier and/or the end-equipment manufacturer. Without close ties, large potential exists for mistaken product definitions and directions. Strategic alliances are essential. Broad-line semiconductor suppliers have an edge from previously forged connections in end markets. New or specialty smart-power suppliers must align with users or with suppliers/users such as ASEA Brown-Boveri, Delco, Ford, General Electric, Sharp, Siemens, and Telefunken.

Custom, Semicustom, and Standard Products

Because of the close vendor/user relationships and the application-specific nature of smart-power products, the product evolution has moved away from standard products and into custom and semicustom smart-power products. Dataquest believes that the growth of smart power will be more in the custom or semicustom segment of the power IC market rather than from standard products. The semicustom area of power-mixed analog/digital

ASICs is a particularly attractive product for the fast product turnaround required in the automotive and consumer markets.

DATAQUEST CONCLUSIONS

The smart-power market potential is significant, but so are the pitfalls. Dataquest believes that strategic alliances with other smart-power vendors can help share the product risks associated with smart-power ICs. More important, however, are strategic alliances with key customers, a custom product orientation, and a strong technology position, which are vital for ensuring growth in the smart-power market.

Gary Grandbois

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Research Newsletter

ANALOG ICs IN THE 1990s: THE FUTURE IS MIXED

INTRODUCTION

The analog IC market has remained at a fairly consistent 20 percent of the total IC market for nearly two decades, yet analog products have been going through significant changes during this period. The pure analog signal processing ICs such as amplifiers, regulators, timers, and other mature product types are losing ground to more advanced products that feature mixtures of analog and digital circuits. Although much has been made of mixed-mode ASIC as a growth area for the next decade, this area represents only a small part of the substantial growth that will be experienced by mixed analog/digital ICs in the coming years. Irrespective of design methodology—ASIC, full-custom, or standard—the market is looking for more complex ICs that simplify design, reduce board space, increase reliability, and lower costs. Mixed signal or mixed-mode ICs provide this solution for the analog/digital interface.

Dataquest estimates that the mixed analog/digital portion of the market is growing 34 percent faster than the analog IC market in general. We expect the mixed-mode products to grow by more than 16 percent compounded over the next five-year period, a period that is expected to see a significant IC sales slowdown in 1989 and 1990. This growth is paced by the 21.4 percent compounded growth anticipated for the mixed ASIC market during the next five years.

MIXED-MODE PRODUCTS AND MARKETS

A mixed-mode or mixed-signal IC combines both analog and digital signal processing functions on the same chip. As Figure 1 shows, the $2.29 billion market for mixed-signal ICs is made up of products from many traditional segments. For this evaluation, we have excluded any mixed-signal portion of the consumer-specific IC market because of the difficulty in quantifying these product types at this time.

Forecast Growth Rates

A comparison of the anticipated compound annual growth rates (CAGRs) for the various analog product categories is given in Figure 2. It is significant that most of the fastest-growing product categories are the categories of mixed products, which are identified by an asterisk (*) on the chart. In addition to the identified mixed-mode categories, the fastest-growing subsegments of largely nonmixed products (such as the switching regulator portion of voltage regulators) also are included in the consolidated mixed-mode products.

The combination of the identified mixed-mode segments and subsegments and their individual forecasts yields the mixed IC forecast listed in Table 1 and depicted graphically in Figure 3.

Figure 3 shows the individual contributing categories to this aggregate five-year growth forecast for mixed-mode ICs.

Analog Market Segments

Partitioning the analog IC market into mixed-mode (or mixed-signal) ICs, pure analog ICs, consumer-specific ICs, and hybrid ICs shows that the mixed-mode ICs will be growing faster than the pure analog products, gaining an additional 5 percent share of the analog market in just five years. Market share will be lost by both hybrid ICs and the traditional analog signal processing ICs to the mixed monolithic ICs. Figure 4 shows the proportional growth of the mixed-mode ICs versus the three other categories. It should be noted that the consumer-specific ICs also will show a rapid

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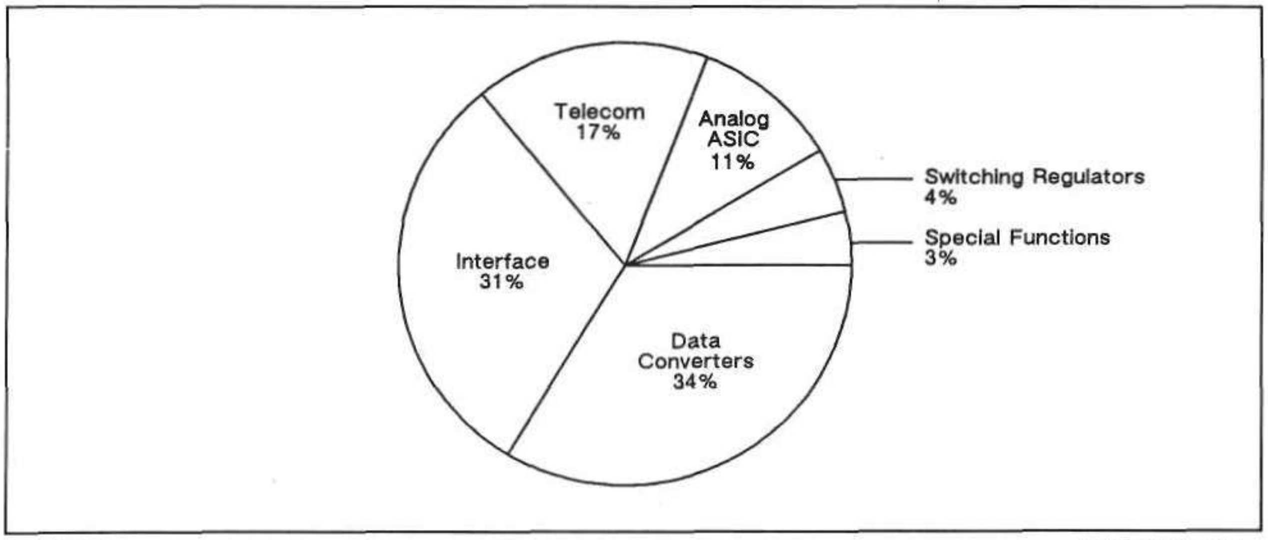
FIGURE 1
Mixed-Mode ICs by Product Category



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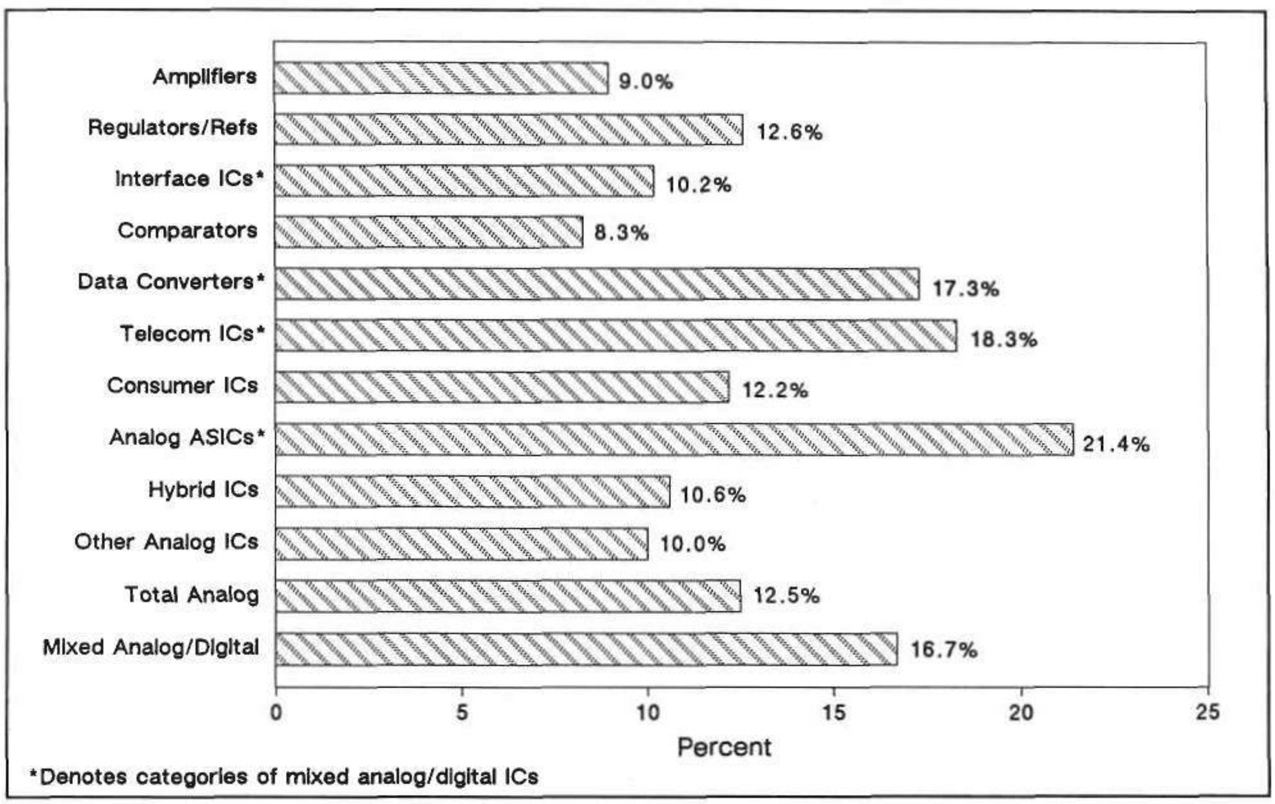
Source: Dataquest
August 1989

FIGURE 2
Forecast CAGRs by Product Category



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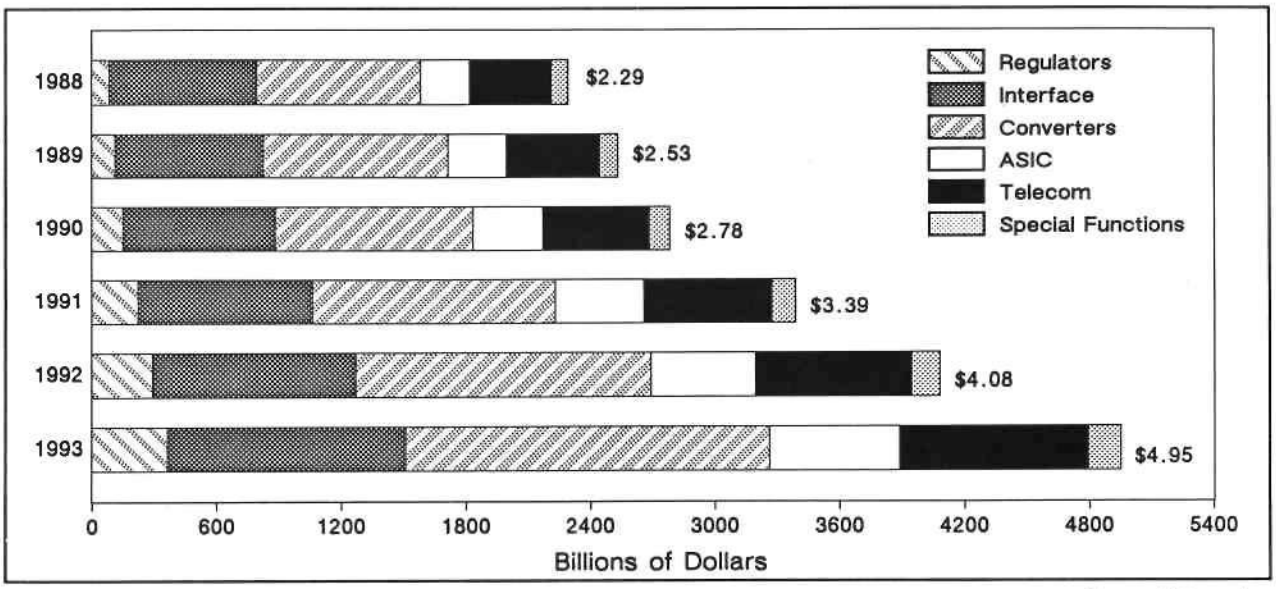
Source: Dataquest
August 1989

TABLE 1
Estimated Mixed Analog/Digital Market (1988-1993)

Segment (Billion $)	1988	1989	1990	1991	1992	1993	CAGR 1988-1993
Total Analog Sales	9.00	9.35	9.80	11.50	13.80	16.30	12.5%
Total Mixed IC Sales	2.29	2.53	2.78	3.39	4.08	4.95	16.7%
Mixed ASIC Sales	0.24	0.29	0.35	0.42	0.50	0.62	21.4%

Source: Dataquest
August 1989

FIGURE 3
Mixed-Mode IC Forecast



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Source: Dataquest
August 1989

change to mixed-mode ICs as demand increases from the entertainment (HDTV, digital audio) and automotive markets.

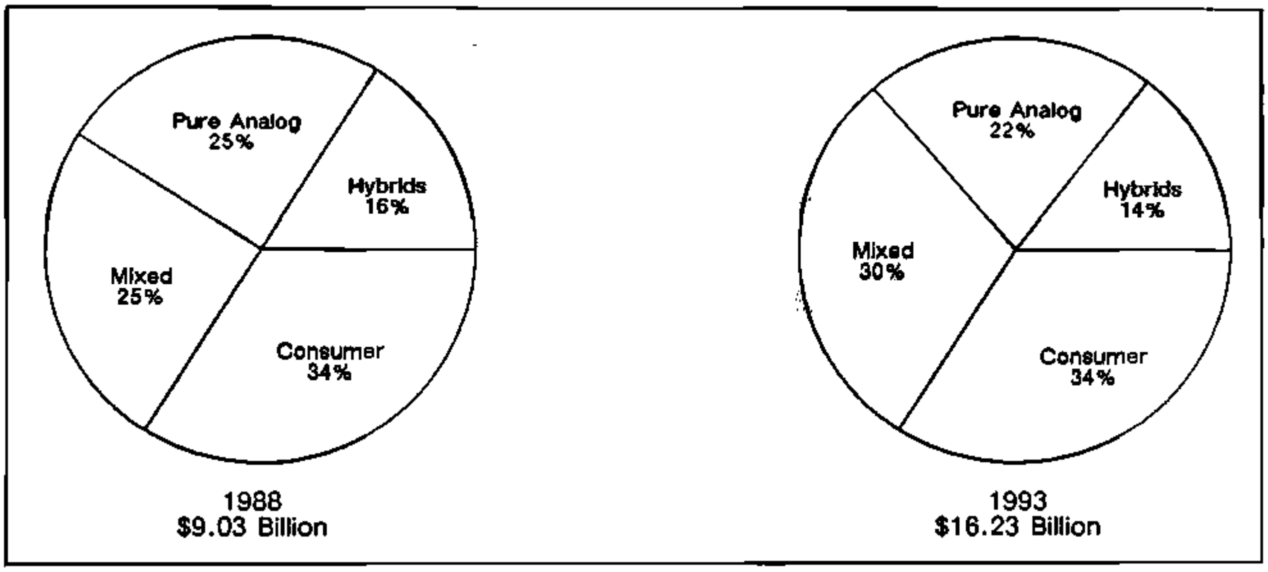
Mixed ASIC and Smart Power

The mixed-mode IC grouping contains ASIC and smart power ICs as well as standard, nonpower ICs. As Figure 5 shows, both ASIC and smart power are relatively minor portions of the mixed-signal grouping. These product types are growing faster than the standard product segments, however, and they present specialized opportunities for growth within the broad mixed-mode product grouping. Mixed ASICs have the potential to replace many of the data converter, interface, and telecom devices now offered as standard mixed-mode products.

Mixed-Mode IC Application Markets

Because the mixed-mode category is a collection of the fastest-growing segments of the analog market, it should not be surprising that these mixed-signal ICs serve the fastest-growing end-application markets. Figure 6 illustrates 1988 mixed-mode IC consumption by application markets. Note that the combination of computer, consumer, and telecom markets consumed 72 percent of the mixed-mode products in 1988.

FIGURE 4
Analog IC Forecast by Special Category



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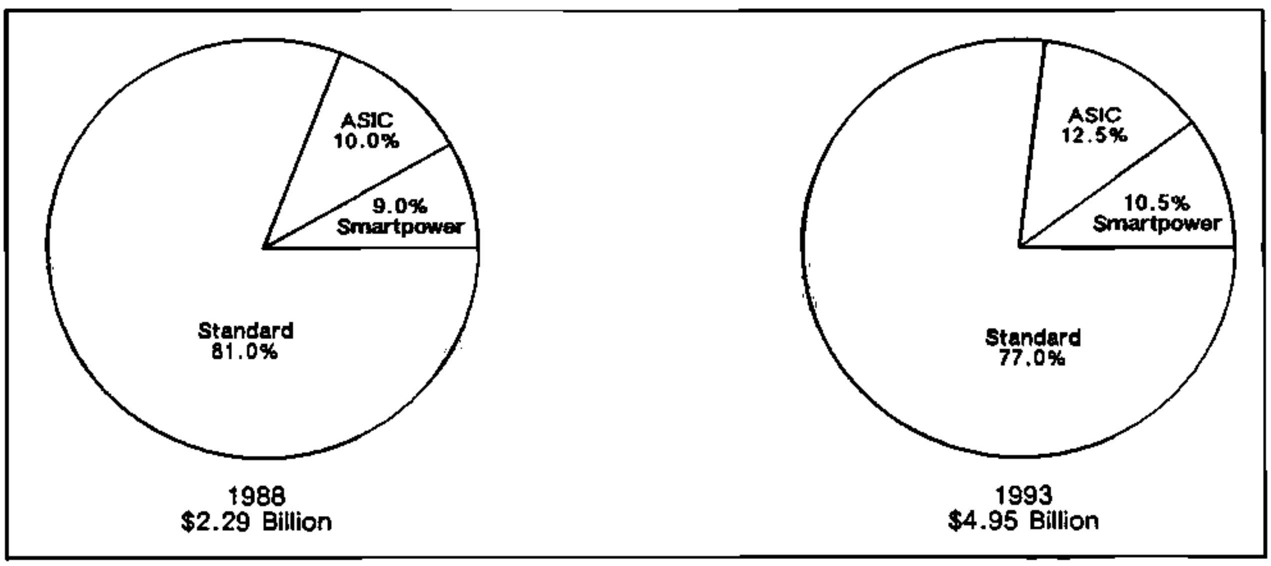
Source: Dataquest
August 1989

FIGURE 5
Mixed-Mode IC Forecast by Specialty Products



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Source: Dataquest
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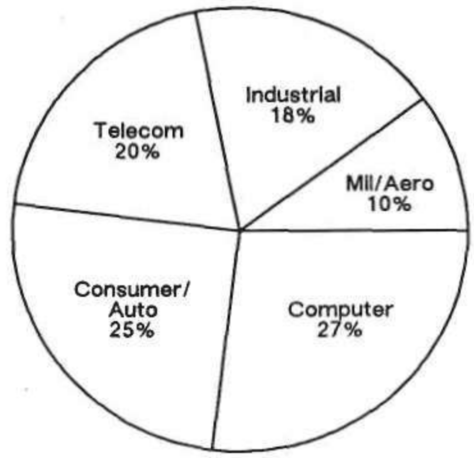
Process Technology

Mixed-mode ICs are processed with a wide variety of technologies. Bipolar still dominated in 1988, but we expect it to continue losing ground to CMOS and the various combinations of bipolar, CMOS, and DMOS that we refer to under the BiCMOS designation. BiCMOS is the preferred technology to optimize mixed analog/digital ICs. (See the Dataquest Analog Newsletter entitled, "BiCMOS: A High-Performance Complement to CMOS.") Fewer than 2 percent of analog ICs were

FIGURE 6
Mixed-Mode IC Consumption by Application Markets



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Source: Dataquest
August 1989

processed with this technology in 1988. Dataquest estimates that 7 percent of all IC revenue will come from products utilizing BiCMOS by 1993. The mixed IC forecast by technology is shown in Figure 7.

Suppliers

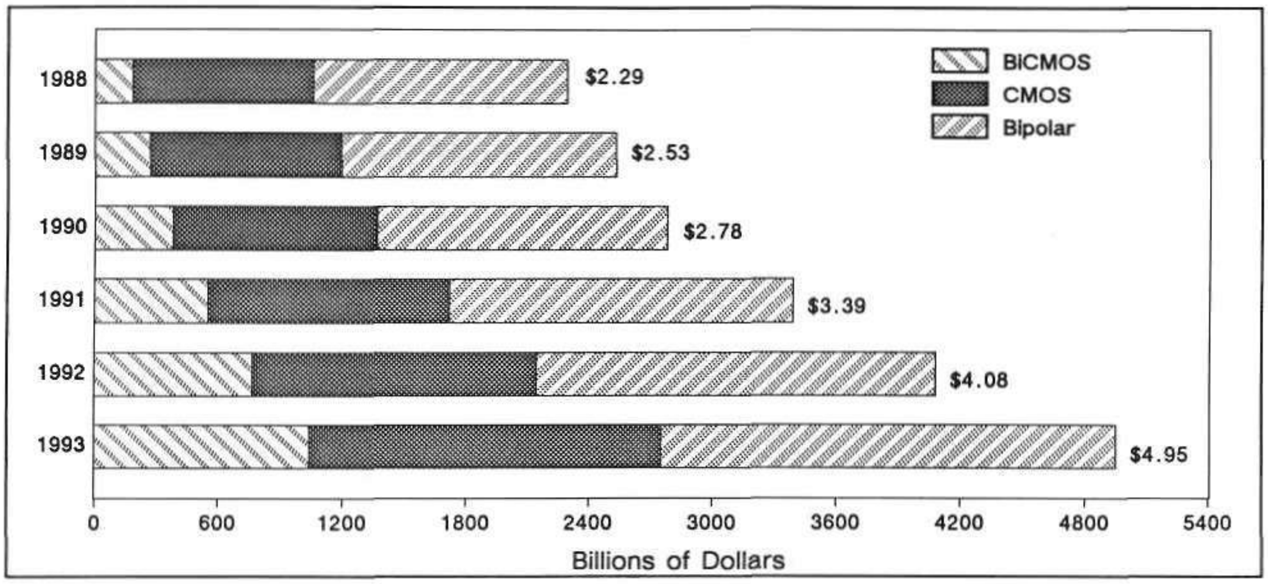
Because mixed-mode analog has long been part of the broad analog IC definition, the majority of analog IC suppliers do offer mixed-mode products. Table 2 lists these suppliers in order of market share. The consumer-specific product segment was not included in this review of mixed-mode products; therefore, the top five suppliers are U.S. manufacturers. A review of this chart shows that the mixed-mode IC market is quite fragmented, with a 3 percent market share sufficient for "top 10" status.

DATAQUEST CONCLUSIONS

Mixed analog/digital ICs are not a new phenomenon; analog suppliers have a long history of supplying mixed-signal ICs to the market. Now, however, the trend toward mixed-signal ICs is accelerating, pressed by the continued incursion of both analog and digital ICs into previously "pure" analog or digital applications and by the success of digital ASICs to integrate digital functions. Mixed-mode is not synonymous with ASIC, but mixed-mode ASIC does represent an explosive growth area for mixed-mode ICs if the standard cells, design tools, and design capability can be brought together. Whether in custom, semicustom, or standard ICs, the future of analog ICs is certainly mixed.

Gary Grandbois

FIGURE 7
Mixed-Mode IC Forecast by Process Technology



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Source: Dataquest
August 1989

TABLE 2
1988 Market Share for Mixed-Signal ICs

Rank	Company	Market Share	Millions of Dollars
1	Analog Devices	8.5%	$ 193.0
2	National Semiconductor	8.1	184.0
3	Texas Instruments	6.9	158.0
4	Motorola	5.8	133.0
5	AMD	4.0	92.0
6	SGS-Thomson	3.8	86.0
7	Ericsson	3.5	80.0
8	Philips	3.4	78.0
9	Sprague	3.3	76.0
10	Matsushita	2.7	61.6
11	Silicon Systems	2.7	61.0
12	Burr-Brown	2.3	53.4
13	Inmos	2.1	47.6
14	Brooktree	2.0	45.0
15	Fujitsu	1.9	44.0
16	GE Solid State	1.9	43.0
17	Toshiba	1.8	42.0
18	Siemens	1.8	40.3
19	NEC	1.8	40.0
20	Harris	1.7	38.2
21	Exar	1.7	37.7
22	Hitachi	1.6	36.1
23	Oki Semiconductor	1.4	31.5
24	Rohm	1.1	24.0
25	Precision Monolithics	1.0	23.8
26	Sierra	1.0	23.0
27	Plessey-Interdesign	1.0	23.0
28	NCR Microelectronics	1.0	23.0
29	Mitel	1.0	22.5
30	Sharp	1.0	22.5
31	Sony	0.9	20.0
32	Telefunken Electronics	0.9	20.0
33	Unitrode	0.9	19.7
34	Silicon General	0.9	19.5
35	International Micro Products	0.8	18.9
36	TRW	0.8	18.0
37	Mitsubishi	0.7	17.0
38	Teledyne Semiconductor	0.7	17.0
39	Maxim	0.7	17.0
40	Linear Technology	0.6	12.7
	Other	10.4	247.0
	Total	100.0%	$2,290.0

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
August 1989

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Research Newsletter

HARRIS' ACQUISITION OF GESS: THE IMPACT ON THE ANALOG MARKET

SUMMARY

The acquisition of GE Solid State (GESS) has had a significant impact on Harris' position in both the semiconductor and analog product markets. The merger boosted Harris' overall semiconductor presence; it went from being the 29th largest supplier worldwide to being the 19th and moved from 19th to 15th place among the world's analog product suppliers. Through the acquisition, Harris not only gains added credibility as a world-class supplier but adds operational balance and strength with GESS' world-based facilities and commercial business emphasis.

BACKGROUND

Harris acquired GESS for $206 million in the fall of 1988. With the acquisition, Harris changed its operations mix—from military as the number one revenue generator, to semiconductors. Harris' operations mix prior to the merger included government systems, $792.0 million; information systems, $588.0 million; communications, $383.0 million; and semiconductors, $299.2 million. The before-and-after operations scenarios are presented in Table 1.

THE SEMICONDUCTOR ORGANIZATION

Six divisions were formed to address the new company entity: military and aerospace, power products, commercial products, commercial ASIC, marketing, and manufacturing. The military and aerospace division provides standard, semicustom, and custom products for the military and government markets. The power products, commercial products, and commercial ASIC divisions manufacture power and integrated smart-power devices, general-purpose standard products for the signal-processing and control market, and commercial semicustom and application-specific standard products, including circuit development, for the automotive and telecommunications markets.

TABLE 1
Harris' 1988 Applications Focus—Before and After the Acquisition (Fiscal Year Ending June 20, 1988)

Business/Application Sector	Harris	GESS	Harris/GESS
Communications	$ 383.1	N/A	$ 383.1
Information Systems*	587.8	N/A	587.8
Government Systems	792.5	N/A	792.5
Semiconductors	299.2	$550.0	849.2
Total	$2,062.6	$550.0	$2,612.6

N/A = Not Applicable
*Includes Lanier Division

Source: Harris 1988 Annual Report

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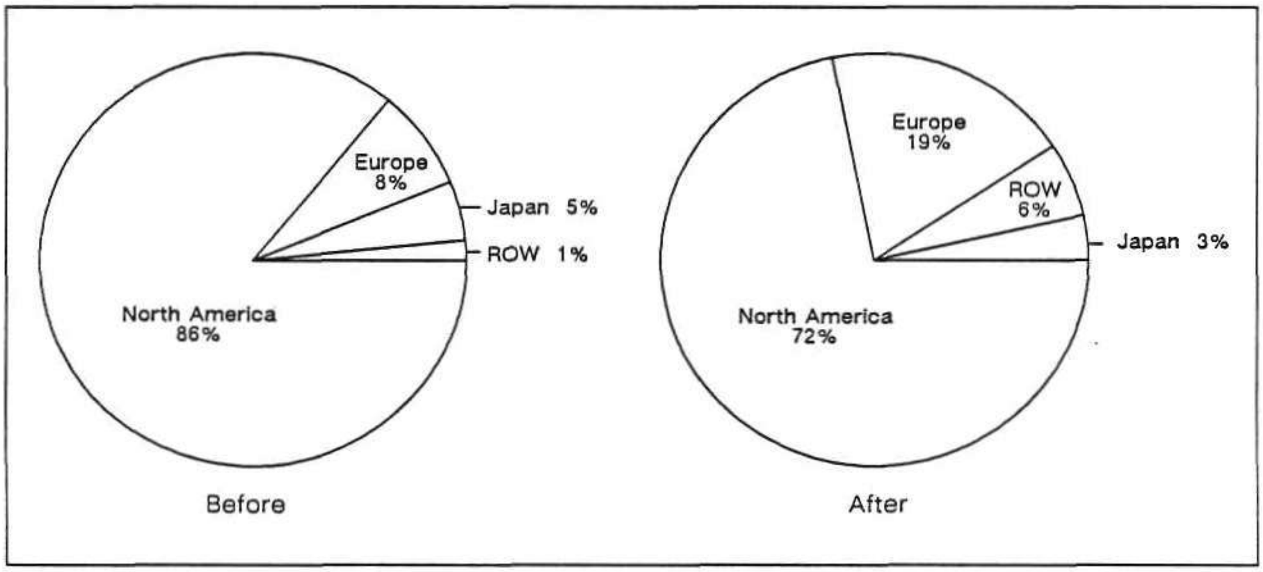
The management center for power, digital ICs, and ASICs is located in Somerville, New Jersey; integrated power is headquartered in Research Triangle Park, North Carolina; and signal processing/analog, military products, and the marketing and manufacturing divisions all are located in Melbourne, Florida.

REGIONAL MARKET IMPACT

The international flavor of the company also changed with the addition of GESS. Sales of semiconductors and analog ICs to European and Asian markets strengthened considerably, as noted in Figures 1 and 2.

FIGURE 1
Harris' 1988 Semiconductor Regional Sales–Before and After the Acquisition



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Source: Dataquest
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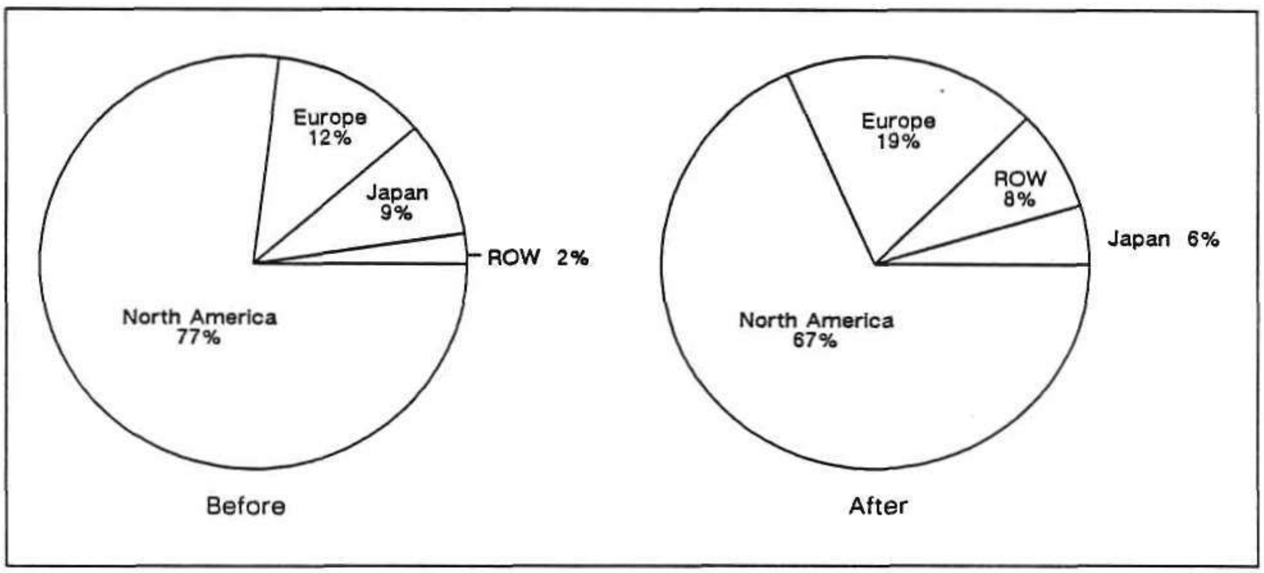
FIGURE 2
Harris' 1988 Analog IC Regional Sales–Before and After the Acquisition



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Source: Dataquest
September 1989

TABLE 2
Harris/GESS—1988 Analog Market Repositioning (Millions of Dollars; Position Rank)

Product Segment	Harris	Rank	Harris/GESS	Rank
Amplifiers	$ 48	7	$ 76	4
Regulators/References	2	33	8	15
Comparators	0	19	6	7
Interface ICs	3	25	15	12
Data Converters	48	4	78	2
Other Analog ICs	21	11	28	8
Telecom ICs	13	15	19	11
Consumer ICs	1	29	20	21
Hybrids	0	-	0	-
Total Analog ICs	$138	19	$250	15

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
September 1989

ANALOG MARKET IMPACT

Focusing more specifically on the product segments of analog, Dataquest notes upward positioning in certain markets. The most notable changes are to data converters and amplifiers. As shown in Table 2, Harris/GESS moved from fourth to second place in data converters and from seventh to fourth place in amplifiers. Positive rank changes are seen across the board in all product areas.

DATAQUEST CONCLUSIONS

The unification of the companies was from the first a challenge, considering the very different entities of Harris, GE, RCA, and Intersil. Yet the successful union undoubtedly can create a much stronger company that banks on the strengths of both companies, Harris' military expertise, and GE/RCA's commercial strength. The diversification of operations can offer strength by balancing the two application markets and opening up new opportunities.

Barbara Van

Dataquest
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Research Newsletter

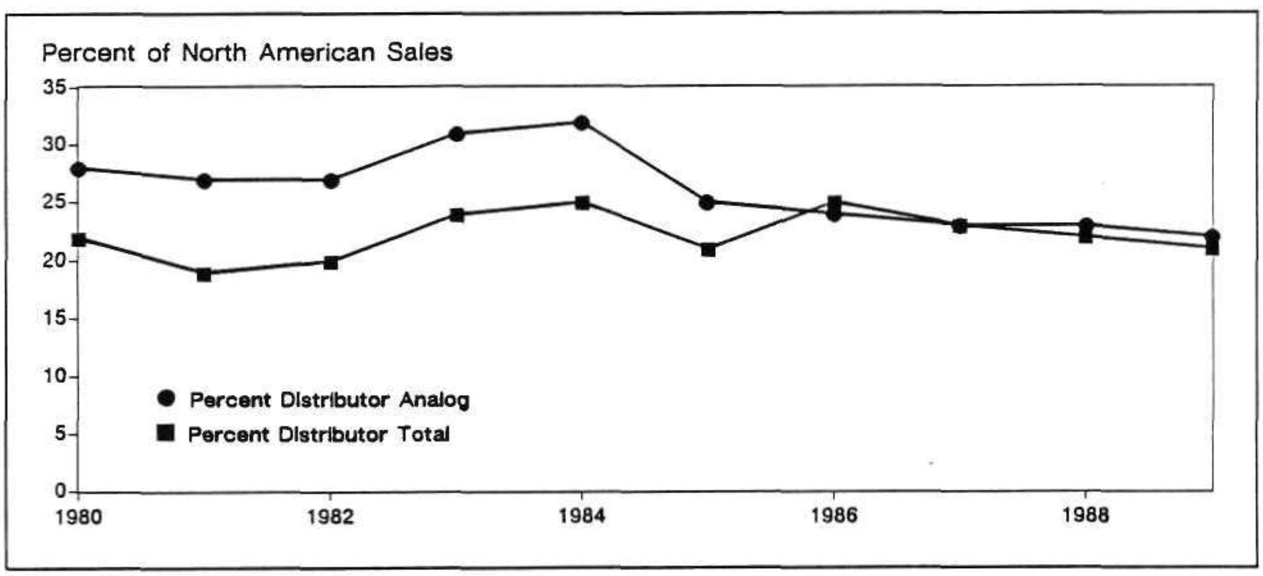
DISTRIBUTORS AND COMMODITY LINEAR: THE BASTIONS ARE CRUMBLING

Distributors have long provided a significant channel for analog IC sales. Traditionally, the rule of thumb for many analog suppliers has been that the distributor channel should account for approximately 27 percent of total North American sales. Higher percentages were expected for companies highly involved in commodity linear ICs (e.g., National Semiconductor) and lower percentages for suppliers of high-performance specialty products (e.g., Analog Devices). The pattern of the last five years shows that the distributors' percentage of analog IC sales in North America has declined about 5 percent, as shown in Figure 1.

Although the North American share of the analog market has declined significantly in the past decade, analog IC consumption in this region grew 41 percent between 1985 and 1988. A notable problem, however, is that the growth of analog revenue through distribution grew only 31 percent during the same period. This lagging sales growth has reduced the percentage of analog sales through distributors to 22 percent, bringing analog in line with the percentage of all ICs sold through distribution to the North American market.

One school of thought views this decline in the analog distributor/OEM ratio as a distortion

FIGURE 1
Analog Distribution versus Total Distribution, 1980-1989



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Source: WSTS
Dataquest
September 1989

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brought about by Japanese suppliers reporting all North American sales as OEM sales. The problem with this argument is that this reporting anomaly, if true, should distort the total IC ratio as much as that of analog ICs. That this does not appear to be the case is shown in Figure 1, where it can be seen that the total North American distributor IC sales average about 22 percent during the last decade and have shown little change after 1984 (the year Japanese reporting to World Semiconductor Trade Statistics (WSTS) started).

COMMODITY LINEARS FUEL THE DECLINE

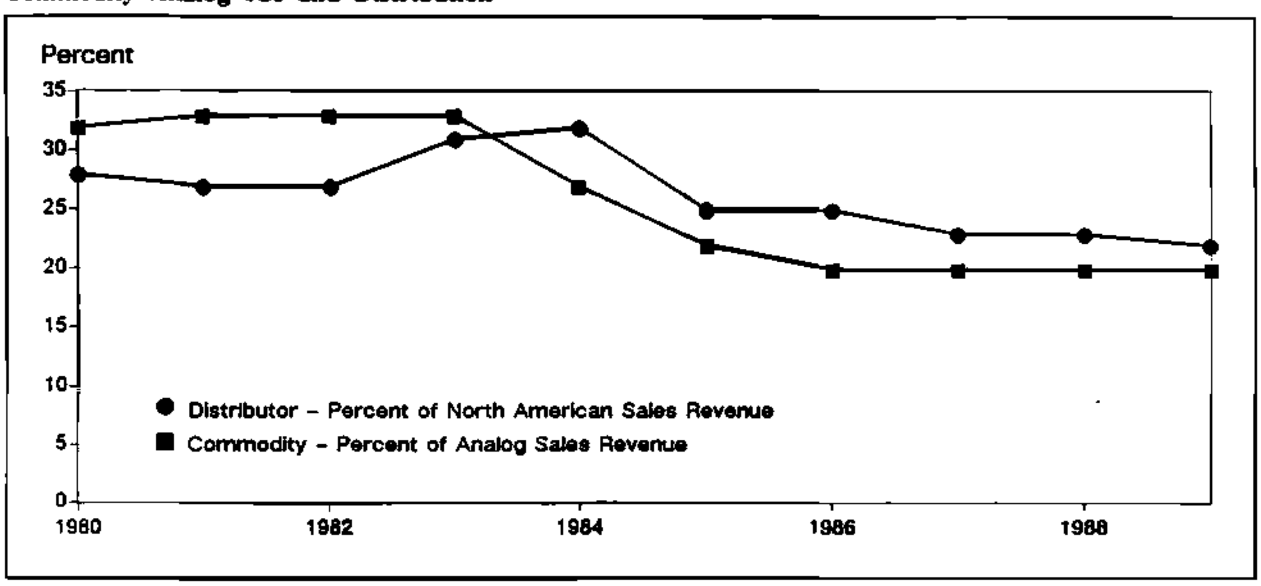
One of the mainstays of the analog market is the commodity linear IC. This product is a standard, simple linear building block such as an amplifier, timer, comparator, or voltage regulator, commonly sold through distributors. Because commodity linear products and distributors have been strongly intertwined, the decline in distributors' importance in the North American market can be attributed to the decline in the sales growth of commodity linear ICs.

The main factors in this decline are as follows:

- Rapidly eroding average selling prices (ASPs) in commodity linear ICs
- Decline in the growth of commodity linear IC units
- Decline in the U.S. share of the linear market
- The emergence of specialty, application-specific products including custom, semicustom, and mixed-mode products
- Higher levels of integration, which incorporate the standard linear blocks, thereby decreasing the market for commodity linear functions
- Digital signal processing decreasing the use of linear signal processing products
- Closer supplier-customer relationship needed for effective application of application-specific products

Figure 2 shows the changing mix of analog as the combined sales revenue of the two major categories of commodity linears, amplifiers and regulators, are plotted along with the change in the percentage of distribution revenue. Although the

FIGURE 2
Commodity Analog ICs and Distribution



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Source: WSTS
Dataquest
September 1989

WSTS data prior to 1984 may be suspect (due to the need to estimate Japanese sales), the trend since 1984 is quite definite. Together, commodity linear ICs and distribution are declining in importance in the analog IC sales mix.

DATAQUEST CONCLUSIONS AND RECOMMENDATIONS

The role provided by distributors will continue to be important to analog IC suppliers and users. Nonetheless, it should be realized that the weakening of distributor sales to 22 percent of total North American analog sales is not a temporary phenomenon, but a significant readjustment to the changing nature of analog ICs and their consumption. Sales channels and strategies for analog ICs are not independent of the changing nature of the product, application, or purchaser. As commodity linear ICs decline in importance, the analog IC market more closely resembles the broad IC marketplace.

Gary Grandbois

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Research Newsletter

OEM MONTHLY–SEPTEMBER 1989 COLOR MONITORS DISPLAY SALES GROWTH AND DESIGN INNOVATION

OEM Monthly provides insight into application markets so that clients can make better strategic and technical marketing decisions.

MONITOR SHIPMENTS

Rapidly growing sales of color monitors have caught the attention of semiconductor suppliers, and some of these companies are ending up with a big piece of the action. The results are application-specific standard products (ASSPs) that improve performance and reduce costs.

Dataquest's worldwide forecast of color monitors is presented in Table 1. Low- and high-resolution monitors have five-year compound annual growth rates (CAGRs) of 10 and 65 percent, respectively.

Monochrome displays are losing market share. We estimate that 58 percent of the PCs and workstations sold in 1988 had color monitors, and that this ratio will increase to 65 percent by 1993.

TABLE 1
Forecast of Worldwide Color Monitor Shipments (Millions of Units)

Year	Low Resolution	High Resolution
1988	11.2	0.19
1989	12.7	0.41
1990	13.2	0.93
1991	14.6	1.91
1992	15.2	3.50
1993	16.6	4.80

Source: Dataquest
September 1989

MONITOR INNOVATIONS

A color system includes a monitor connected to a PC or workstation (see Figure 1).

The video DAC in the PC/workstation changes the information to be displayed from digital data to red, green, and blue (RGB) analog signals. After amplification by the video circuits in the monitor, these signals appear on the cathode-ray tube (CRT) as either text or graphics.

High-resolution displays present greater challenges to engineers because wideband analog circuits are more difficult to design and build. Low- and high-resolution graphics require monitor bandwidths in the 5- to 50- and 50- to 200-MHz ranges, respectively (see Table 2 for a listing of screen and bandwidth requirements).

Integrated Wideband Analog Circuits

Until recently, the video amplifiers in high-resolution color monitors have been built with discretes. (The 1-volt signals from the video DAC must be boosted to 60 volts for the CRT.) Today, companies such as National Semiconductor and TRW/Motorola have introduced monolithic and hybrid amplifier circuits designed specifically for use in these monitors.

A major benefit of this integration is a 50 percent reduction in the number of adjustments needed to align the RGB channels in the monitor. Another benefit is the need for fewer parts, which also reduces assembly time and cost.

DATAQUEST CONCLUSIONS

There is still room for further innovations in color monitors. For example, the monitor channels

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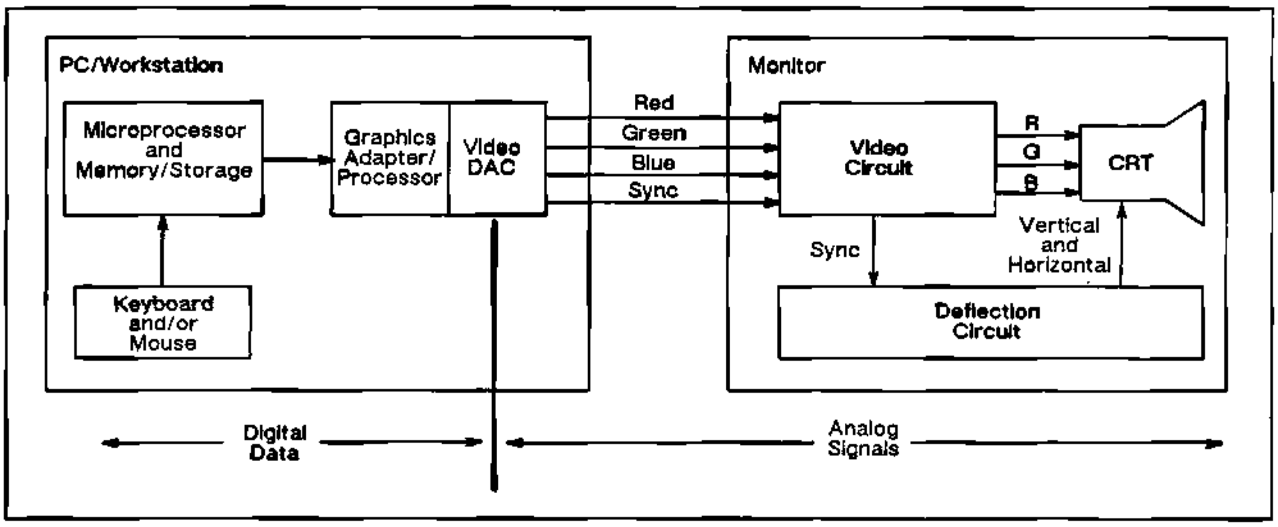
FIGURE 1
Block Diagram of a Color Display System



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Source: Dataquest
September 1989

TABLE 2
Graphics Display Requirements for Color Monitors

Segment	Standard	Screen	Bandwidth (MHz)
Low-Resolution Graphics	CGA	640 x 200	10
	EGA	640 x 350	20
	VGA	640 x 480	25
	VESA	800 x 600	35
High-Resolution Graphics	8514/A, TIGA	1,024 x 768	60
	Workstation	1,152 x 900	80
	Workstation	1,280 x 1,024	100
	Workstation	1,664 x 1,248	160

Source: Dataquest
September 1989

still must be aligned so that the correct colors will appear on the screen. These adjustments now are done manually and take approximately five minutes to complete.

This adjustment time could be reduced to less than five seconds using electronic methods. Digitally controlled monitor circuits, for example, could be aligned initially at the factory. The settings might then be updated regularly by a microcontroller in the monitor to compensate for the wear that causes the display to look fuzzy (e.g., CRT aging).

The result would be a high-resolution display that always looks sharp. Dataquest believes that these "smart monitors" are being developed now for market introduction by 1991.

Dataquest realizes that only a few semiconductor companies will have the high-frequency transistor and hybrid component capabilities needed to develop integrated monitor circuits. We featured color monitors in this issue of *OEM Monthly* to illustrate how entrepreneurial thinking can lead to the discovery of hidden needs and create proprietary solutions.

Gary Grandbois
Roger Steciak

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Research Bulletin

THE TOP 30 ANALOG IC SUPPLIERS 1988: THE WORLD MARKET SYNOPSIS

SUMMARY

The top 30 analog IC suppliers account for 86.5 percent of the total worldwide analog IC market and also comprise the majority of Dataquest's product categories. Within the ranks of the top 30, we see the supplier stars in our product categories of amplifiers, regulators, data converters, interface ICs, other analog ICs, telecom ICs, consumer ICs, and hybrids. This bulletin highlights the characteristics of some of these analog stars and their positioning in the various markets.

OVERVIEW

National Semiconductor plays a dominant role in the world supply of analog products. Although it is not the largest supplier of analog products (including hybrids), it is the largest supplier of monolithic analog circuits and a leader in five out of eight product segments identified in Table 1. Texas Instruments and Motorola also are very strong U.S. suppliers that hold leadership positions in various product segments (see Table 1).

TABLE 1
Top 5 Worldwide Suppliers by Select Analog Product Category

Rank	Amplifiers	Regulators	Interface	Data Converters
1	National	National	TI	Analog Devices
2	NEC	Motorola	National	Burr-Brown
3	TI	Matsushita	Motorola	Siliconix
4	Mitsubishi	SGS-Thomson	SGS-Thomson	Harris
5	Analog Devices	TI	Matsushita	Inmos

Rank	Other Analog	Telecom	Consumer	Hybrids
1	Hitachi	SGS-Thomson	Toshiba	Sanken
2	Silicon Syst.	AMD	Sony	Sanyo
3	Sprague	Ericsson*	Philips	NEC
4	National	National	Sanyo	Rohm
5	TI	Motorola	Matsushita	Hitachi

*Ericsson is primarily a captive manufacturer.

Source: Dataquest
October 1989

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TABLE 2
Top 30 Worldwide Analog IC Suppliers by Revenue (Millions of Dollars)

Rank	Company	Revenue
1	Toshiba	$ 569.0
2	National	540.0
3	Sanyo	471.0
4	NEC	469.0
5	Philips	456.0
6	Motorola	425.0
7	Matsushita	423.1
8	Texas Instruments	422.0
9	Sony	420.0
10	Hitachi	415.0
11	Mitsubishi	400.0
12	SGS-Thomson	352.0
13	Analog Devices	340.0
14	Rohm	271.0
15	Fujitsu	180.0
16	Siemens	165.0
17	Sanken	157.0
18	Burr-Brown	143.8
19	Harris	137.7
20	New Japan Radio	119.0
21	GE Solid State	114.0
22	Silicon Systems	112.0
23	Sprague	111.0
24	AMD	107.0
25	Ericsson	100.0
26	Sharp	95.2
27	PMI	86.2
28	Telefunken Electronic	82.0
29	Linear Technology	66.5
30	Siliconix	63.0
	Total Top 30	$7,812.5
	Percentage of Total	86.5%
	Total Analog Market	$9,034.0

Source: Dataquest
October 1989

Among the Japanese companies, prominent analog positions are held by Hitachi, Matsushita, NEC, and Toshiba. Although Japanese companies normally are associated with consumer ICs, they also compete effectively in the product areas of amplifiers, regulators, and interface. European companies are well represented by SGS-Thomson—a leader in telecom, regulators, and interface—and Philips—a strong contender in the consumer IC market.

The data converter, other analog IC, telecom, and consumer product segments show a very different mix of suppliers from those that are active in supplying building block parts. Specialization has occurred in these product areas. And, interestingly, these product areas are mostly dominated by one particular regional market. For instance, data converters and other analog ICs are dominated by U.S. suppliers, telecom ICs are dominated by U.S. and European suppliers (see Table 1), and consumer ICs are dominated by Japanese suppliers.

Table 2 lists the top 30 suppliers across all analog product categories, arranged in rank order by cumulative analog revenue.

Barbara Van

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Research Newsletter

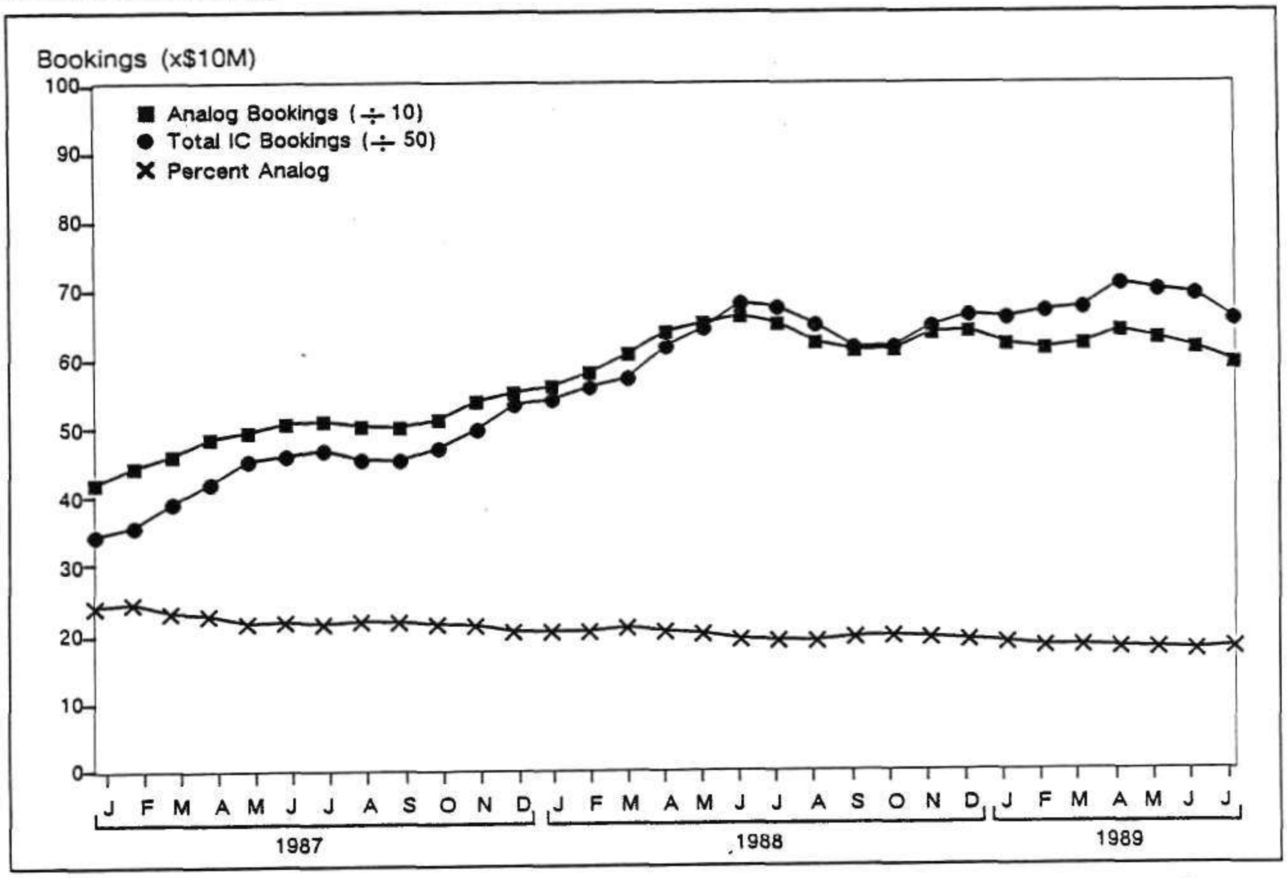
ANALOG ICS: DECLINING ASPs LEAD "SLOWDOWN"

SUMMARY

The summer of 1988 marked the start of a no-growth period for the analog IC market that has persisted during the past year. Although unit shipments stalled in late 1988, they returned to a growth mode during the first half of 1989, while average selling prices (ASPs) eroded rapidly in most analog IC categories, especially in the traditional or "commodity" linear ICs.

Figure 1 shows the three-month rolling average for bookings during the past two and a half

FIGURE 1
Analog and Total Bookings 1987-1989
(Three-Month Average)



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Source: WSTS
Dataquest
October 1989

SIS Newsletters 1989 Analog

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years. This figure shows the analog IC and total bookings divided by 10 and 50, respectively, to place them in close conjunction on the graph. Note that by mid-1988, analog IC bookings were flattening out; they then remained essentially flat during the past year. This contrasts somewhat with total IC bookings, which showed some growth during this same period.

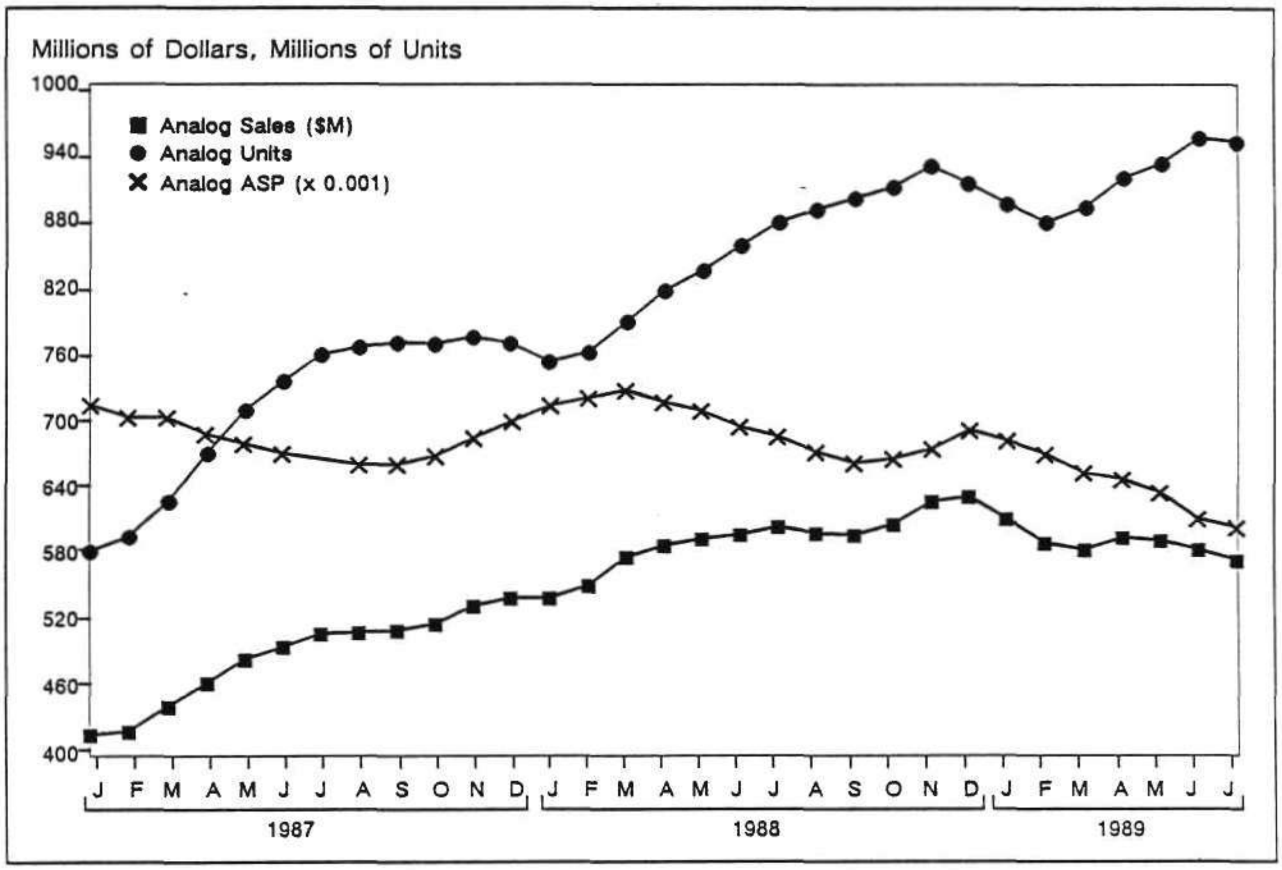
LEADING INDICATOR

In previous newsletters, Dataquest showed that analog IC sales stayed consistently in the 20 percent range of total IC sales during the past 18 years. There is nothing magic about 20 percent. It is merely an arbitrary number that is close to the mean of the analog percentage variations over time. Because of this fact, the crossing of the 20 percent boundary generally has indicated that a change in market conditions, usually a growth or slowdown period, is occurring. The year 1988 was no exception to this observation. Note in Figure 1 that analog IC bookings went flat, coinciding with the crossing of the 20 percent boundary.

AVERAGE SELLING PRICES (ASPs)

In terms of units, analog IC shipments are continuing at a strong rate after some weakness in late 1988. Figure 2 shows the three-month rolling averages for units, revenue, and ASPs during a two-and-a-half-year period that started in 1987. Although the recent slowdown in revenue originated in a downturn in unit shipments, it continued into 1989 as a rapid decline in ASPs. Unit growth in voltage regulators has remained particularly strong, while their ASPs have dropped 20 percent during the past year to maintain a flat revenue

FIGURE 2
Analog IC Unit, Revenue, and ASP History



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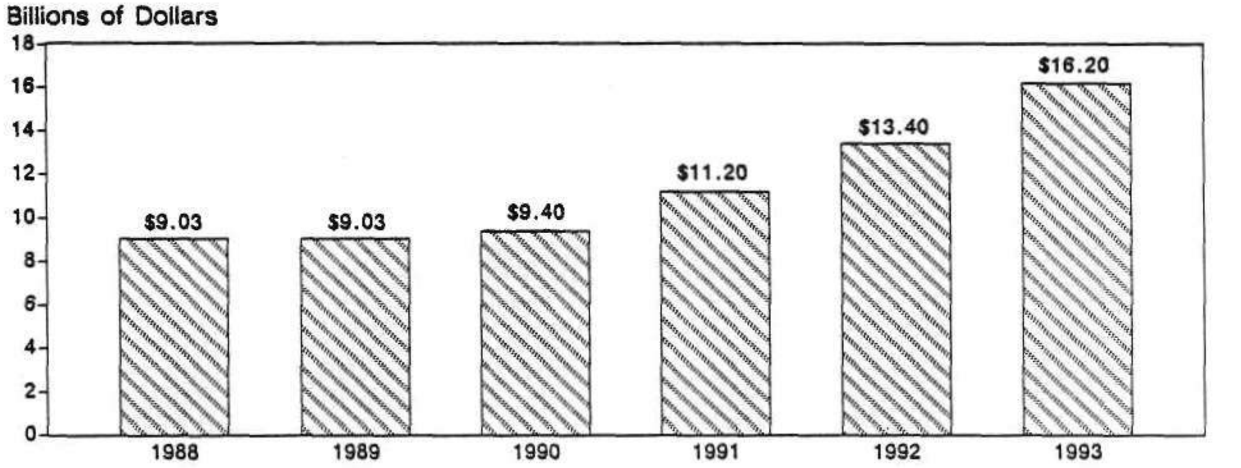
Source: WSTS
Dataquest
October 1989

FIGURE 3
Analog IC Forecast
1989-1993



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Source: Dataquest
October 1989

profile. During the first half of 1989, data converter ASPs rose but unit shipments were weak. The net effect is that analog revenue essentially has been flat since the summer of 1988.

The present no-growth trend is expected to continue until September 1990. The result is that 1989 will have no analog IC growth over 1988 and that 1990 will have only 4 percent growth over 1989. Analog IC growth will exceed 17 percent annual growth in the 1991 through 1993 period. The forecast is presented graphically in Figure 3. The impact of the two very flat years is a low compound annual growth rate (CAGR) of 12.4 percent from 1988 to 1993.

CONCLUSIONS

The slowdown occurred faster than anticipated for analog ICs. The good news is that unit demand continues, albeit at a slower pace; the bad news is that ASPs are eroding, especially on commodity linears. Nonetheless, price erosion on analog ICs during the past year can hardly compare with the memory chip erosion that Dataquest expects to occur in the coming year. For most analog IC suppliers, we predict that this period will continue to be a slowdown rather than a recession.

Gary Grandbois

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Research Newsletter

ANALOG IC FORECAST: THE IMPACT OF THE MARKET SLOWDOWN

SUMMARY

The semiconductor market slowed considerably during the past year, and this change is affecting the market for analog ICs. First quarter 1989 signaled the start of a shaky year that will apparently continue into 1990. This newsletter examines some of the history and expectations with respect to analog worldwide, regional, and product markets.

OVERVIEW

The strongest change to date in worldwide quarterly analog trends was the surprising negative 8.0 percent growth registered in first quarter 1989. Quarterly shipments weakened in all regions and are expected to remain relatively flat to slightly up during the next four quarters. Figure 1 looks at the immediate worldwide analog IC past and forecasts the future in quarterly growth rates.

REGIONAL TRENDS

All regional markets are slowing down, but North America and Japan, in particular, are weak. At year-end 1989, Dataquest expects North America and Japan to register the weakest performance at negative 3.4 percent and negative 2.5 percent, respectively. In the long term, we anticipate that Asia/ROW will become a much larger consumer of analog circuits, as illustrated by Figure 2. We expect other regions to decline slightly in their overall percentage consumption of analog circuits.

Issues influencing Dataquest's regional forecast include GNP expectations for the various regions and the shifts in regional manufacturing/consumption. These factors are identified in the following subsections.

Regional GNP

Highlights of regional GNP expectations include the following:

- In the U.S. market, GNP is expected to drop from 4.4 percent in 1988 to 2.6 percent in 1989 and 1990. Although this decline may create a general slowdown, it is not expected to trigger a recession.
- GNP levels in the major European markets are expected to be on a par with or slightly above U.S. levels in 1989 and 1990.
- Forecast GNP for Japan is expected to be 4.0 percent and 3.0 percent in 1989 and 1990, respectively. These figures are slightly above both the United States and European countries, but significantly below the newly industrialized economies (NIEs) of Asia (i.e., South Korea, Taiwan, and Hong Kong).
- GNP growth for NIE countries in Asia is expected to range between 6.2 percent and 9.7 percent in 1989 and 1990.

Manufacturing/Consumption Shifts

Some highlights of manufacturing and consumption pattern changes are described below.

- The 1992 phenomenon, which will open European trade barriers and offer advantage to goods manufactured in Europe, is drawing plants to Europe. As a result, European semiconductor consumption should rise in the near future.
- Japanese companies are moving much of their electronic equipment manufacturing to the United States and Europe to take advantage of the strong consumer markets.

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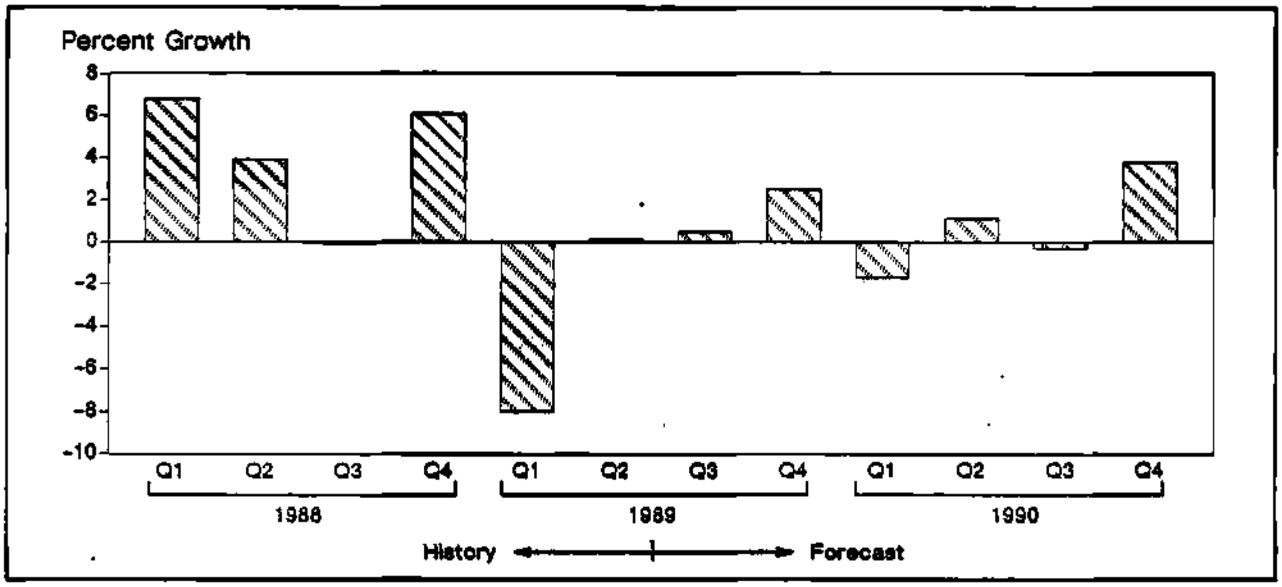
FIGURE 1
Quarterly Worldwide Analog IC Growth—History and Forecast
(In Percent)



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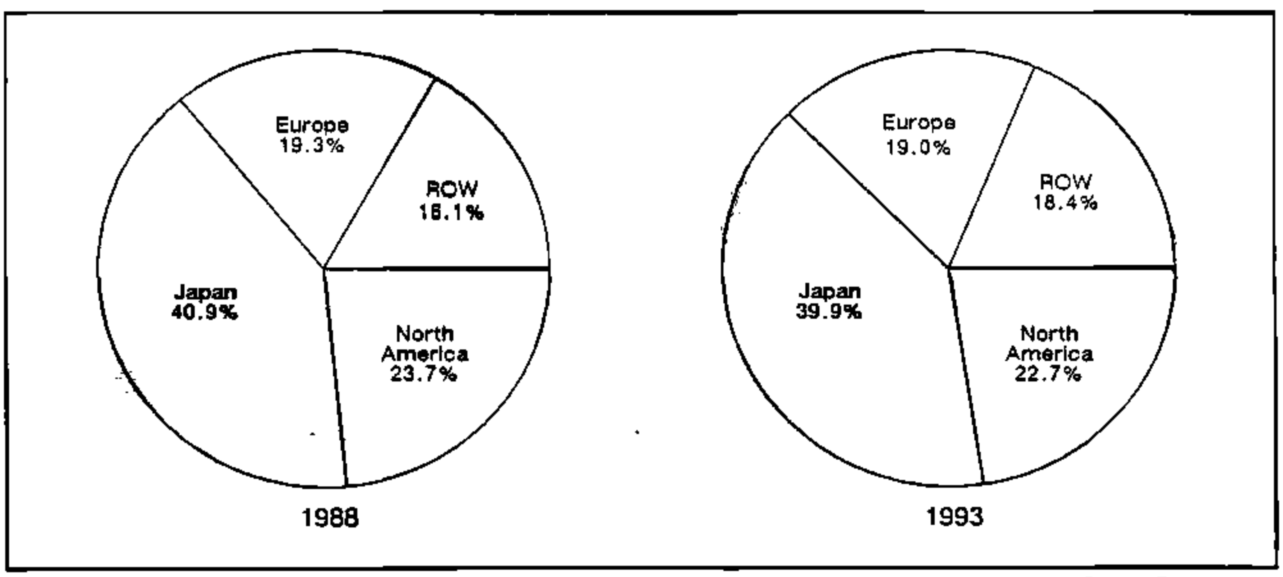
Source: WSTS
Dataquest
October 1989

FIGURE 2
Worldwide Regional Markets—1988 and 1993
(In Percent)



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Source: Dataquest
October 1989

TABLE 1
Analog IC Forecast by Product Segment, 1989-1993 (Millions of Dollars)

	1988	1989	1990	1991	1992	1993	CAGR 1988-1993
Amplifiers	$ 935	$ 935	$ 945	$ 1,080	$ 1,240	$ 1,440	9.0%
Regulators	552	530	577	697	827	1,000	12.6%
Interface ICs	709	690	715	830	970	1,150	10.2%
Comparators	171	170	175	200	228	255	8.3%
Data Converters	790	790	850	1,057	1,370	1,755	17.3%
Other Analog ICs	612	600	620	720	840	985	10.0%
Telecom ICs	614-	634	700	840	1,040	1,300	16.2%
Consumer ICs	3,057	3,060	3,100	3,700	4,475	5,500	12.5%
Analog ASIC	235	270	335	420	510	620	21.4%
Hybrids	1,358	1,350	1,400	1,620	1,890	2,200	10.1%
Total Analog ICs	$9,033	$9,029	$9,417	$11,164	$13,390	$16,205	12.4%

Source: Dataquest
October 1989

Product Trends and Forecast

Dataquest believes that analog ASICs and telecom IC products will be the only areas that will show growth in 1989. Most of the traditional analog product areas either will be flat or negative in growth from 1988 to 1989. In the long range, (i.e., 1988 through 1993), Dataquest anticipates strong growth in the areas of analog ASICs, data converters, and telecom ICs. Traditional analog products are expected to grow at less than the total market rate of 12.4 percent.

Dataquest expects analog ASIC growth to be strong over the next five years. This growth is driven by an interest in integration and the proven benefits known to exist with digital ASICs. Although this growth is strong, it comes from a small revenue base. Telecom and graphics systems also will continue to demand higher-end chips with higher prices and increased units, leading to high growth rates for both data converters and telecom ICs. The analog IC forecast by product is shown in Table 1.

Barbara Van

0005232

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Research Newsletter

ANALOG IC FORECAST: MAJOR MARKETS PROVIDE MAJOR OPPORTUNITIES

SUMMARY

In addition to forecasting the general business climate, the 1989 through 1993 analog IC product forecast is predicated on the following three broad product trends:

- The product growth trends based on recent sales history
- The application market changes resulting from product evolution
- The consumption growth trends tied to the growth of the end-application markets

This newsletter relates the IC sales forecast to end-market use and growth.

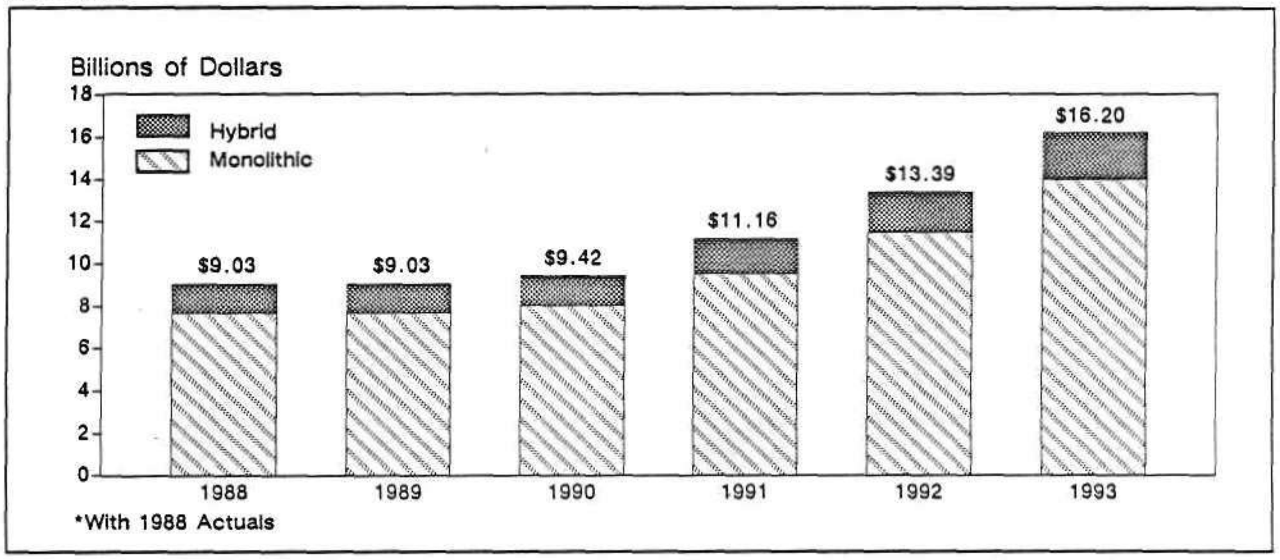
THE FORECAST

Dataquest expects analog ICs to grow by 12.4 percent from 1988 through 1993. Analog sales by year for the sum of monolithic and hybrid production by IC suppliers are shown in Figure 1.

Table 1 presents Dataquest's analog IC forecast segmented by product category.

This product forecast, based on historical trends and anticipated market needs, also takes into account the changing nature of the products themselves (e.g., linear versus mixed-signal, standard versus ASIC) as well as the changing nature of the end markets. Figure 2 shows the historical and forecast compound annual growth rates (CAGRs) by product category. Most product categories are forecast to show declines in CAGR as a result of the anticipated flat period from 1989 through 1990.

FIGURE 1
Analog IC Forecast*
1989-1993



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SIS Newsletters 1989 Analog

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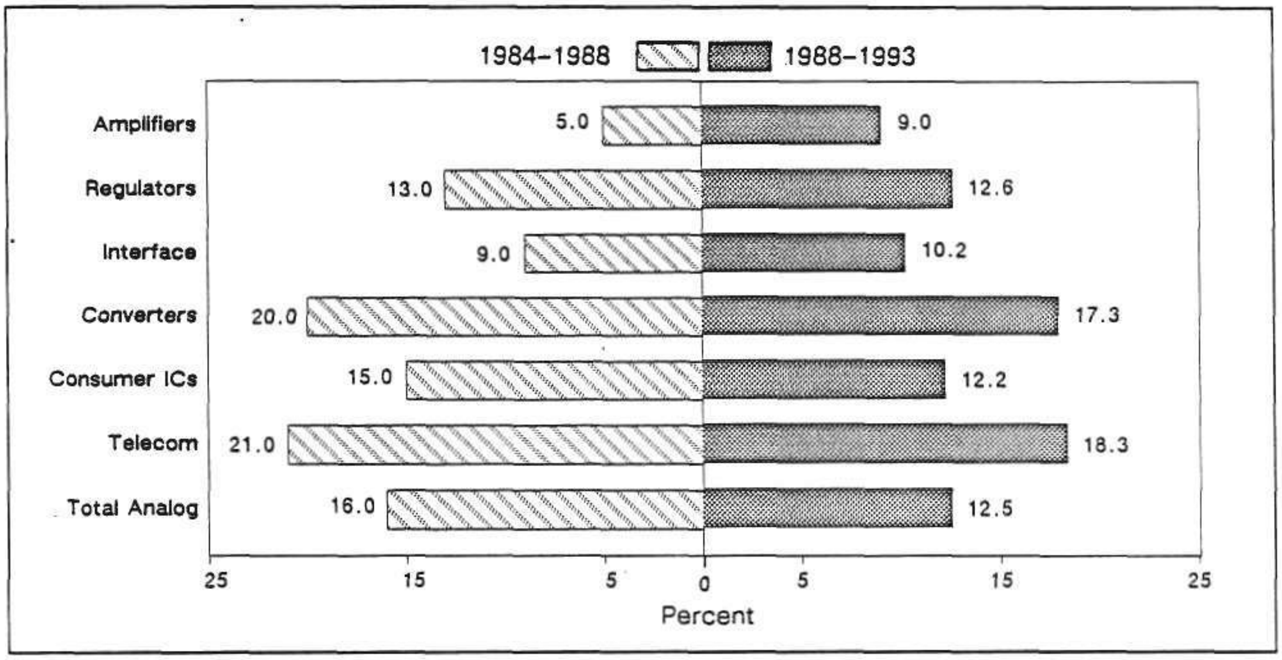
TABLE 1
Analog IC Forecast by Product Category*
1988-1993

Product	1988	1989	1990	1991	1992	1993	CAGR 1988-1993
Amplifiers	935	935	945	1,080	1,240	1,440	9.0%
Comparators	171	170	175	200	228	255	8.3%
Voltage Regulators	552	530	577	697	827	1,000	12.6%
Data Converters	790	790	850	1,057	1,370	1,755	17.3%
Interface	709	690	715	830	970	1,150	10.2%
Special Functions	612	600	620	720	840	985	10.0%
ASIC	235	270	335	420	510	620	21.4%
Telecom Specific	614	634	700	840	1,040	1,300	16.2%
Consumer Specific	3,057	3,060	3,100	3,700	4,475	5,500	12.5%
Monolithic Total	7,675	7,679	8,017	9,544	11,500	14,005	12.8%
Hybrids	1,358	1,350	1,400	1,620	1,890	2,200	10.1%
Analog Total	9,033	9,029	9,417	11,164	13,390	16,205	12.4%

*With 1988 actuals

Source: Dataquest
October 1989

FIGURE 2
Product Growth History/Forecast
(1984-1993)



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Source: Dataquest
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Market Breakdown and Review

Figure 3 shows 1988 monolithic analog IC consumption by the six major market categories, further segmented by product type. These major markets are data processing, communications, industrial, military, consumer, and transportation/automotive.

Data Processing

Although the data processing market is largely digital, it does represent a strong and growing market for analog ICs. Interface ICs find substantial use in data transmission and display as well as in power control. Power supply requirements fuel the need for regulators. Data converter consumption derives from many different conversion needs but largely from the video DACs for color graphics. Peripheral products such as printers show a strong use for all types of analog ICs.

The market for data processing products—computers and peripherals—is expected to grow at a CAGR of 11.4 percent. Although the products for this market have a high IC content, the projected analog IC growth of 15.8 percent shows that greater growth is expected for analog support components. As computers gain features to assist in human interface (such as high-resolution graphics, video frame grabbers, speech-to-text, and sensors) and data transmission, they necessarily will increase their analog IC content.

Communications

This market is a strong user of both custom and application-specific standard ICs. A moderate 8.8 percent CAGR is forecast for end-market growth in communications. We anticipate analog IC growth in this market to continue strongly through the 1990s with a 13.6 percent CAGR.

Industrial

The industrial market uses a wide range of product types. Analog technology is well entrenched because of the need for signal acquisition, processing, and control interface. Instruments use analog ICs in substantial quantities. Sensor and motor controller products represent some portion of the "special function" category used in the industrial market.

The industrial sector is not growing greatly (6.8 percent CAGR), nor is the analog IC market penetration anticipated to increase significantly. Dataquest forecasts a 7.8 percent analog IC growth rate through 1993.

Military

A broad-spectrum user of analog ICs, the military market represents the slowest growth area for these devices. Declining military programs in the United States will be instrumental in slowing growth in this market sector to approximately 3.7 percent compounded.

Consumer

Like the communications market, this market is a substantial user of custom and application-specific standard ICs. Analog ICs dominate in consumer electronics, especially in entertainment products. We anticipate that analog IC revenue will grow even faster than the consumer market (12.6 percent versus 5.3 percent, respectively) as more feature-laden products are introduced. Digital audio and video enhancements to entertainment products as well as "smart" appliances will lead this growth.

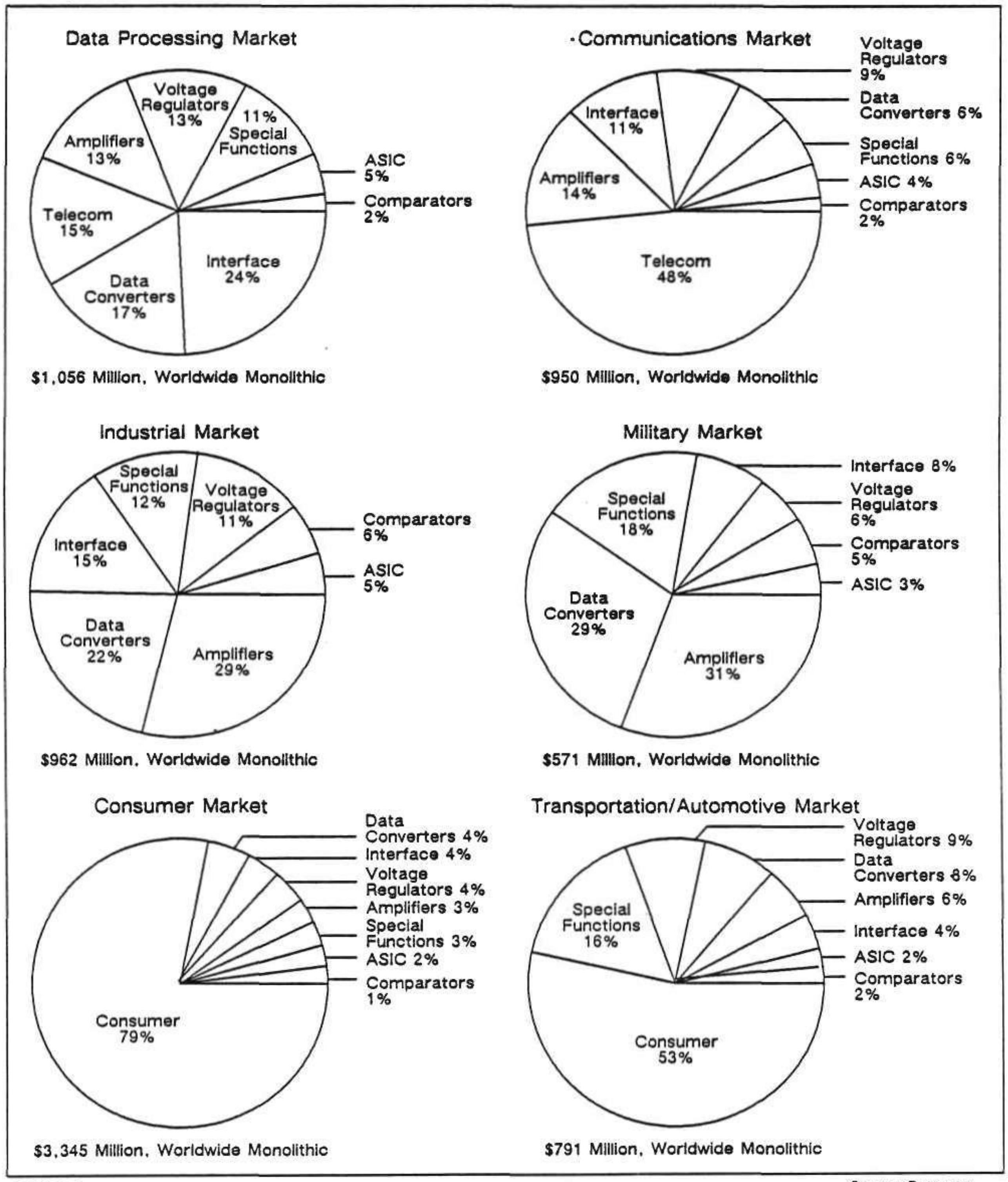
Transportation/Automotive

Essentially a consumer market, the automotive portion of the transportation market also uses custom and application-specific ICs. Dataquest expects all analog IC segments to experience rapidly increasing revenue in this market. Analog ICs are crucial to the sensing, conversion, interface, and power control functions so prevalent in automotive electronics. We expect strong CAGR of 18.8 percent, despite a setback in auto sales in the coming few years and the lower 8.0 percent CAGR anticipated for the automotive electronics market.

Forecast Growth by Market

Table 2 summarizes the forecast growth for analog ICs in the six major markets, listed in order of forecast growth rate.

FIGURE 3
Analog IC Consumption by Market and Product



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Source: Dataquest
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Total Monolithic Analog IC Market

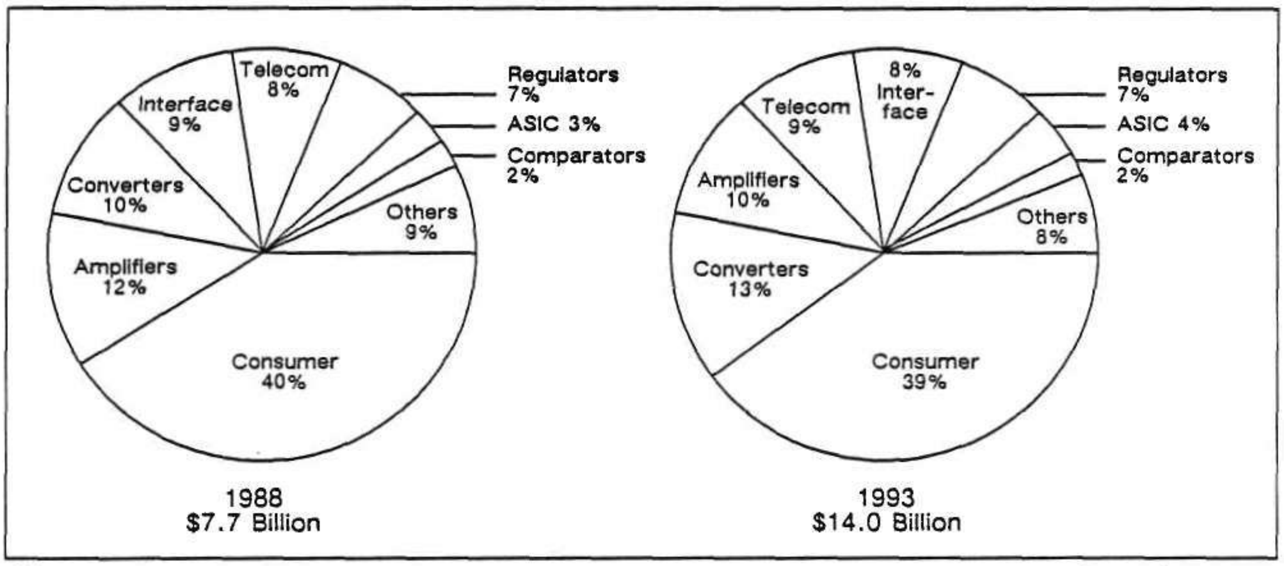
The summation of these markets gives a 12.8 percent compound growth rate for monolithic analog ICs. A somewhat slower growth for hybrid ICs reduces the total analog IC growth to 12.4 percent. Figure 4 shows the monolithic revenue for 1988 by product categories, as well as the 1993 forecast. Changes are most notable in the converter, amplifier, and ASIC products. Figure 5 shows the present and forecast market segmentation for monolithic analog ICs.

TABLE 2
Analog IC Growth Forecast by Market

Market	1988	1989	1990	1991	1992	1993	Analog IC CAGR 1988-1993	Market CAGR 1988-1993
Transportation	791	810	900	1,134	1,450	1,870	18.8%	8.0%
Data Processing	1,056	1,056	1,100	1,370	1,710	2,200	15.8%	11.4%
Communications	950	950	990	1,190	1,465	1,800	13.6%	8.8%
Consumer	3,345	3,330	3,452	4,125	5,000	6,050	12.6%	5.3%
Industrial	962	962	990	1,115	1,235	1,400	7.8%	6.8%
Military	571	571	585	610	640	685	3.7%	3.0%
Total Analog	7,675	7,679	8,017	9,544	11,500	14,005	12.8%	

Source: Dataquest
October 1989

FIGURE 4
Analog IC Revenue by Product Category



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Source: Dataquest
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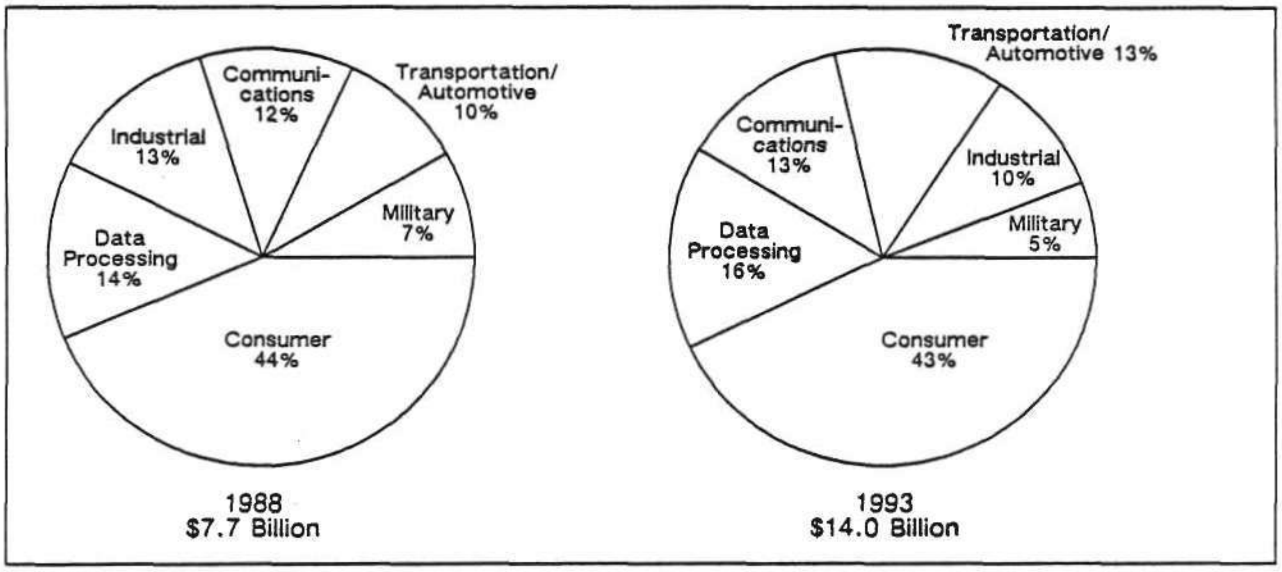
FIGURE 5
Analog IC Revenue by Market



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Source: Dataquest
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DATAQUEST CONCLUSIONS

It is an axiom that the maximum growth will occur with the fastest-growing products in the fastest-growing markets. Mixed-mode ICs in the Data Processing, Consumer, Transportation/Automotive, and Communications markets represent the fast track of analog IC growth. Dataquest estimates that these markets provide growth opportunities for analog ICs that are 50 to 100 percent faster than the end-market growth itself.

Gary Grandbois

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Research *Bulletin*

ANALOG INTEGRATION: THE PRESSURE GROWS

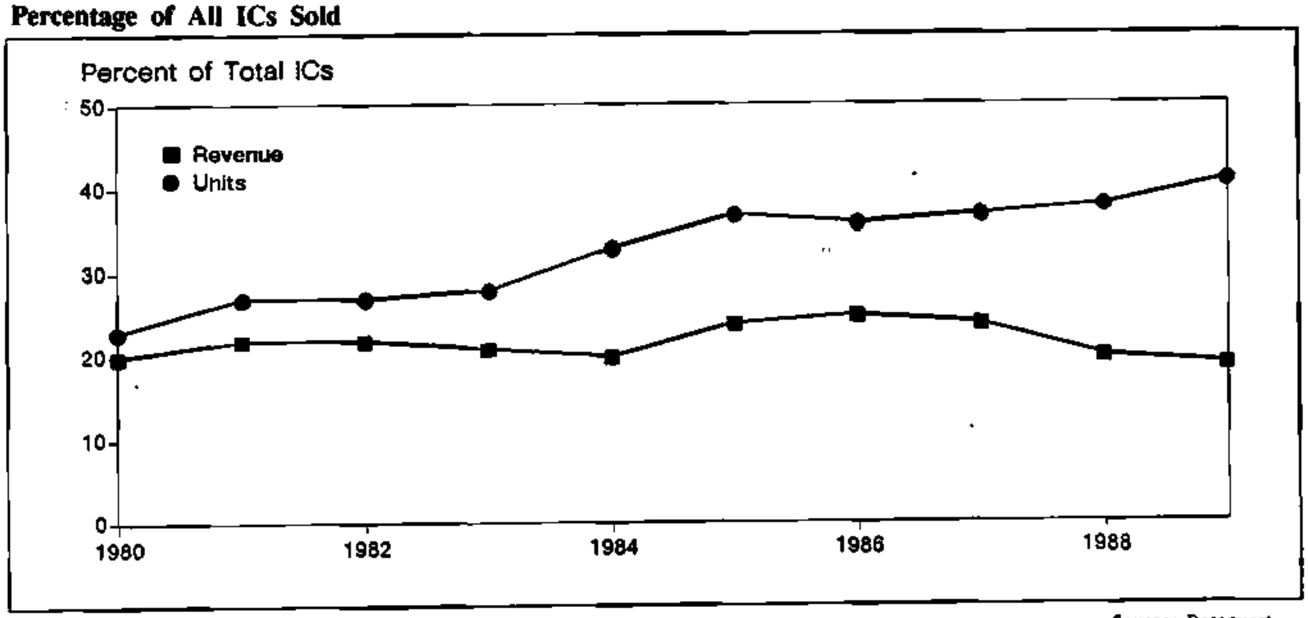
Many of the "hot" analog issues of the 1990s revolve around a single concern—meaningful integration. The lack of significant gains in the level of analog integration creates continuing erosion of selling prices and substantial pressure toward alternative solutions. Some of the solutions to the integration problem include the following:

- Mixed analog/digital ICs
- Mixed-mode ASICs
- Application-specific standard products (ASSPs)
- Digital signal processing (DSP) to minimize analog content
- BiCMOS processing technology

THE PATH OF INTEGRATION

Integration of digital functions has progressed at a furious rate during the past two decades. Advances in process technology and ASIC methodology have assisted the consolidation of complex digital functions. As Figure 1 shows, at the start of the 1980s, analog ICs composed about 20 percent of both total IC revenue and total units. For a variety of reasons, both technical and market oriented, analog ICs have not benefited from the same functional consolidation as digital ICs. The result is that monolithic analog ICs are expected to make up more than 40 percent of the total IC units shipped in 1989 but to account for the same 20 percent of the IC revenue that they have aver-

FIGURE 1
Analog ICs
Percentage of All ICs Sold



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aged for almost 20 years. The average PC board is now reaching the state where equivalent numbers of digital and analog ICs are used.

DATAQUEST CONCLUSIONS

Despite a lack of analog integration, the need for analog ICs continues to grow. Integration gains will be made in all analog IC types in the coming decade, but especially in the mixed-mode and ASSP areas. Computers, automobiles, and home appliances need analog ICs to interact with the physical world directly to become "smart." Analog ICs will be key to growth in high-resolution graphics and high-definition TV (HDTV) as well as expansion of DSP in both audio and video applications. A resurgence of analog techniques in neural networks and "fuzzy" logic will drive the leading edges of analog technologies and integration. Is analog dull? Not in the coming decade.

Gary Grandbois

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Research Newsletter

ANALOG HYBRID ICs: THE WHAT, WHY, WHEN, WHO, AND WHERE?

SUMMARY

Hybrid ICs often are at the forefront of performance, offering otherwise unavailable speeds and functions. Although these capabilities tend to be transferred into monolithic circuits over time, the need for high performance undoubtedly will continue to foster this high-end portion of the market. Significant in size and growth expectations, hybrid ICs are recognized to be an important dimension of the analog world.

Note that Dataquest does not track the entire hybrid IC market. With the analog segment, however, we do track hybrid ICs that are an alternative form of packaging for companies that make the analog devices used in the circuits. This newsletter looks at the market segments included within our analog database; future newsletters will examine new and demanding applications for hybrid ICs.

WHAT?—THE SIZING OF THE ANALOG HYBRID IC MARKET

Dataquest's analog hybrid IC database addresses a worldwide market of approximately $1.4 billion, which is 15 percent of our total analog database. Although this is sizable, we believe that the total hybrid IC market, which includes captive manufacturers and merchant manufacturers of various sizes, is many times larger. The total market for hybrid devices may be as much as 6 to 10 times the figure reported here.

WHY?—WHY USE HYBRID ICs OVER MONOLITHICS?

Why does a company chose a hybrid circuit design over a monolithic chip? There are numerous reasons why a hybrid IC may be a more attractive option. First, there is the issue of high-end performance. Hybrid circuits frequently are at the cutting edge of performance, offering faster speeds or unique function combinations. These combined circuit packages can be optimized in varied technologies without the performance degradation that may occur in a monolithic design or because of excessive signal path length when using multiple packages. Power dissipation problems also can be improved in a hybrid IC because of power and signal partitioning. From a cost standpoint, development costs for a hybrid IC design are considerably lower than for a monolithic design. Finally, there are many more hybrid IC suppliers from which to choose.

WHEN?—THE ANALOG HYBRID IC FORECAST

Dataquest expects the portion of the hybrid IC market that it tracks to grow at a rate of 10.1 percent annually over the next five years. Currently valued at $1.4 billion, this market is expected to reach $2.3 billion in 1993. Dataquest's hybrid IC forecast is presented in Figure 1.

WHO?—THE SUPPLIERS

Many types of hybrid IC manufacturers exist. Hybrid IC suppliers include large captive houses that manufacture solely for internal purposes, large semiconductor houses that are primarily in the monolithic circuit business, small hybrid IC houses that purchase monolithic circuits for hybrid assembly, and some foreign contractors. Although most companies that supply hybrid ICs are very small, the highest cumulative revenue is believed to come

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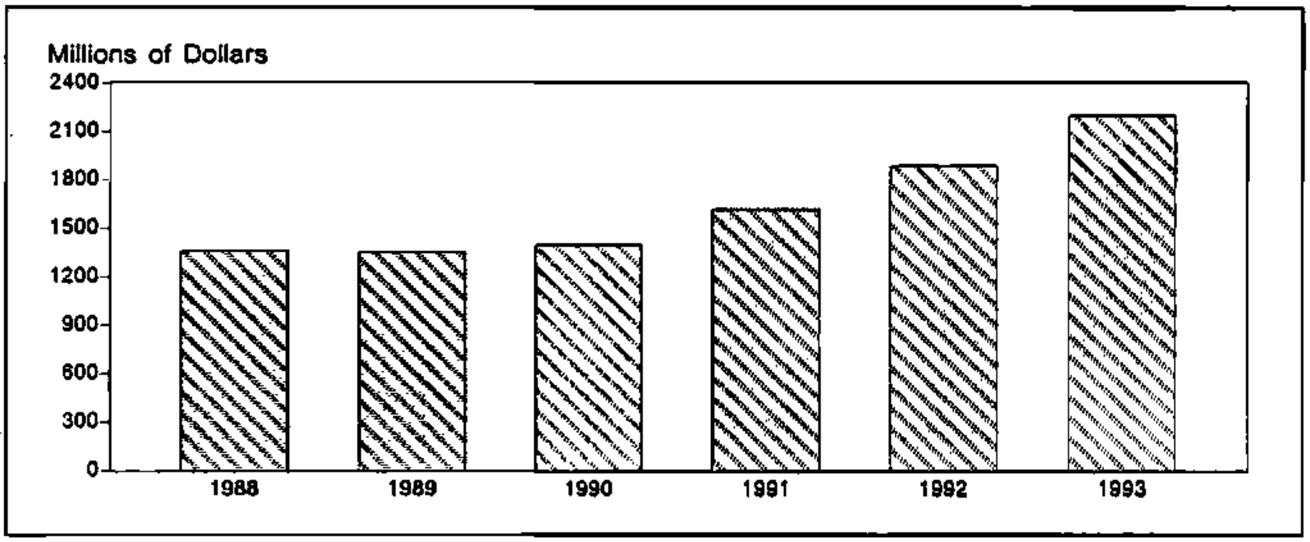
from captive manufacturers as a whole. Dataquest, however, measures only the business associated with analog circuit manufacturers that sell hybrid ICs in the merchant market. Analog hybrid IC suppliers that we track and their revenue are listed in Table 1.

FIGURE 1
Worldwide Analog Hybrid IC Forecast
(Millions of Dollars)



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Source: Dataquest
December 1989

TABLE 1
1988 Worldwide Market Share of Analog Hybrid ICs
(Millions of Dollars)

Rank	Company	Percent Share	Sales
1	Sanken	11.6%	$ 157.0
2	Sanyo	10.6	143.5
3	NEC	9.9	134.0
4	Rohm	7.8	106.0
5	Hitachi	7.4	101.0
6	Mitsubishi	6.5	88.0
7	Toshiba	6.3	85.0
8	Fujitsu	4.8	65.0
9	Analog Devices	4.6	63.2
10	Burr-Brown	4.4	59.4
11	Sony	3.7	50.0
12	Motorola	3.1	42.0
13	National Semiconductor	2.9	39.0
14	Sharp	1.9	26.0

(Continued)

TABLE 1 (Continued)
1988 Worldwide Market Share of Analog Hybrid ICs
(Millions of Dollars)

Rank	Company	Percent Share	Sales
15	Unitrode	1.7	23.0
16	Goldstar	1.5	21.0
17	Ericsson	1.5	20.0
18	Sipex	1.4	19.0
19	Philips	1.3	18.0
20	Mitel	1.2	16.3
21	Elantec	0.4	4.8
22	Silicon General	0.2	3.3
23	Oki Semiconductor	0.2	3.0
24	Fuji Electric	0.2	2.9
25	Maxim	0.1	2.0
26	New Japan Radio	0.1	1.0
	Other Companies	4.7	64.6
	Total	100.0%	$1,358.0

Note: Columns may not add to totals shown because of rounding.

Source: Dataquest
December 1989

WHERE?—WHERE THE MARKETS ARE

Regionally speaking, our analog hybrid IC database identifies a much larger user market in Japan. The Japanese market consumes more than $800 million in hybrid ICs. The next largest market is North America, with analog hybrid IC consumption of slightly more than $200 million. We believe that the North American market is characterized by many small companies that purchase chips from large semiconductor manufacturers; we do not track these companies because counting them would misrepresent analog circuit sales. The Asia/Pacific region ranks third at $187 million, and Europe's market is $138 million.

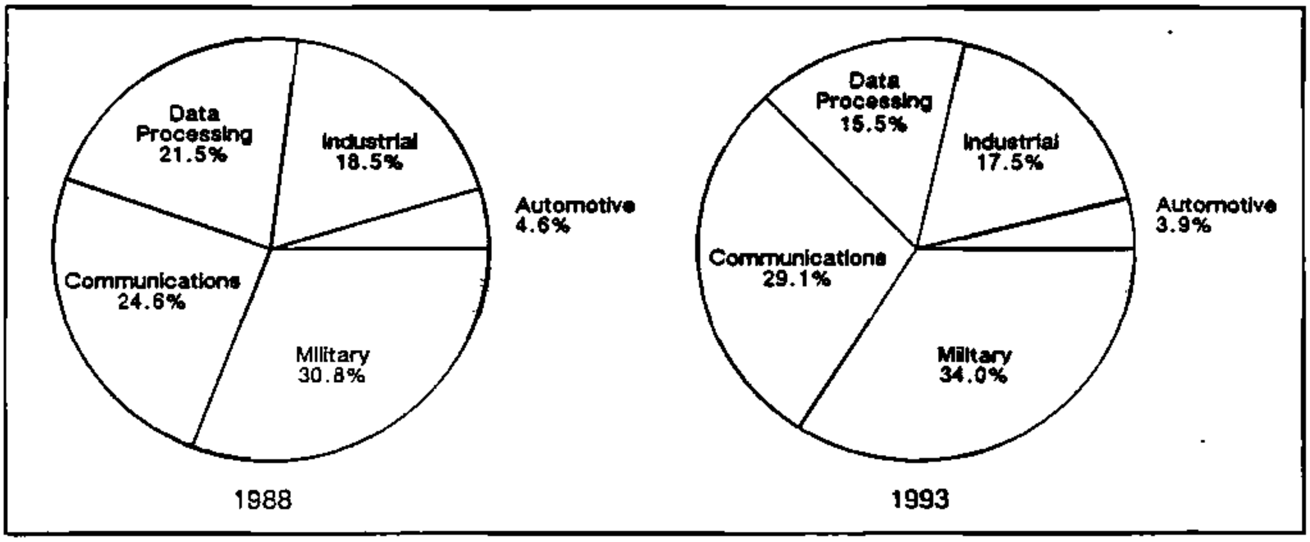
From an applications standpoint, although all markets use hybrid ICs, those that are emerging especially strong are the military and communications markets. Focusing on the U.S. market, we expect both of these application segments to grow as a percentage of the total market, which is in excess of our forecast total market value of 10.1 percent. The changing configuration of the U.S. applications market is shown in Figure 2. The military market, which was the dominant U.S. market in 1988 at 30.8 percent, is expected to grow to 34.0 percent by 1993. The communications segment of the U.S. hybrid IC market is expected to go from 24.6 percent to 29.1 percent between 1988 and 1993.

DATAQUEST CONCLUSIONS

The analog hybrid IC market continues to be strong, with heightened demand from new application markets such as power ICs and ASICs. Although the market is not expected to grow as fast as the total analog IC market even with these driving applications, it should hold its own with 10.1 percent growth forecast over the next five years. Companies that participate in the hybrid IC market and companies that push the performance limits on monolithic circuits should find that hybrid IC developments bear watching.

Barbara Van

FIGURE 2
U.S. Hybrid ICs by Application Market—1988 and 1993



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December 1989

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Research Newsletter

SIS Code: Newsletters 1989
ASIC/PMT
0003736

"OUR TIME, OUR CHOICE, OUR ANGUISH, OUR DECISION"

SUMMARY

When Stephen Vincent Benet wrote those words, he could have been referring to the ASIC segment of the semiconductor industry. He was writing about destiny and opportunity, and that is just what the ASIC industry will face in the 1990s. Dataquest believes that ASICs are entering a time of choice, and the entire infrastructure of the supplier base will face some tough decisions. We believe that ASICs are going to experience the following four fundamental megatrends that will alter the course of the industry:

- A growing demand for regionalism
- A slower growth rate for consumption
- An accelerating capital investment in technology
- A break in the DRAM-ASIC "food chain"

Together, these trends will test the mettle of every supplier and user; out of this shakeup will come an industry with fewer but stronger suppliers.

ASIC REGIONALISM

Dataquest believes that there is an unrelenting trend toward regionalism with ASICs just as there is with all semiconductors. Customers around the world want their ASICs locally. This growing demand is driven by many factors, all of which hinge on the desire for more local content. From Bangkok to Bruxelles, we see customers under increasing pressure to design and manufacture with ever-faster turnaround time. The end-product life cycles have become shorter and shorter, which in turn is placing demands on ASIC suppliers to compress development cycles. But it does not stop there; now ASIC users are giving preferential treatment to suppliers who manufacture locally, too. This situation is driven partially by the local content laws and partially by the nature of the products manufactured. For example, in the Pacific Rim, we see heavy concentration of consumer electronics; in Europe, we see telecom applications; and in North America, we see computers.

It is easy to personally experience this megatrend; a brief trip to a local electronics store tells it all. One can see a dazzling array of electronic gadgetry that seems to change in feature content almost monthly. What was a simple four-function calculator a few years ago is today a calculator for the accountant, or the engineer, or the financial analyst. Clock radios now come with phones, answering machines, or cassette recorders. Products have become more specialized, and the rate of change in features is increasing. This trend is not confined to just consumer electronics. We see the same pattern repeated across the telecom, computer, and industrial sectors as well.

All this suggests challenges and opportunities for the ASIC supplier of the 1990s. Serving the regional markets of the next decade means making key changes in the infrastructure of the ASIC industry. It means that the ASIC supplier must locate design and manufacturing close to the user. Historically, regional design centers have been a part of the scene for a long time; but looking to the future, that will not be enough. It means that production in each region will become a critical success factor, too. The challenge here is to build small, quick-turn factories that are tailored to the markets of the region. It is conceivable that even manufacturing processes would be tailored to suit the region. For example, in the Pacific Rim, where consumer electronics is dominant, an ASIC supplier may offer a low-voltage CMOS process, or in Europe, a double-poly process to support telecom applications.

This regionalization has some interesting implications for ASIC suppliers. First, it will severely tax the financial resources of the cadre of companies that have been marginally profitable for some time. Second, it will accelerate mergers and alliances in order to gain access to certain markets. Third, it means that suppliers not wishing to be world-class suppliers must specialize. Fourth, it could spell the departure of some of the weaker suppliers.

Regardless of which scenario occurs, the implication is quite clear. The survivors will require deep pockets and worldwide perspective or they will have to find a specialty market that is not well served and become the dominant supplier for that market.

ASIC GROWTH TAKES A PAUSE

Historically, the ASIC segment has grown for the past five years at a compound annual growth rate (CAGR) of 20 to 30 percent. However, the next five years will be different. Dataquest believes that over the next five-year horizon, ASICs will experience a CAGR of 15 percent, which is considerably slower. This slowdown can be traced to two primary forces. First, ASIC is now a major component in the total IC industry; thus, it is subject to forces that affect the entire industry. The second force is also related to ICs; namely, the entire industry is expected to experience a slowdown in the third and fourth quarters of 1989 and the first two quarters of 1990. Our current forecast shows ASIC growth for 1989 at 15.7 percent and growth for 1990 at a mere 5.6 percent. This forecast is substantially below the historical rates of the past five years, leading us to believe that suppliers will experience considerable profit pressure in an industry that is already only marginally profitable.

ASIC TECHNOLOGY AND DEEP POCKETS

Figure 1 shows the ASIC technology road map for the past six years. This figure illustrates when each new CMOS process technology was, or will be, introduced in a production environment. What is interesting to note is that for the last six years, a new process has been introduced each year, and along with each new process has come an increase in gate count. For example, with the introduction of 2-micron CMOS in 1985, we saw gate arrays in the 20K gate range for the first time. Moving forward two years to 1987, we see 100K gate arrays in a 1.25-micron technology. This process evolution largely results from scaling of successive generations of the CMOS process. Dataquest believes that this pattern will continue, but as development work moves closer to 0.5-micron technology, the cost of process development will rise substantially. It is widely believed that current stepper technology will not work at the 0.5-micron level. Furthermore, the entire CMOS process must be redesigned to achieve geometry in the 0.5-micron range. Most observers expect that major investments will be required to achieve gate counts in the 500K range, so once again, ASIC suppliers will be required to make heavy investments in order to stay competitive.

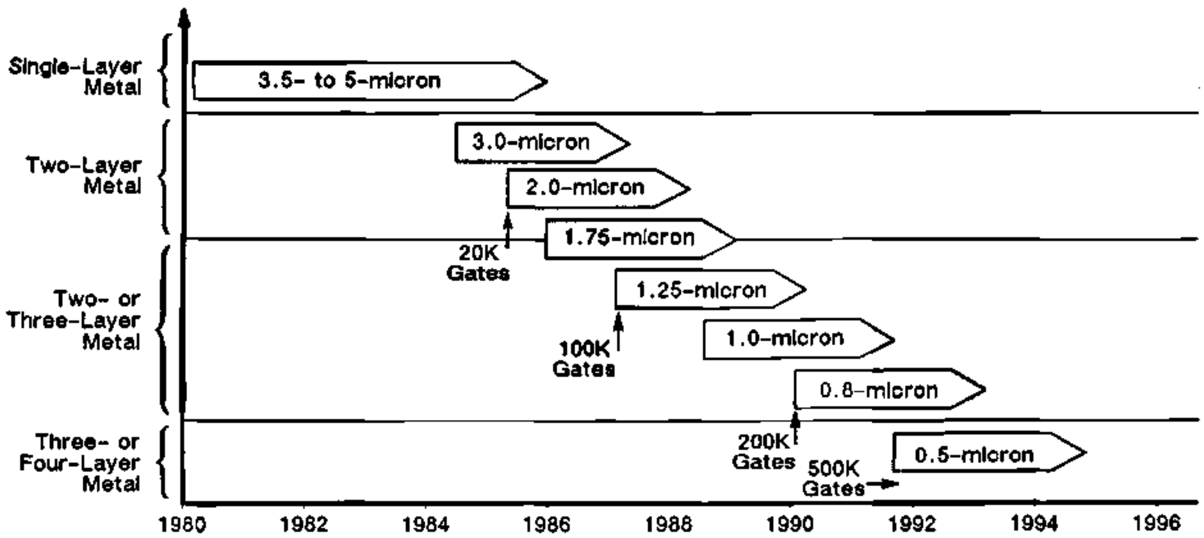
DRAM-ASIC FOOD CHAIN

Another factor spells heavy investments for ASIC suppliers; it relates to the DRAM-ASIC food chain. Historically, ASIC suppliers have followed DRAM process development. That is to say, much of the process development effort used today in ASICs is derived from work done earlier for DRAMs. Conventional thinking would suggest that this trend would continue as both industries move to 0.5-micron technology. The DRAM suppliers would first develop the basic process, and about a year later the ASIC suppliers would use the same technology to make ASICs; but a closer look shows a very different picture.

ASICs and DRAMs follow very different paths. Figure 2 shows a parting of ways. The food chain still exists, but the next phase for each product line will require separate development. This parting of ways is driven by the nature of the products themselves. ASIC suppliers are obsessed with the challenge of interconnect. They must develop ways to connect complex cells or macros, and they are preoccupied with how to connect logic blocks without sacrificing chip area. It only seems natural that ASIC companies would be interested in developing processes that make interconnect easier, or to say it another way, in making the surface of the chip planar so that more complex interconnect can be achieved. There are other factors that differentiate ASICs from DRAMs. ASIC suppliers are not interested in large production volumes. Most ASICs are sold in very low quantities when compared with DRAMS. ASIC suppliers must ship the product on very quick turnaround and must make yield improvements over limited production runs. ASIC suppliers also must pioneer investment in high lead count packaging technology.

Figure 1

Technology Road Map (CMOS and ASIC)



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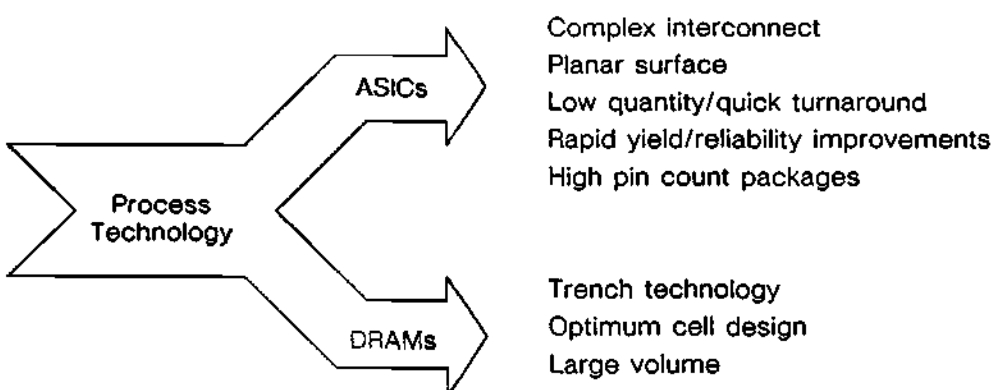
Source: Dataquest May 1989

Figure 2

ASICs and DRAMs: A Parting of the Ways!



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Source: Dataquest May 1989

DRAM suppliers have a very different agenda. The success of the next generation of DRAMs will depend on developing trench process technology, which has nothing to do with complex interconnect required in ASIC applications. DRAM developers are obsessed with RAM cells. The ultimate cost of a DRAM chip is directly related to the size of the memory cell. Therefore, it stands to reason that DRAM suppliers will devote major portions of their resources to optimizing the memory cell. DRAMs are made in very large production quantities. Yield improvements tend to be cyclical rather than one-time efforts, as with ASICs.

This leads us to believe that the ASIC and DRAM process developments are about to part ways. While much of the base technology is similar, and will continue to be so in the core process, a major portion of future development will be funded separately. For the ASIC supplier, this means that one more major expenditure must be added to the already-strained development budget. The ASIC company of the 1990s must divide the research funds three ways: CAD tools, ASIC manufacturing equipment, and now ASIC process development. Therefore, ASIC companies must have very deep pockets indeed—deeper than some can afford—leading us to conclude that it is fallout time for ASICs.

A CONVERGENCE OF FORCES

When we stand back and look at the prevailing forces expected to be at work during the next five years, we can reach only one conclusion. The ASIC industry is going to experience a pruning of suppliers. As the four factors previously outlined converge, we can expect major changes in the infrastructure. As demand grows for regional production centers, as ASIC consumption slows, as process development requires heavier investment, and as ASIC departs from the DRAM food chain, Dataquest expects a major consolidation to occur.

IMPLICATIONS

We do not expect the consolidation to fall equally across all ASIC product areas. For the swift and strong, and for certain product categories, the impact will vary, as follows:

- Gate Arrays—We see the gate-array market destined for a severe pruning of suppliers. With 57 suppliers in a very mature and very price-sensitive market, it seems inevitable that fallout will occur. Pressure to cut turnaround time, spiraling process development costs, and massive regional investment will force as many as one-third of the suppliers to exit the market.

- Cell-Based ICs (CBICs)—Dataquest believes that CBICs are less vulnerable for several reasons that are unique to this segment. First, the regional markets are less mature. From a regional point of view, CBIC is largely a North American and European market, and less developed in Japan and the Pacific Rim. Second, users appear to be willing to tolerate longer turnaround times, largely because of the extra time required in manufacturing. A third reason is that the cell libraries are so diverse and often proprietary, direct competition is less prevalent. Once users become familiar with certain suppliers' libraries and how to apply them to their needs, there is a strong reluctance to switch. Last, production volumes tend to be much higher with CBICs than with gate arrays, which in turn means that the customer must invest a larger NRE during the design phase; thus, the user is less willing to abandon a project once the funds are committed.

- Programmable Logic Devices (PLDs)—We see this segment as the least vulnerable segment, and this is especially true for the CMOS segment. Regional presence is easier to achieve, because distribution of this product is similar to a standard product. In a PLD, the customization occurs at the user's site. From the user's perspective, PLDs offer the quickest turnaround time of any ASIC product. One should also remember that of all the ASIC markets, the CMOS PLD market is the least mature. It is about one-seventh the size of the gate array market and about one-fourth the size of the CBIC market. The food chain also is different. PLDs are by-products of EPROM, EEPROM, or SRAM technology, and the technology gap is expected to narrow over the next few years. Finally, this segment is largely populated by small companies with very innovative products; thus, direct competition on a product basis is limited.

DATAQUEST CONCLUSIONS AND RECOMMENDATIONS

We believe that our clients should look at the following ASIC megatrends from two perspectives—as both suppliers and as users of ASICs:

- Suppliers—Dataquest believes that any supplier who plans to be a world-class ASIC company must establish regional design and production centers <u>now</u>. ASIC process development is going its own way, and to be competitive in the 1990s will mean funding process development aimed specifically at ASIC applications. We recommend that our clients seek out another company to share process development for the suppliers who do not wish to go it alone.
  - We strongly urge the smaller suppliers to reexamine their product lines to ensure that they are really protected from mainstream competition and to seek out those niches that make them the dominant supplier.

- Users—Dataquest recommends that its clients pick a gate array supplier with great care.

  - Choose a CBIC supplier on functional performance. If the supplier has cells that suit your applications, then continue to foster the relationship.

  - With respect to PLD suppliers, we recommend a higher level of risk. The current products emerging from these companies are quite innovative and may give a competitive edge.

Andy Prophet

Dataquest

Conference Schedule

1989

Semiconductor User/ Semiconductor Application Markets	February 27-28	Le Meridien Hotel San Francisco, California
Japanese Components	April 20-21	Tokyo Bay Hilton International Tokyo, Japan
Computer Storage	April 26-28	The Doubletree Hotel Santa Clara, California
Document Processing	May 16-18	Monterey Sheraton Hotel Monterey, California
Copiers	May 16-17	
Printers	May 16-17	
Electronic Publishing	May 18	
Imaging Supplies	May 18	
Color	May 18	
SEMICON/West Seminar	May 24	The Dunfey Hotel San Mateo, California
Telecommunications	June 5-7	Silverado Country Club Napa, California
European Components	June 7-9	Park Hilton Munich, West Germany
Asian Semiconductor and Electronics Technology Seminar	June 28	Radisson Hotel San Jose, California
Financial Services	August 22-23	The Doubletree Hotel Santa Clara, California
Technical Computing and Applications	September 11-13	The Doubletree Hotel Santa Clara, California
European Copying and Duplicating	September 18-19	Majestic Hotel Cannes, France
Western European Printer	September 20-22	Majestic Hotel Cannes, France
Taiwan Conference	September 25-26	Grand Hotel Taipei, Taiwan
Distributed Processing	September 26-28	The Doubletree Hotel Santa Clara, California
SIA/Dataquest Joint Conference	September 27	Santa Clara Marriott Santa Clara, California
Information Systems	October 2-6	Tokyo American Club Tokyo, Japan
Semiconductor	October 16-18	Monterey Sheraton Hotel Monterey, California
Asian Semiconductor and Electronics Technology	November 2-3	Kunlun Hotel Beijing, China
European Telecommunications	November 8-10	Grand Hotel Paris, France
European Personal Computer	December 6-8	Athens, Greece

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Research Newsletter

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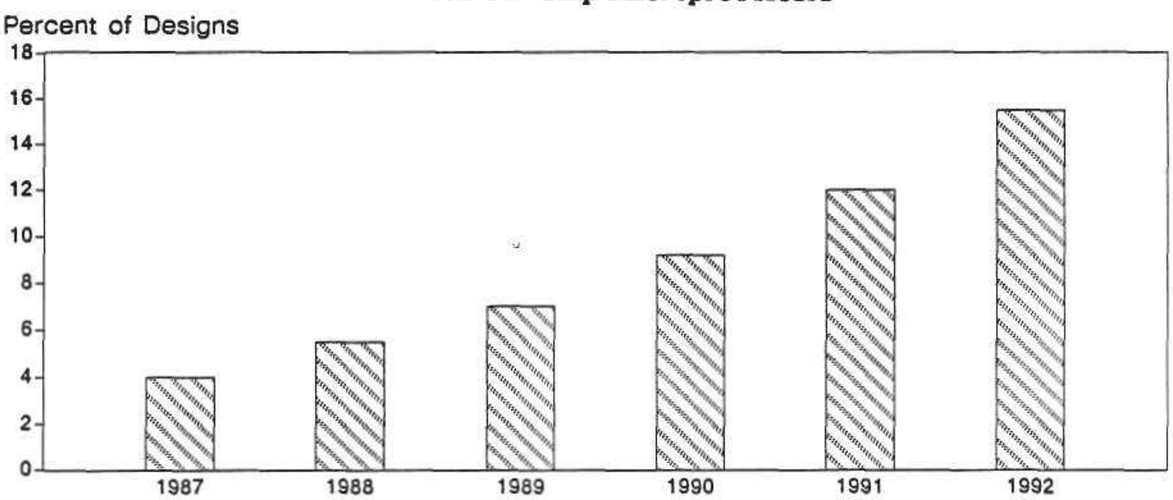
CELL-BASED ICs—THE BRIDGE TO SINGLE-CHIP SYSTEMS

Integrated circuits (ICs) have evolved from simple gates and flip-flops containing less than 10 transistors to chips containing more than 1 million transistors. Consider this: Technology now enables an entire computer system to be placed on a single chip. With this capability, application-specific integrated circuits (ASICs), specifically cell-based ICs (CBICs) and gate arrays, become the bridge to single-chip systems. With ASICs, the microprocessor, memory, and logic can be incorporated on a single chip, thus reducing the size and cost of a system while improving the performance and reliability. In 25 years, IC technology has gone from conception to a reality that far exceeds the wildest dreams of the inventors.

Microprocessor core cells are critical to single-chip systems. As Figure 1 shows, only 83 designs (4 percent of 1987 North American CBIC designs) used microprocessor core cells. However, Dataquest believes that by 1992 this percentage will exceed 15 percent, primarily as a result of submicron CMOS technologies, increases in CAD efficiency, and high demand for alterable RISC microprocessors.

Figure 1

Estimated North American CBIC Design Starts with On-Chip Microprocessors



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Source: Dataquest May 1989

As suppliers strive to offer single-chip system solutions, large megacells and compilable cells rise in importance. Ultimately, the end users will determine the functions required for cell libraries. Most CBIC suppliers are analyzing the needs of each application market and have found that microprocessor, memory, and analog cells are in high demand.

While single-chip CBIC systems are just starting to emerge, the CBIC market has already become quite large. During 1988, Dataquest estimated worldwide CBIC consumption to be $1.3 billion, up 33.4 percent over 1987. AT&T Technologies was the top 1988 CBIC supplier, followed by two very aggressive suppliers, Texas Instruments (TI) and Toshiba.

Key areas addressed in this newsletter include the following:

- 1988 supplier market share
- Design starts
- Cell library trends
- 1989 and beyond

1988 SUPPLIER MARKET SHARE

As shown in Figure 2, AT&T Technologies had a significant lead over its competitors in 1988; however, AT&T received a large portion of its revenue from sales to internal divisions (intracompany revenue). Texas Instruments and Toshiba both had great years with growth in excess of 60 percent, which gave them the momentum to surpass both NCR and VLSI Technology.

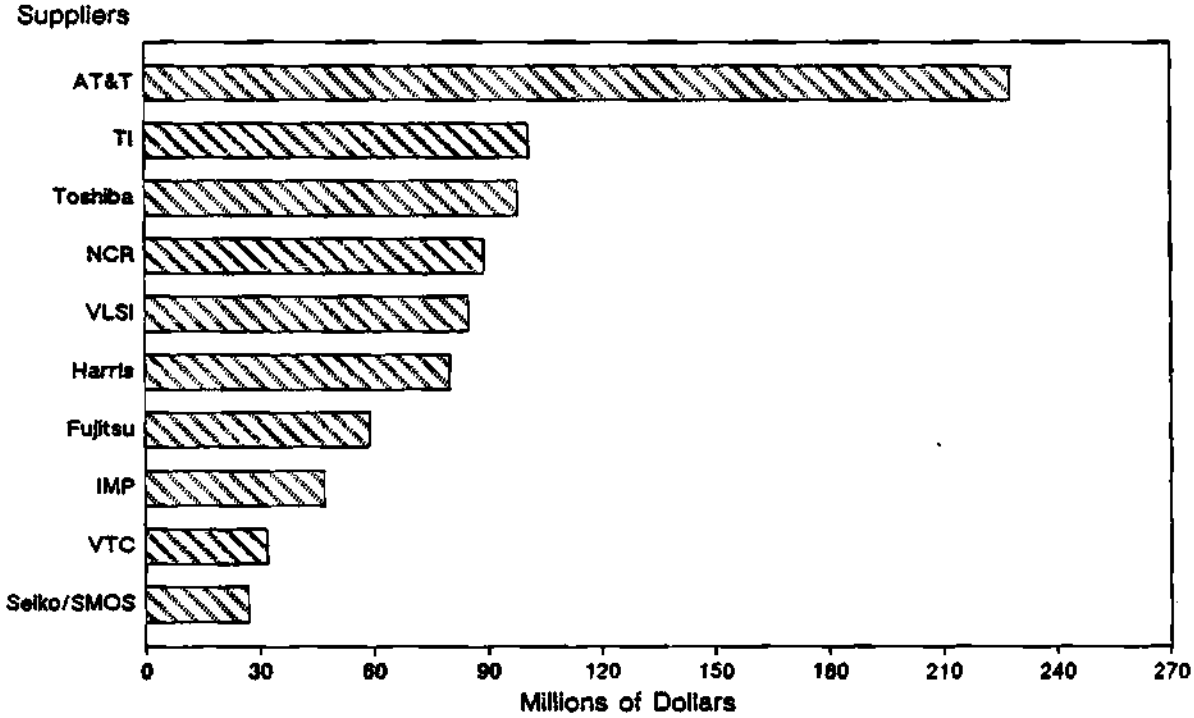
While Toshiba has made major headway in the CBIC market, we believe that a large portion of Toshiba's 1988 sales were derived from what we call optimized gate arrays. Toshiba modified some of its gate arrays that were running in high volume by removing the unused gates and routing channels; the company retooled the devices using a full set of masks. This fits the CBIC definition because they were customized using a full set of masks, yet they were not traditional CBICs. Furthermore, we believe that other Japanese companies such as Fujitsu and Seiko/SMOS generated a portion of their CBIC revenue in the same manner.

Dataquest believes that the Japanese companies will continue to focus on gate arrays, optimized gate arrays, and structured arrays (megacells embedded in gate array base wafers), and that traditional CBICs will be of secondary importance to them.

Three of the leading suppliers—NCR, VTC, and IMP—made the top-ten ranking by focusing on mixed analog/digital CBICs. Mixed analog/digital ASICs have been exclusively targeted by North American suppliers until early this year, when NEC announced its "stepped array" (structured array), which included analog cells. We believe that other Japanese companies will soon follow suit with mixed analog digital ASICs.

Figure 2

Estimated Worldwide CBIC 1988 Shipments



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Source: Dataquest May 1989

DESIGN STARTS

Design starts are a leading indicator of future product trends. Dataquest analysis indicates that there were 3,520 worldwide CBIC design starts during 1988, with 94.4 percent MOS and 5.6 percent bipolar.

Bipolar design starts consist of two types: analog and digital emitter-coupled logic (ECL). During 1988, more than 80 percent of the bipolar design starts were analog. By the early 1990s, we believe that the vast majority of bipolar design starts will be digital ECL, and that BiCMOS will emerge as the premier solution for mixed analog/digital CBICs. Texas Instruments is the first supplier to capture analog BiCMOS CBIC designs, while National and Fujitsu were the first to capture ECL CBIC designs. Table 1 shows estimated worldwide CBIC design starts from 1987 through 1992, broken down by MOS, bipolar, and BiCMOS.

Table 1

Estimated Worldwide CBIC Design Starts
by Technology

Technology	Number of Design Starts					
	1987	1988	1989	1990	1991	1992
Total	2,930	3,531	4,266	4,914	6,107	7,662
MOS	2,785	3,333	3,992	4,556	5,578	6,892
Bipolar	145	187	236	269	325	395
BiCMOS	0	11	38	89	204	375

Source: Dataquest
May 1989

CELL LIBRARY TRENDS

Microprocessors

As mentioned earlier, microprocessor core cells are a critical element in single-chip systems. The following three microprocessor strategies currently are being implemented by ASIC suppliers:

- Bit-slice processors (2901 family)
- General-purpose CISC processors
- RISC processors

The first type of processor to be included in CBIC libraries was a version of Advanced Micro Devices' 2901 bit-slice processor. The 2901 was popular because of its flexible architecture, small cell size, and fast speed. The 2901 is 4 bits wide and can be stacked to achieve 16- and 32-bit processor cores. Currently, the percentage of CBIC designs using this approach is in decline because of the emergence of general-purpose and RISC microprocessors.

General-purpose microprocessor cells such as 6502, 80C49, 80C51, and Z80 emerged in cell libraries two to three years after the first bit-slice processors. Most general-purpose microprocessor cores that have been designed in thus far have been 8 bits wide because 16-bit and 32-bit microprocessor cores have been too large and uneconomical for 2-micron and 1.5-micron CMOS libraries. As sub-1.3-micron CMOS libraries emerge, some suppliers will offer 16-bit and 32-bit microprocessor cells. Dataquest believes that the demand for these processors may not be as large as many suppliers believe, because using off-chip standard product microprocessors may be more cost-effective in many applications. The demand for general-purpose microprocessors is declining also because of the high demand for RISC microprocessor cores.

Dataquest predicts that CBIC designs with RISC microprocessor core cells will experience rapid growth in the next five years. The demand for RISC microprocessors as standard products, as well as the number of suppliers, has increased dramatically in the last two years. Many of these RISC-standard product suppliers are also CBIC suppliers. Users want to tailor the memory and logic in combination with the RISC processor in a single chip for their application. LSI Logic has already announced RISC microprocessor CBIC cells, and we believe that others will soon follow suit.

Memory

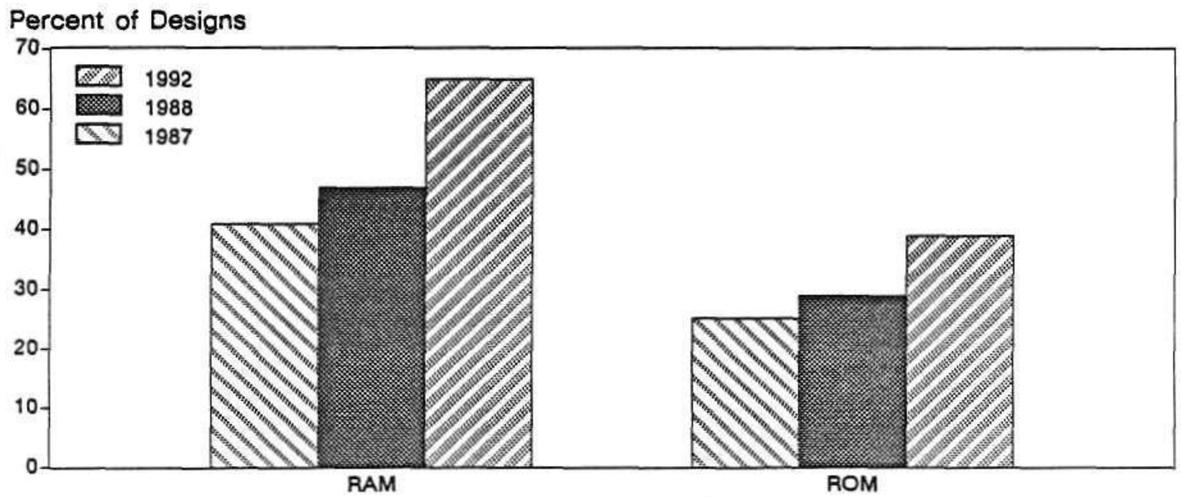
Memory cells are also important when designing single-chip systems. Almost all CBIC suppliers offer RAM and ROM in a variety of configurations. Dataquest believes that the percentage of CBIC designs that incorporate memory will increase because on-chip memory increases the system performance by reducing the number of times the processor must go on- and off-chip. This is not to say that all system memories will go on-chip, but some on-chip memory is necessary to reduce access times.

Dataquest believes that compiled cache memory will be the trend for the 1990s. End users will configure the exact amount of on-chip memory required for their unique applications. Many suppliers already offer configurable memory. Furthermore, we believe that as process geometries shrink toward the 0.5-micron level and maximum gate counts increase beyond 100,000 gates, larger cache memories will go on-chip to further reduce access times.

Figure 3 illustrates the percentage of North American CBIC designs that incorporate on-chip RAM and ROM for 1987, 1988, and 1992.

Figure 3

Estimated North American CBIC Design Starts with On-Chip Memory



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Source: Dataquest May 1989

1989 AND BEYOND

During the first quarter of 1989, many of the CBIC suppliers started to experience a slowdown in their bookings and billings. Personal computer business (including disk drives) was reported to be soft. This especially affects suppliers who are focusing on the mixed analog/digital CBICs. We believe that this is an indication that the worldwide CBIC market is decelerating, as Dataquest had predicted, and that growth rates will decline from the 33.4 percent in 1988 to 22.5 percent and 13.0 percent in 1989 and 1990, respectively.

Table 2 shows the estimated worldwide CBIC consumption forecast by technology from 1987 through 1994. Dataquest forecasts and supplier shipment revenue include nonrecurring engineering (NRE) revenue, device revenue, CAD software, and intracompany revenue (internal sales). Please note that our forecasts do not include captive manufacturing of companies that do not sell to the merchant market, such as Digital Equipment, IBM, and Northern Telecom.

Table 2

Estimated Worldwide CBIC Consumption by Technology (Millions of Dollars)

	1987	1988	1989	1990	1991	1992	1993	1994
Total	949.5	1,266.2	1,551.0	1,753.1	2,298.9	3,094.4	3,994.3	4,731.7
MOS	912.9	1,214.4	1,481.5	1,659.4	2,153.9	2,843.1	3,553.8	4,015.8
Bipolar	36.6	50.8	64.5	74.7	94.0	126.3	159.2	181.5
BiCMOS	0	1.0	5.0	19.0	51.0	125.0	281.3	534.4

Source: Dataquest
May 1989

Single-chip systems are the wave of the future. Cell-based ICs and gate arrays are in a race, with the finish line being the ultimate single-chip system solution. Dataquest believes that gate arrays and CBICs ultimately will look very similar. We believe that during the next three years, structured arrays (megacells embedded in gate array base wafers) will emerge that combine the best of both worlds. RISC microprocessor cores and memory will be embedded in the base wafer, and random logic will be routed with the final layers of interconnect. This offers the efficiency and increased speeds of cell-based ICs, along with the flexibility, shorter time to market, reduced design cost associated with gate arrays, and security from cloning.

By the 1990s, it will be very difficult to tell a CBIC product from a gate-array product. Perhaps the way that these products emerged will be only of historical interest. One thing that is certain, however, is that their impact on system design is transforming the IC industry.

Bryan Lewis

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Research Newsletter

SIS Code: Newsletter 1989
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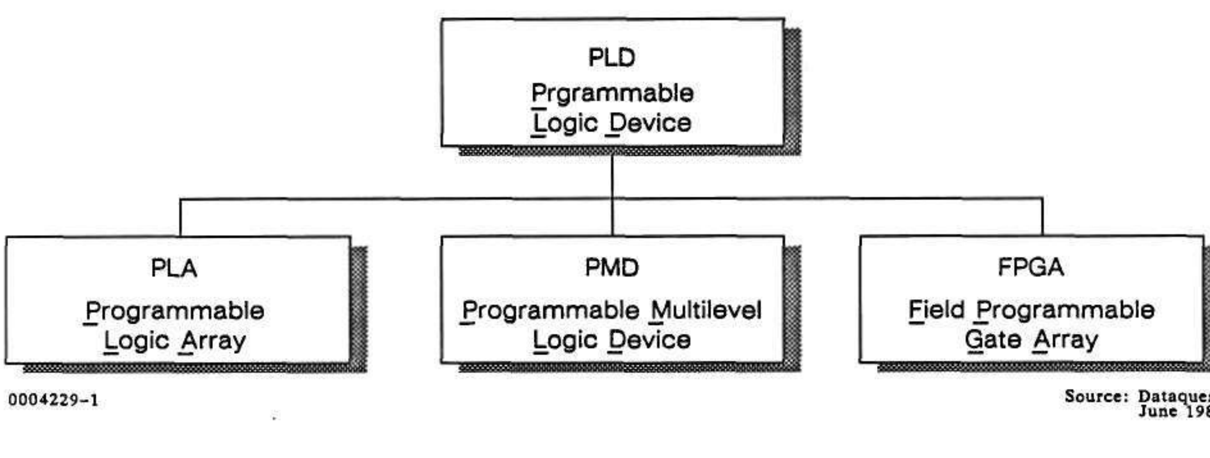
THE PLD EVOLUTION

SUMMARY

PLDs are going through a rapid evolutionary cycle. Fueled by high-density, high-performance process technologies, PLDs have evolved from low-density, low-functionality devices to products capable of implementing up to 9,000 equivalent gates. PLDs have grown from one to three basic architectures. The first is the traditional programmable logic array (PLA), which incorporates up to two levels of logic; the second is the programmable multilevel logic device (PMD), which evolved from the PLA but is capable of implementing multiple levels of logic; and the third, field programmable gate array (FPGA), traces its roots back to conventional gate arrays (see Figure 1). The latter two are capable of implementing very complex logic functions while still maintaining the inherent benefits of a PLD—low risk, low development cost, and quick time to market.

Figure 1

PLD Family Tree



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Source: Dataquest
June 1989

Although the traditional PLA still provides more than 95 percent of the 1988 PLD sales revenue, Dataquest believes that it is time to define the other PLD categories and to track and forecast them separately from the PLA. Starting this process now will provide more meaningful analysis and forecasts to our clients, while resulting in only a modest modification to historical data.

SIMPLE QUESTIONS

Simple questions deserve simple answers. The answer to the question, "What is a PLD?" is, of course, "A PLD is a programmable logic device. Next question?" However, much confusion surrounds that "simple" question today. Dataquest's definition of a PLD is quite generic. Put simply, a PLD is any device containing logic elements, which, in its packaged form, can be programmed to implement an application-specific function.

This definition covers logic devices of all complexities. A device may contain dedicated I/O with fixed internal interconnects, or it may be able to configure any pin as an input, output, or I/O with complete flexibility in interconnecting the various elements within the device. It may contain a single logic array, or it may provide a nearly infinite number of internal logical levels.

The term PLD is meant to be as generic a descriptor as possible while still referring only to logic devices. Any use of broader terminology invariably would include other programmable devices such as PROMs, EPROMs, and EEPROMs. Inclusion of the word "logic" in the general descriptor specifically excludes these nonlogic products.

Another question is: "What are the various subgroups within the PLD category?" Dataquest has observed three, which are as follows:

- PLAs—These devices have fixed or preconnected architectures capable of providing up to two levels of logic without using additional input, output, or I/O cells or pins (e.g., PAL, GAL, PEEL, and 22V10-type devices). (PAL is a registered trademark of Advanced Micro Devices; GAL is a registered trademark of Lattice Semiconductor; PEEL is a registered trademark of Integrated CMOS Technology.)

- PMDs—These are devices with primarily fixed or preconnected architectures that can implement multiple levels of logic (more than two) without using additional input, output, or I/O cells or pins (e.g., PML, PEEL-Array, and MAX-type devices). (MAX is a registered trademark of Altera Corporation; PML is a trademark of Signetics.)

- FPGAs—These devices are based on programmable interconnect technology. Typically, they are capable of implementing multiple levels of logic, as is a PMD; however, they contain no preconnected routing channels (e.g., LCA- and ACT-type devices).

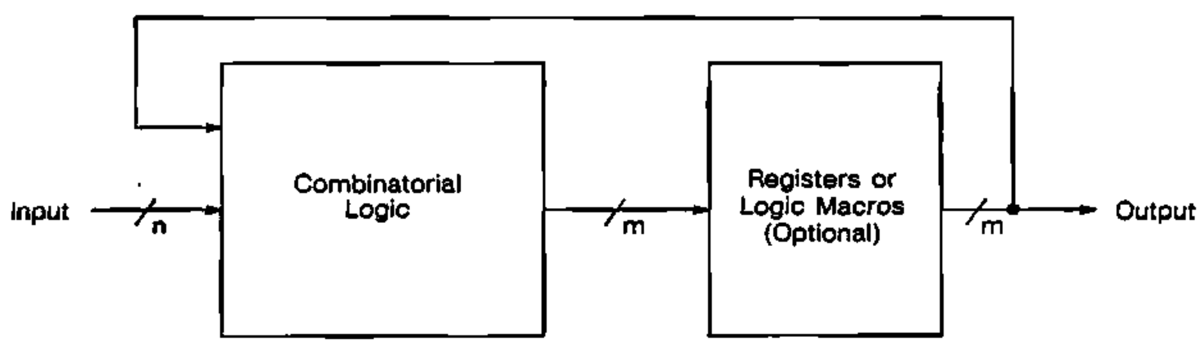
PLDs DEFINED

Programmable Logic Array (PLA)

PLA devices incorporate a one- or two-level programmable logic array with fixed interconnect paths (see Figure 2). This is the basic architecture of the original PLD product offerings, and it still is the primary contributor to the 1989 PLD sales revenue forecast of $898 million.

Figure 2

Typical PLA Block Diagram



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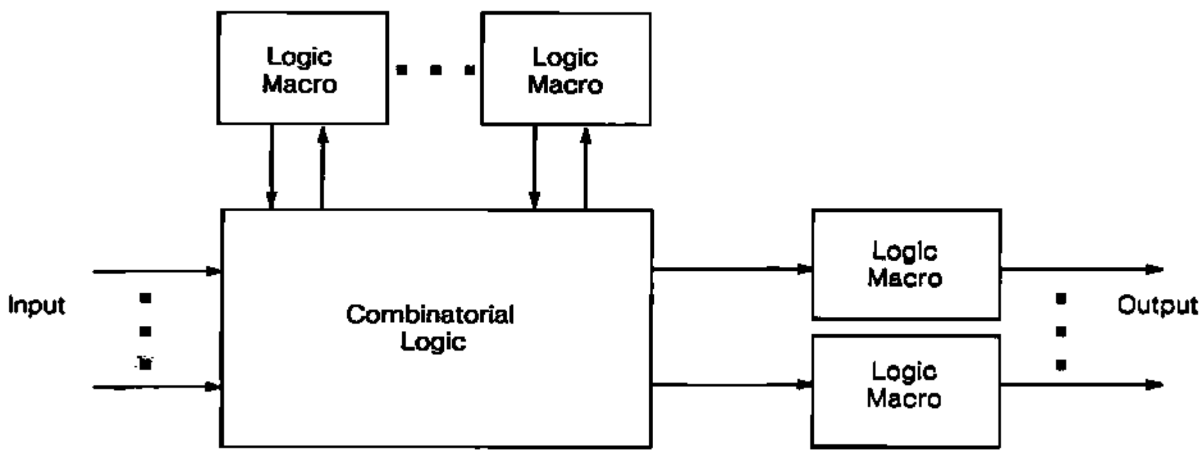
Source: Dataquest June 1989

Programmable Multilevel Logic Device (PMD)

PMDs evolved from the basic PLA (see Figure 3). However, PMDs incorporate architectures to efficiently implement complex logic functions that cannot be addressed by the basic PLA. Typically, they are preconnected, as in a PLA; however, their architecture is not limited to an and-or array feeding a register bank. PMDs can implement multiple levels of logic (more than two) without sacrificing input, output, or I/O cells or pins. Simultaneously, these devices enjoy the benefits of a basic PLA in that they are easy to understand, development tools are available, and timing is predictable.

Figure 3

Typical PMD Block Diagram



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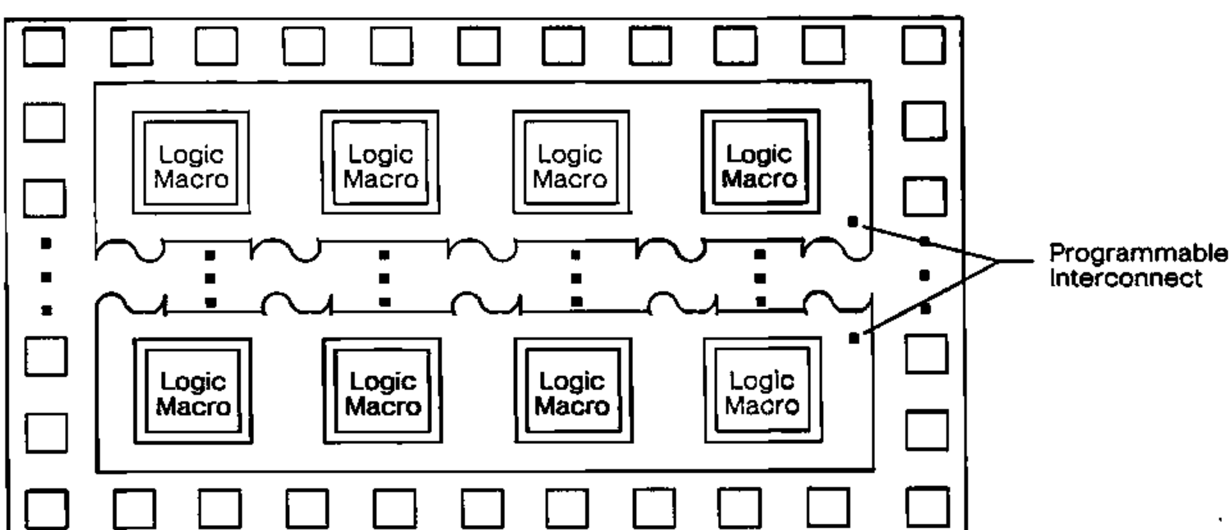
Source: Dataquest June 1989

Field Programmable Gate Array (FPGA)

FPGAs incorporate an array of programmable logic elements that are not preconnected. Interconnections between the various elements are user programmable (see Figure 4).

Figure 4

Typical FPGA Block Diagram



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Source: Dataquest June 1989

The programmable interconnect consists of predetermined levels of interconnect that can be connected to, or disconnected from, other interconnect lines as defined by the user. The device is analogous to a gate array in that it requires the use of the programmable interconnect in order to operate. The gate array analogy continues in that the performance of the device is a function of the fixed delays of the logic elements, as well as the variable delays of the interconnect paths. The interconnect delays in an FPGA can be quite substantial, as they consist of not only the resistance of the metal or polysilicon trace but also the resistance, capacitance, and propagation delay of the programmable switch used to connect one trace to another.

The development tools for FPGAs are somewhat more complex than those required for PMDs in that they must perform some form of AC timing analysis and require auto place and route software.

DATAQUEST CONCLUSIONS

The rapid transition of PLDs from low-density two-level logic replacements to devices that can implement multilevel logic functions of up to 9,000 equivalent gates demands that the PLD category be broken into finer resolution. The term "programmable logic device" (PLD) remains the generic descriptor, as any broader term does not exclude nonlogic devices. To reiterate, the PLD category easily breaks down into three distinct subcategories, as follows:

- Programmable logic array (PLA)
- Programmable multilevel logic device (PMD)
- Field programmable gate array (FPGA)

All future forecasting and product analysis will be based on these PLD definitions. Dataquest believes that this is the most comprehensive and meaningful way to analyze and forecast the PLD market.

Jerry Banks

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Research Newsletter

SIS Code: Newsletters 1989
ASIC
0004093

THE ASIC PACKAGE PROLIFERATION

SUMMARY

Surface-mount technology is now mainstream. Dataquest believes that surface-mount devices (SMDs) will continue to grow at a pace that exceeds traditional packaging and assembly techniques. As ASICs continue to grow in usage, many new surface-mount package families will be developed. This will cause multiple package choices for the same IC, resulting in difficulties for design engineers, assembly engineers, and purchasing agents (i.e., nonstandard packages for second-sourcing). It could make it more costly for semiconductor manufacturers to compete.

This newsletter will discuss the packages currently being used or under development for ASICs. It will also review the issues and choices pertaining to standards involved in ASIC packaging.

INDUSTRY ANALYSIS

Dataquest expects the worldwide integrated circuit package market to grow at a 10 percent compound annual growth rate (CAGR) from 1987 to 1992. We expect surface-mount devices to continue to show the greatest gain. They are expected to grow from the current level of 20 percent (year-end 1988) to almost one-half of all IC packages (48.4 percent) by 1992. These statistics are shown in Tables 1a and 1b.

The forecast shows the fastest growth area to be the quad flat package (76.3 percent CAGR). This is directly related to the worldwide increase in ASIC production.

Table 1a

Estimated Worldwide Shipments by Package Type (Millions of Units)

Package	1987	1988	1989	1990	1991	1992	CAGR 1987-1992
Plastic DIP	23,194	26,282	25,292	21,741	21,103	20,625	(2.4%)
CERDIP	3,346	3,738	3,274	2,778	2,783	2,727	(4.2%)
Ceramic DIP	270	277	250	231	225	203	(5.9%)
Quad/Ceramic and Plastic	284	805	1,357	1,640	2,785	4,833	76.3%
Ceramic Chip Carrier	207	315	374	383	430	562	22.1%
Plastic Chip Carrier	508	1,024	1,412	1,513	1,987	2,792	40.6%
SO	3,092	4,954	6,202	7,167	9,396	12,881	33.0%
PGA/Ceramic and Plastic	234	614	983	1,118	1,583	2,339	58.5%
Other (TAB/COB/ FCHIP)	470	860	1,224	1,480	2,249	3,817	52.0%
Others	479	657	684	596	612	608	4.9%
Total	32,084	39,526	41,051	38,647	43,153	51,386	9.9%
Total of SMT	4,561	7,958	10,569	12,183	16,847	24,885	40.4%
Percent of SMT	14.2%	20.1%	25.7%	31.5%	39.0%	48.4%	

Table 1b

Estimated Worldwide Shipments by Package Type (Percent)

Package	1987	1988	1989	1990	1991	1992
Plastic DIP	72.3%	66.5%	61.6%	56.3%	48.9%	40.1%
CERDIP	10.4	9.5	8.0	7.2	6.5	5.3
Ceramic DIP	0.8	0.7	0.6	0.6	0.5	0.4
Quad/Ceramic and Plastic	0.8	2.0	3.3	4.2	6.5	9.4
Ceramic Chip Carrier	0.7	0.8	0.9	1.0	1.0	1.1
Plastic Chip Carrier	1.6	2.6	3.4	3.9	4.6	5.4
SO	9.6	12.5	15.1	18.6	21.8	25.1
PGA/Ceramic and Plastic	0.7	1.6	2.4	2.9	3.7	4.6
Other (TAB/COB/ FCHIP)	1.4	2.2	3.0	3.8	5.2	7.4
Others	1.4	1.6	1.7	1.5	1.4	1.2
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Note: Percentages may not add to 100.0% because of rounding.

Source: Dataquest
June 1989

PACKAGE TYPES

Quad Flat Packs—Old and New

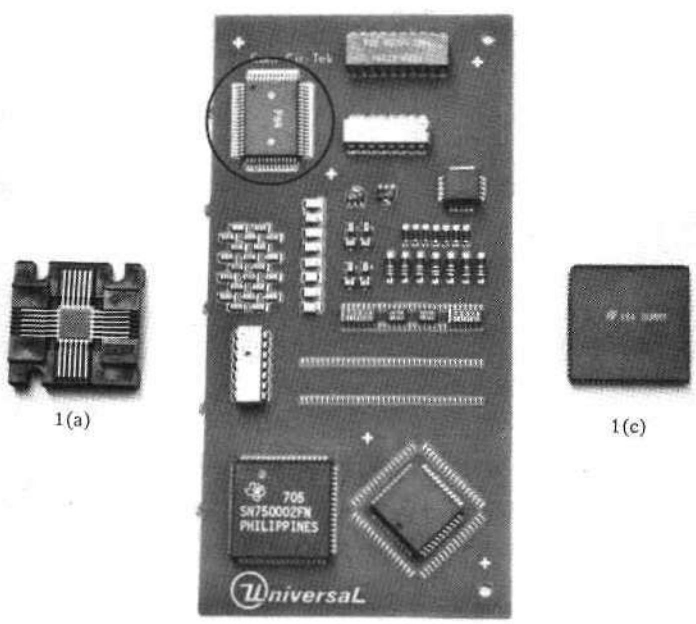
The true, original flat package is not new. Based on 50-mil lead spacing and ceramic technology, it has been and still is used primarily in military applications. The quads are mostly flat, retangular packages with bodies constructed of alumina or beryllia, with glass-to-metal seals. The long leads are splayed out away from the package body on all sides, in a gull-wing-style lead form. Lead counts generally range from 12 to 28 leads. Figure 1(a) shows a photograph of a ceramic quad flat package.

As commercial development of surface mount became prevalent in the early 1980s, the Electronic Industries Association of Japan (EIAJ) began to develop its own plastic versions of the quad flat package. These packages were based on the premise of keeping package body sizes the same and varying the lead pitch, thus increasing lead count density. Pitches of 1.0mm (39.4 mils), 0.8mm (31.5 mils), and 0.65mm (25.6 mils) form standards that define packages from 20 to 240 leads, depending upon body size. This package is also called the quad flat pack (QFP), as seen in Figure 1(b).

Expanding on this, the U.S. manufacturers agreed that placing leads on all four sides of a package was beneficial. But bending the leads underneath the package would increase density even further, and it also could be compatible with the ceramic leadless chip carrier board footprint. Thus the J-bend plastic leaded chip carrier (PLCC) was developed, with lead counts ranging from 18 to 100 leads on 50-mil center lead spacing (see Figure 1(c)).

Figure 1

Ceramic Quad Flat Package



1(a) 1(b) 1(c)

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Source: Dataquest
June 1989

However, the PLCC on 50-mil spacing did not address the increasing demand of ASIC products for higher lead counts (more than 100 pins). So, the United States through the Joint Electronics Device Engineering Council (JEDEC) developed the plastic quad flat package (PQFP) for this requirement. It uses the same plastic body sizes as the PLCC, but has leads on 25-mil centers and a molded "bumper" protruding from each corner for lead protection during handling. Lead counts for this package family range from 44 to 244 leads, and the gull wing is the preferred lead form (see Figure 2).

Figure 2

Plastic Quad Flat Package

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Source: Dataquest
June 1989

Finer Pitch Packages

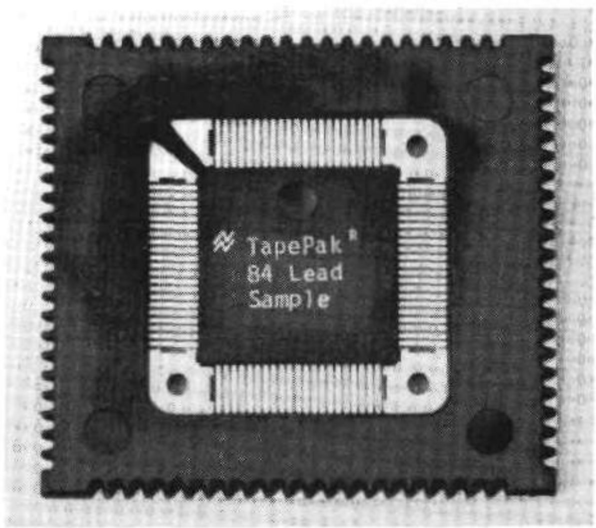
With the consumer market driving for smaller, less costly electronic gadgets and the ASIC market needing higher lead count packages, the Japanese have developed yet another package family: The shrink quad flat package (sometimes called the very small quad flat package (VQFP)). In some ways, this family is an extension of the EIAJ quad flat package (QFP). It also uses standard body sizes, but the package is one-half the thickness, and the lead pitches are reduced to 0.5mm (19.7 mils), 0.4mm (15.7 mils), and 0.3mm (11.8 mils). Lead counts range from 32 to 520 leads.

Besides those mentioned, two more surface-mount package families have recently been introduced into the market for ASIC packaging. One is TapePak developed by National Semiconductor; the other is the TQFP, a TAB quad flat pack developed by LSI Logic.

TapePak uses TAB (tape automated bonding) tape as the lead frame that is attached directly to the die. No wire bonding is used. This die-on-tape combination is then molded in plastic so that an outside ring is formed apart from the inside encapsulated die. This outside ring provides for lead protection and test capabilities. The package body is excised from the carrier ring by the pick-and-place machine and is subsequently attached to the printed circuit board. Like the Japanese quad flat pack, the TapePak family uses standard body sizes with lead counts from 40 to more than 460 leads on 20-, 15-, and 10-mil pitch. This package is shown in Figure 3.

Figure 3

TapePak



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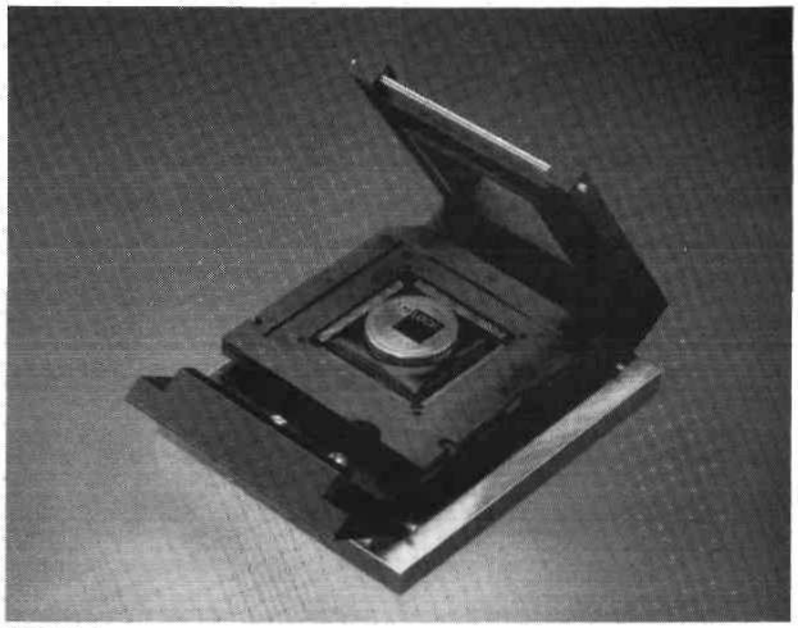
The TQFP is similar to TapePak, except for the following:

- It uses wire bonding for lead counts up to 300 and TAB from 300 to 524 leads.
- The die is encapsulated, using a liquid epoxy "blob."
- A two-piece plastic disposable slide carrier is used for lead protection and test.
- Pin counts range from 164 to 524 leads.

A picture of the TQFP is shown in Figure 4.

Figure 4

TAB Quad Flat Pack



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Higher Lead Counts and the No-Package Package

Another packaging solution to ASICs is the pin grid array. Although not assembled to the board using surface-mount technology, it does provide high-density capability to 1,000 leads and beyond. Rows of pins on 100-mil spacing (and more recently 50 mil) are arranged in a grid format to form the PGA (see Figure 5). It is available in both ceramic and plastic and is capable of dissipating more heat than most surface-mount packages.

There is one more approach to ASIC packaging that does not really use a package in the traditional sense. Chip-on-board (COB) technology enables the bare die to be attached directly to the printed circuit board. The die is attached to the board via an adhesive (usually epoxy) and wire-bonded directly to the pads or traces on the PCB. After bonding, the die is usually coated with a blob of plastic material to provide for mechanical and environmental protection.

Variations of the COB approach include TAB-on-board (TOB). Component leads are etched on single-layer or multilayer copper/copper-polyimide tape. The tape is etched to form patterns that correspond to the die pad layout. These patterned leads then make the connection between the die and the printed circuit board. Whereas wire-bonded COB is done on a chip-by-chip basis, TOB can be done via an automated, reel-to-reel process. The die-on-tape can then be attached to the board and encapsulated, as in the COB process. An example of TOB is Siemens' Micropak. A basic flow of the TOB process is shown in Figure 6.

Figure 5

Rows of Pins Forming the PGA

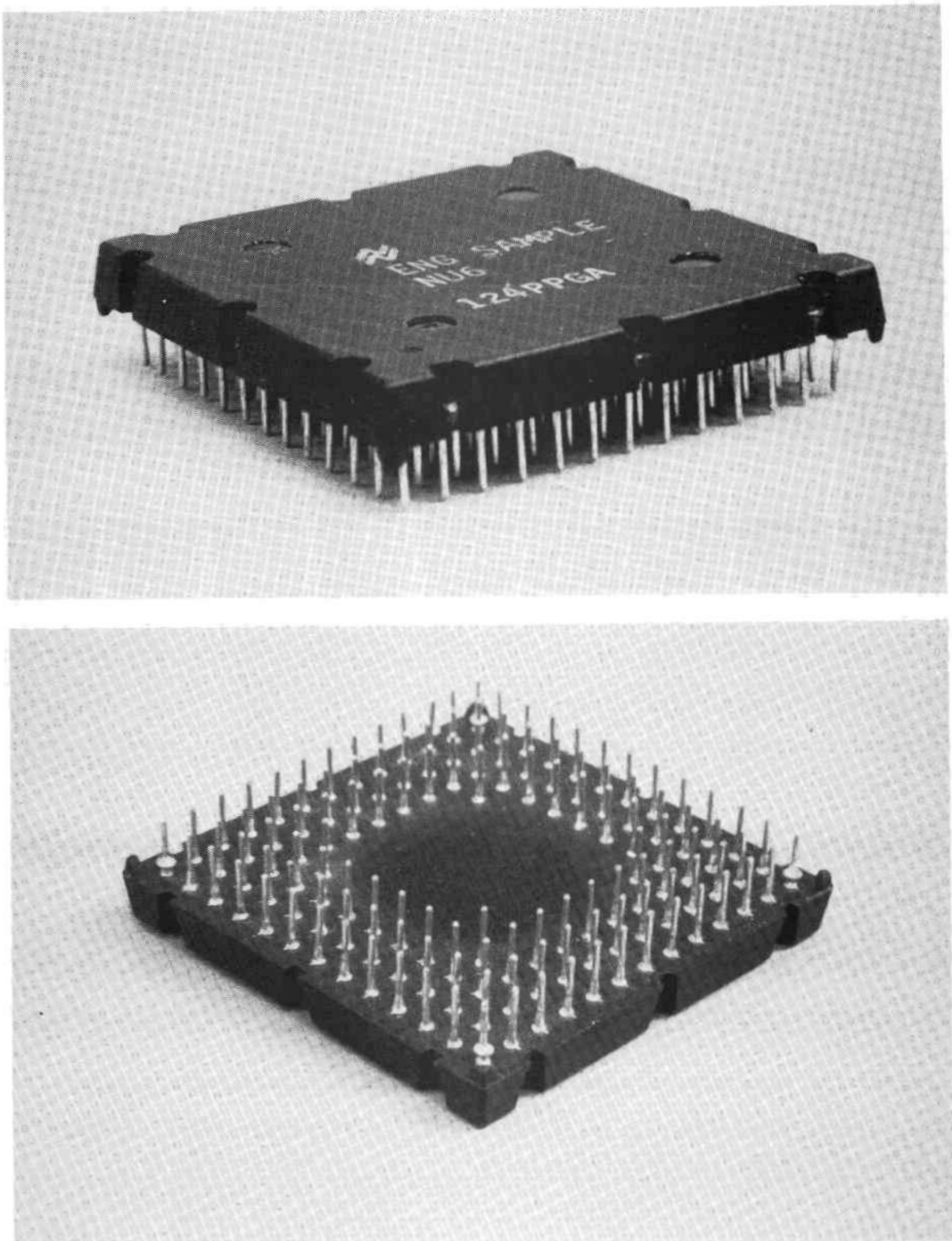

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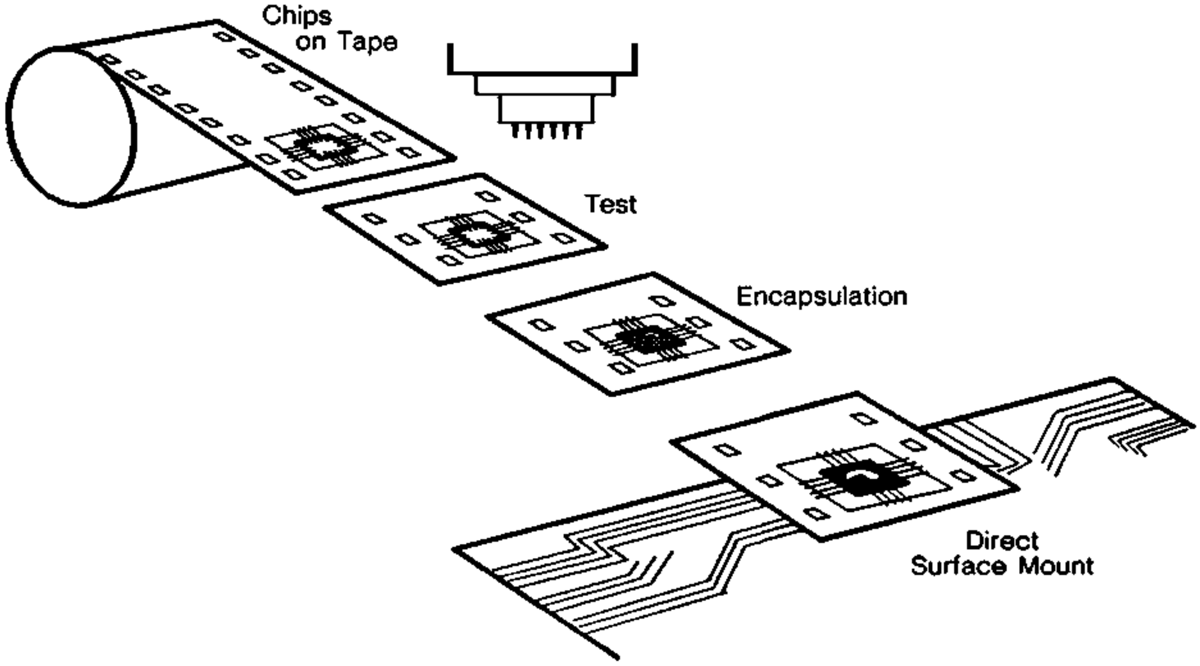
Figure 6

TOB Process (Basic Flow)



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Source: MESA Technology

Finally, flip chip is one other assembly process that can be used in ASIC packaging. This process was developed by IBM in the late 1960s and is known as C-4, for controlled-collapse chip connection. It is basically a process in which the chip is designed for facedown reflow soldering. The bond pads are bumped with solder while in wafer form. Passivation (silicon nitride) is added, and the wafer is tested via the solder bumps. After testing, the dice are placed facedown, or flipped, on the ceramic substrate, and the assembly is heated in a furnace to reflow the solder. The surface tension of the solder aligns the dice properly to the substrate. This is the maximum use of interconnect density, as no lead frame, wires, or tape are used.

A DESIGNER'S NIGHTMARE

What package should an ASIC design engineer choose? Assuming that it is an ASIC requiring 68 leads, the following choices can be made if a plastic package is desired:

- 68-lead PLCC (JEDEC)
- 68-lead PQFP (JEDEC)
- 68-lead QFP (EIAJ)
- 68-lead VQFP (EIAJ)
- 68-lead TapePak (JEDEC)
- 68-lead PPGA (JEDEC)
- 68-lead COB (No standard)
- 68-lead TOB (EIA/IPC/ASTM)
- 68-lead Micropak (Europe/DIN)

The following section discusses the above listing in more detail. Table 2 lists some common specifications for each package.

Table 2

68-Lead Package Options*

	Lead Pitch	Lead Width	Package Size	Package Height
PLCC	0.050"	0.028"	0.950" sq.	0.180"
PQFP	0.025"	0.012"	0.550" sq.	0.102"
QFP	0.0256"	0.0118"	0.394" x 0.551"	0.100"
VQFP	0.0118"	0.004"	0.197" x 0.276"	0.050"
TapePak	0.020"	0.010"	0.505" sq.	0.072"
PPGA	0.100"	0.018"	1.14" sq.	0.180"
COB	0.008"	0.0014"	0.378" sq.	0.032"
TOB	0.020"	0.010"	0.378" sq.	0.032"
Micropak	0.0197"	0.009"	0.386" sq.	0.025"

*See Appendix A attached to this newsletter.

Source: Dataquest
June 1989

One can readily see that little, if any, compatibility exists among the various packaging styles, except possibly COB versus TOB. This means that designing with an ASIC from supplier A in PQFP (JEDEC) may not be compatible with the ASIC from supplier B in QFP (EIAJ), even if the silicon function is the same. The possible result is a sole-source supplier based primarily on package offering, not silicon.

STANDARDS ACTIVITY

There has been criticism of industry organizations for their lack of leadership in setting surface-mount standards. Some is justified, as it is difficult to get everyone to agree on one of anything, whether it be process, part, or package. There are major differences between the U.S. and Japanese styles of packages. Work needs to continue to bring commonality to this area.

Package standardization is proceeding within the United States at a faster rate as surface mount becomes a proven technology. To address industry awareness and the need for areas of standardization in surface-mount technology, representatives from EIA, IPC, JEDEC, and ASTM have joined together to form the Surface Mount Council. In January 1989, they issued a document entitled "Survey Report: Surface-Mount Standards, Requirements, and Issues."

This report surveyed responses regarding the awareness and usage of 14 typical standards currently available to the industry. In the case of integrated circuit components, the survey found that only 61 percent of the respondents used all or part of the EIA JEP-95 specification (JEDEC Registered and Standard Outlines for Semiconductor Devices). Eighteen percent were aware of this standard but did not choose to use it, and 16 percent were not aware of the standard. Highlights from this report related to component standards are shown in Table 3.

Table 3

Surface-Mount Component Standards

	Use Standard	Use Part of Standard	Do Not Use	Unaware of Standard
EIA RS 481A--Taping of SM Components for Automatic Placement	30.6%	18.8%	17.6%	20.0%
EIA PDP 100--Mechanical Outline for Registered and Standard Electronic Parts	14.1%	29.4%	16.5%	27.1%
EIA JEP 95-JEDEC--Registered and Standard Outlines for Semiconductor Devices	24.7%	36.5%	17.6%	16.5%
EIA JESD 11--Chip Carrier Pinouts for CMOS 4000HC and HCT Circuits	9.4%	17.6%	16.5%	44.7%

Source: EIA/IPC Surface Mount Council

In addition, many organizations worldwide have established committees to discuss issues related to surface-mount technology. A list of these is shown as follows:

- ACPI (Automated Component Placement and Insertion Group)—c/o AMP, 1000 AMP Drive, Harrisburg, PA 17112

- ANSI (American National Standards Institute)—1430 Broadway, New York, NY 10018

- ASTM (American Society of Testing and Materials)—1916 Race Street, Philadelphia, PA 19103

- BSI (British Standards Institute)—2 Park Street, London, W1A 12BS, United Kingdom

- CSA (Canadian Standards Association)—178 Rexsdale Boulevard, Rexsdale, Ontario, Canada

- DOD (U.S. Department of Defense, Naval Publications Center)—5801 Tabor Road, Philadelphia, PA 19120

- EIA (Electronic Industries Association)—2001 Eye Street N.W., Washington, D.C. 20006

- EIAJ (Electronic Industries Association of Japan)—250 West 34th Street, New York, NY 10119

- EMPF (Electronics Manufacturing Productivity Facility)—1417 North Norma Street, Ridgecrest, CA 93555

- IEC (International Electrotechnical Commission)—3 Rue de Varembe, 1211 Geneva 20, Switzerland

- IEPS (International Electronic Packaging Society)—114 North Hale Street, Wheaton, IL 60187

- IPC (The Institute for Interconnecting and Packaging Electronic Circuits)—7380 N. Lincoln Ave. Lincolnwood, IL 60646

- ISHM-I/SMT (International Society of Hybrid, and Microelectronics, Inter-connect and SMT Division)—Box 2698, Reston, VA 22090

- SEMI (Semiconductor Equipment and Materials—International)—805 E. Middlefield Road, Mountain View, CA 94043

- SMART (Surface-Mount and Related Technologies Group)—3 Lattimore Rd., Wheathampstead, Herts AL4 8QF, United Kingdom

- SMC (Surface-Mount Club)—British Overseas Trade Board, 1 Victoria St., London SW1H 0ET

- SMC (Surface-Mount Council—Joint ASTM/IPC/EIA/JEDEC Committee)—c/o IPC, 7380 Lincolnwood Ave., Lincolnwood, IL 60646

- SMEMA (Surface-Mount Equipment Manufacturers Association)—71 West St., Medfield, MA 02052

- SMTA (Surface-Mount Technology Association)—5200 Wilson Road, Suite 107, Edina, MN 55424

- STACK (Standard Computer Komoponenten GmbH)—5775 Wayzata Blvd #700, Minneapolis, MN 55416

- VRCI (Variable Resistive Component Institute)—c/o Bourns, Inc., 1200 Columbia Avenue, Riverside, CA 92507

DATAQUEST CONCLUSIONS

We believe that package proliferation will continue as the ASIC market develops. Many new packaging schemes will arise to meet the speed, thermal, and density requirements needed. Custom and semicustom packaging, including multichip modules using COB and TOB, will become more prevalent. Procurement of semiconductor integrated circuits will depend upon package needs and functions in addition to the basic electrical parameters of the chip. As a result, purchasers will need to specify even more details when ordering.

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Jerry Banks
Mark Giudici

Appendix A

Package Standards

PLCC	JEDEC Publication 95, MO-047AA-AH
PQFP	JEDEC Publication 95, MS-069
QFP	EIAJ Specification IC-74-4, 1986
VQPF	EIAJ Specification IC-74-4-I, 1988
TapePak	JEDEC Publication 95, MO-071
TQFP	JEDEC Publication 95, under consideration
PGA	JEDEC Publication 95, MO-083
COB	Standards not available. Use TOB guidelines.
TOB	JEDEC UO-017 and Surface Mount Council--IPC/EIA/ASTM Publication SMC-TR-001, Guideline Introduction to Tape Automated Bonding Fine Pitch Technology
Micropak	Based on DIN 15851

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Research Newsletter

DATAQUEST SLASHES GATE ARRAY DESIGN START FORECAST

SUMMARY

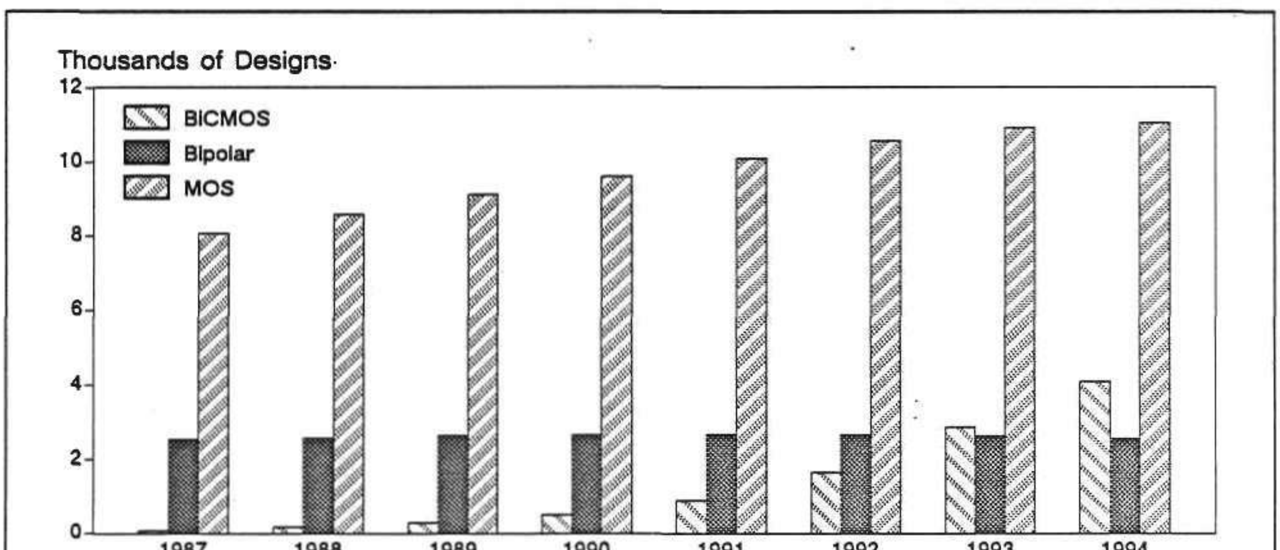
Dataquest has made a major change to its gate array design start forecast: We have decreased the five-year projection by 10,000 designs! After extensive analysis of both gate array suppliers and users, we concluded that there will be far fewer gate array design starts in the future than originally projected, primarily due to increasing chip complexity, field-programmable gate arrays (FPGAs), and chip sets/standard products.

As Figure 1 illustrates, we forecast that MOS gate array designs will have modest growth, bipolar (ECL) will be flat, and the real growth will be in BiCMOS.

INCREASING COMPLEXITY

System designers now are replacing two to three low-complexity gate arrays with one high-complexity array, which is slowing the overall growth of gate array design starts. Although complexity is increasing in all technologies, we will discuss increasing complexity in terms of MOS gate arrays in North America. During 1986, the average number of utilized gates per MOS gate array design was 5,100; in 1987, it was 6,300; in 1988, 7,700; and in 1989, it is estimated to be 9,900.

FIGURE 1
Estimated Worldwide Gate Array Design Starts by Technology



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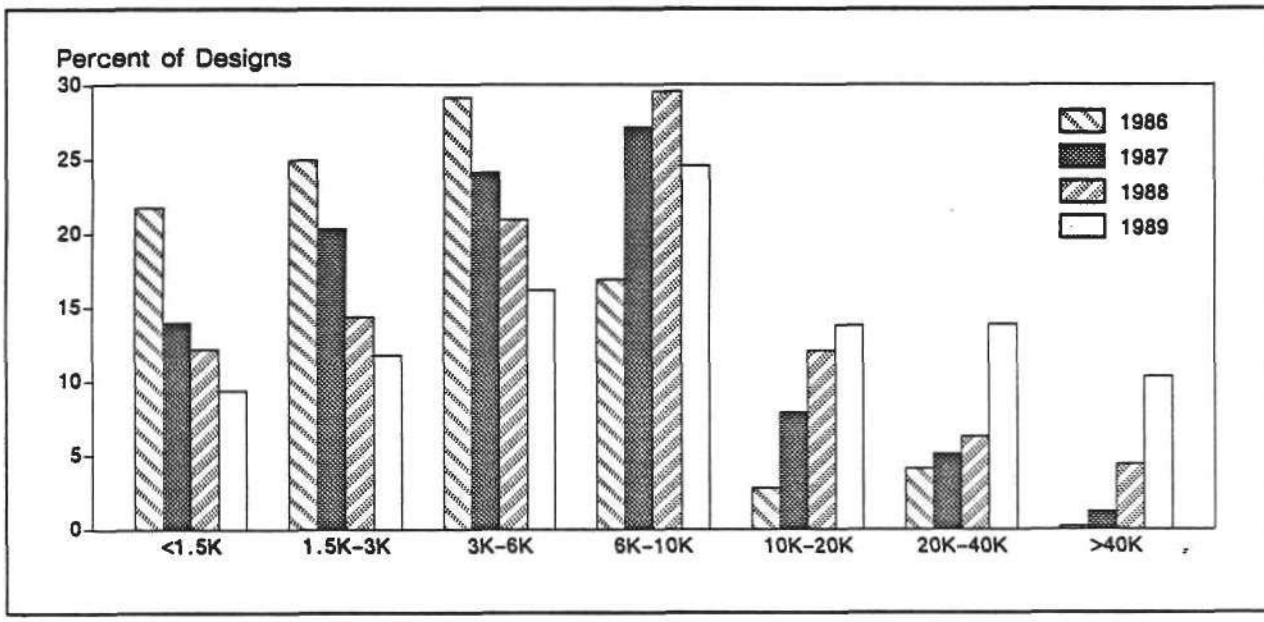
Source: Dataquest
November 1989

Dataquest Incorporated, 1290 Ridder Park Drive, San Jose, CA 95131-2398 / (408) 437-8000 / Telex 171973 / Fax (408) 437-0292

FIGURE 2
Estimated North American MOS Gate Array Design Starts by Gate Count



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Source: Dataquest
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Figure 2 illustrates the percentage of MOS gate array designs captured in North America by available gates from 1986 through 1989.

Furthermore, most of the 1992 MOS gate array designs will have 20,000 to 100,000 available gates, as shown in Figure 3. Fujitsu, LSI Logic, Motorola, NEC, Toshiba, and VLSI Technology are some of the leading suppliers of high-complexity arrays.

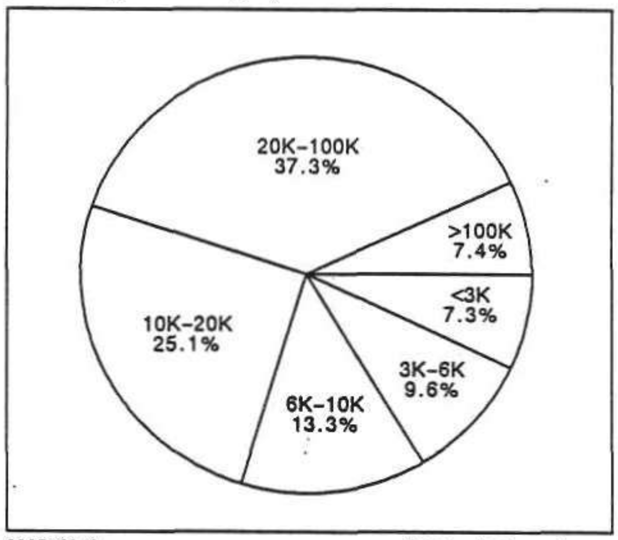
ENCROACHING TECHNOLOGY

Field-Programmable Gate Arrays

FPGAs also are having an impact on the growth of gate array design starts. FPGAs are affecting low-density/low-volume gate array designs today; they also have the potential to impact medium-density/medium-volume gate array designs in the future.

Dataquest estimates that more than 4,000 cumulative FPGA development systems were installed through mid-1989. If each system was used for only 2 designs a year, that would equal 8,000 FPGA designs total. Most of the FPGA designs that have been captured to date have less than 2,500 gates.

FIGURE 3
Estimated 1992 North American MOS Gate Array Design Starts by Gate Count (Percentage of Designs)



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Today, most FPGAs are used for prototyping or for applications that require less than 5,000 units for the life cycle of the design. In the past, gate arrays were used for breadboarding, which tests the logic of the system for problems. System designers now use FPGAs for this application, which saves them both development time and NRE fees.

Figure 4
Estimated 1989 North American MOS Gate Array Units per Design

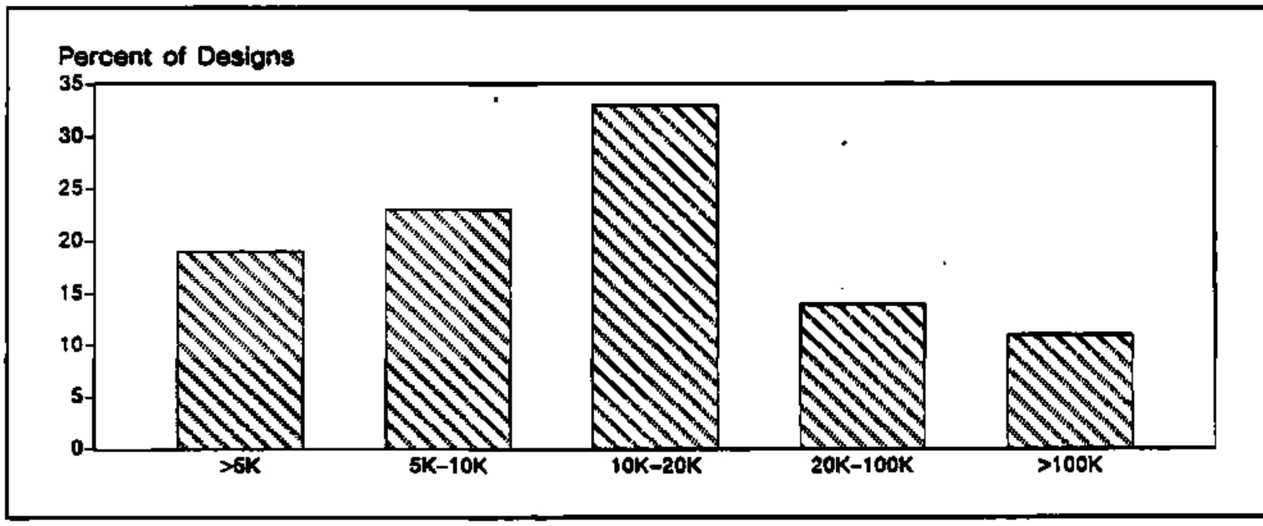

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Table 1
Worldwide Logic Chip Set Forecast (Millions of Units)

	1987	1988	1989	1990	1991	1992	1993	CAGR 1987-1993
DOS PC Shipments	9.6	12.3	13.8	15.4	17.1	18.7	20.6	13.6%
Chip Set Shipments	3.1	8.0	12.7	15.1	16.9	18.5	20.4	36.8%
Saturation	33%	65%	92%	98%	99%	99%	99%	

Source: Dataquest
November 1989

Because the current price per gate for FPGAs is approximately 0.60 to 0.80 cents per gate and a gate array costs approximately 0.15 to 0.20 cents a gate, it is reasonable to assume that most FPGA designs have less than 5,000 units. Gate arrays are not as cost effective in low volumes because the NRE fee is only amortized over a low number of devices.

It is interesting to note that only 18 percent of the 1989 North American gate array design starts in production have unit volumes of less than 5,000 units for the life cycle of the design. If future FPGA pricing falls to less than 0.30 cents per gate during the next two years, FPGAs will affect gate array designs with unit volumes in the 5,000 to 10,000 range, which accounts for an additional 23 percent of the 1989 designs.

Figure 4 illustrates the percentage of 1989 MOS gate array designs in production by unit volumes for the life cycle of the design.

Chip Sets/Standard Products

While FPGAs are attacking low-volume applications, chip sets or standard products are attacking high-volume applications. The personal computer (PC) clone market is a prime example. The goal of a PC clone designer is to make the lowest-cost compatible system. With the use of chip sets and standard products, the system designer can get the same features as in a gate array to make the system compatible without paying the $15,000 to $75,000 NRE fees associated with each gate array.

Dataquest believes that more high-volume gate array applications will be recognized over the next five years and will be lost to chip sets. ASIC suppliers must counter this trend by also offering chip sets and standard products.

Table 1 illustrates the forecast saturation of logic chip sets in personal computers over time.

DATAQUEST CONCLUSIONS

Although Dataquest still believes that gate arrays will remain the dominant ASIC technology over the next decade, we expect overall gate array design start growth to be modest. Key products encroaching on gate arrays include FPGAs, cell-based ICs (CBICs), and chip sets/standard products. Gate array design start growth is slowing not only because of encroaching products but also because of increasing integration per chip.

What does all of this mean for the future ASIC suppliers? They must form close relationships with the end users so they can determine what standard products to offer and what cell libraries to build. We believe that suppliers and users will look toward embedded arrays for increasing integration (i.e., megacells such as RAM and RISC microprocessors embedded in gate array base wafers). BiCMOS will be the new frontier for future ASIC suppliers. Hard times may be ahead for many gate array suppliers as a result of low or negative margins. Service will rise in importance as gate array designs become more scarce.

Bryan Lewis

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Research Newsletter

MIXED-MODE ASICs: AN EDUCATIONAL CRISIS!

SUMMARY

The search for higher levels of integration continues at a fever pitch. Since the advent of the semiconductor era, system designers have looked for functions that can be integrated economically into a minimum number of devices. This effort spawned the evolution from single transistor devices, to small-scale integration (SSI) devices of less than 100 transistors, to today's ultralarge-scale integration (ULSI) devices of more than 1 million transistors.

Until now, the focus of the integration movement has been primarily digital logic components. As a result of this focus, the integration of pure digital logic is fairly well understood and has been widely implemented. Because of this success, the search for other functions that can be integrated has broadened in scope, pinpointing analog as the next focus of the integration movement. This focus is generating an increasing demand for ASICs that mix digital and analog functions on the same IC. Unfortunately, this demand is well ahead of the tools, testers, and user-based mixed-mode design and test expertise required before mixed-mode ASICs will have a significant impact on the ASIC market. A major educational program is necessary to retrain today's digital design experts to become mixed-mode design experts. Also, universities must incorporate mixed-mode design into their engineering curriculums.

A MEASURE OF PROGRESS

Advances in both IC manufacturing technology and development tools have allowed IC manufacturers to offer digital ASICs with extremely high density. These advances have provided system designers with the ability to integrate unprecedented amounts of digital logic into a minimum number of devices.

The personal computer is a good indicator of the advances made in integrating digital logic. As is shown in Figure 1, in 1984 an AT personal computer motherboard used 125 standard logic devices and 7 ASICs. A 1989 version of the AT, as shown in Figure 2, uses only 9 standard logic devices and 9 ASICs. This evolution represents more than an order-of-magnitude decrease in the standard logic component count as well as a 75 percent reduction in total board space.

Included in the standard logic parts count are drivers and buffers that typically are not integrated into an LSI component. Included in the ASIC parts count are three PLDs used for decoding and other specialty functions that are not easily integrated. Clearly, as there is very little standard logic left to integrate, system designers must look elsewhere if they wish to continue on the integration path.

WHAT'S NEXT?

The personal computer motherboard example illustrates a general industry trend toward digital integration. It applies equally well to add-in cards or systems that require both digital and analog functions. However, while the board space required to implement logic functions has been shrinking dramatically, the space required by the analog elements—such as converters and interface circuits—has remained relatively constant. Consequently, analog components use an increasingly larger percentage of a given system's board space. System designers now are faced with the problem of how to reduce the board space required by these analog components.

When they are used for interface functions such as converters or level shifters, analog components are tied quite closely to the digital logic operating on the converted data. Each device is optimized for its particular function. In these types

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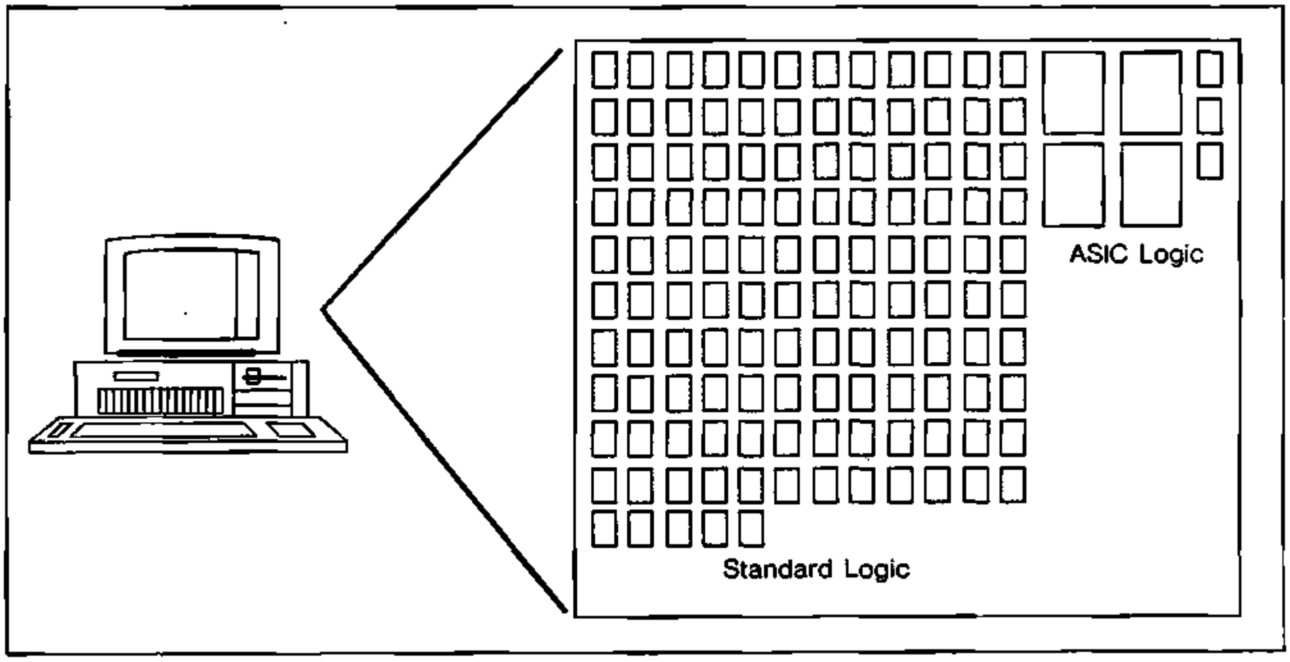
FIGURE 1
AT Personal Computer Logic Components—1984



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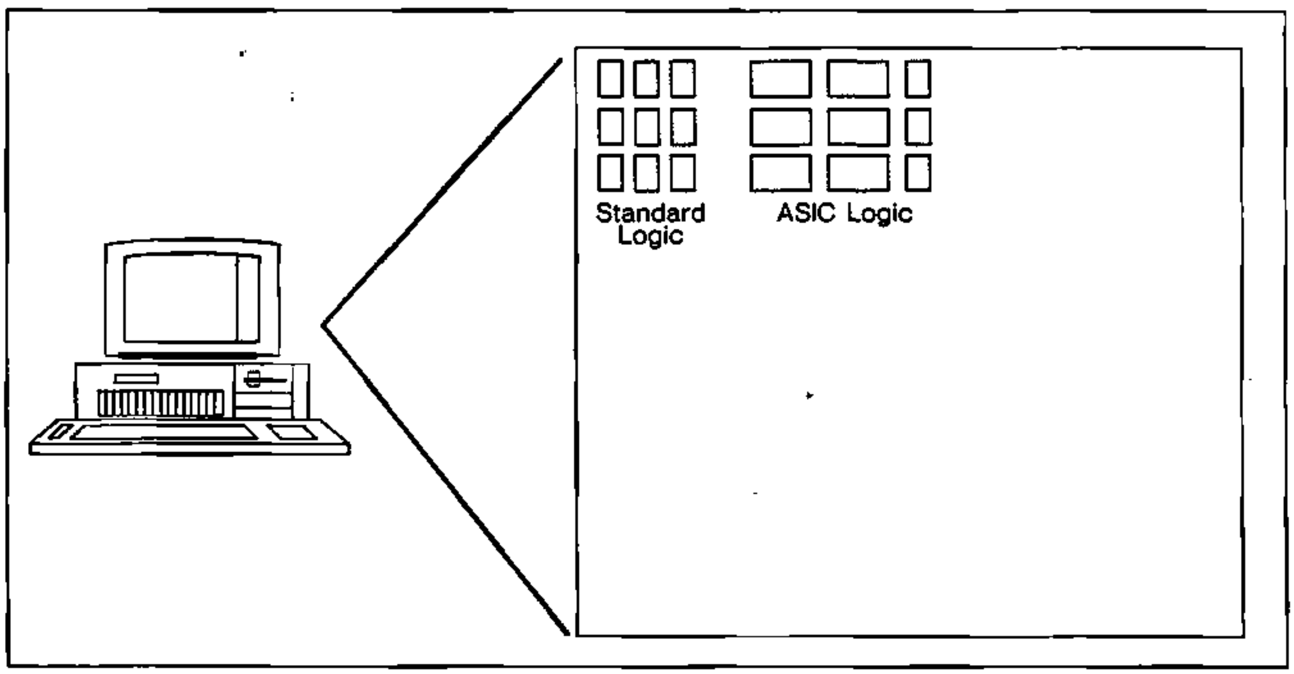
Source: Dataquest
October 1989

FIGURE 2
AT Personal Computer Logic Components—1989



0005234-2

Source: Dataquest
October 1989

of applications, it is difficult to envision large analog ASICs partitioning all analog functions into one or two devices that are separate from the digital logic devices.

System partitioning is much more straightforward if the analog and digital functions can be integrated together. If we assume that the traditional benefits of integration apply to products mixing analog and digital functions, we will continue to see systems that are smaller, cheaper, faster, more powerful, and more reliable.

"Obvious" Answers Are Not Always Easy

This conclusion is, of course, "obvious" to everyone; many industry observers are expecting mixed-mode ASICs to achieve spectacular growth rates. However, the path to mixed-mode ASICs is fraught with fundamental problems yet to be overcome. Among these problems are the following:

- Mixed-mode development tools
- Mixed-mode testers
- Mixed-mode test methodology
- Mixed-mode design expertise

Although they are still in their infancy, progress is being made in the areas of mixed-mode tools and testers. Start-up companies and divisions of larger companies have dedicated significant resources to solving the problems. As a result, tools are available for an experienced analog designer to design a mixed-mode ASIC. However, these ASIC designs are primarily full-custom designs because of the amount of tweaking required in design and layout. Mixed-mode testers are becoming available now; however, testing still requires a tremendous amount of interface between supplier and user.

Education, Education, Education

Overcoming the third and fourth problems—mixed-mode test methodology and limited mixed-mode ASIC design expertise—are more difficult and challenging tasks. These two problems can be overcome only by retraining the existing design community and directing the universities to broaden their engineering curriculums to include all phases of mixed-mode design and test. This retraining is essential for the broad-based use of mixed-mode ASICs. The growth of mixed-mode ASICs will be affected directly by the speed with which mixed-mode ASIC design and test expertise can diffuse into the realm of ASIC designers.

No Quick Fixes, No Gimmicks

Although the development of efficient mixed-mode ASIC design and test tools is essential to grow the mixed-mode ASIC market, these tools will serve only to make today's designers more efficient. By themselves, tools cannot turn today's broad base of digital design experts into mixed-mode design experts. Educating designers in the fundamental basics of mixed-mode design and test is essential to capitalize on the market demand for mixed-mode ASICs. Those companies—both suppliers and users—that do not act to remedy the problem will be left behind in the race for faster, cheaper, smaller, and more powerful electronic systems.

DATAQUEST CONCLUSIONS AND RECOMMENDATIONS

Dataquest believes that education must be provided by the users, the suppliers, and the universities. Users must utilize their in-house analog design talent to bring their digital designers up to speed and gain an advantage over their competition. Suppliers must train their customers in mixed-mode design and test techniques if they want to stimulate growth of the mixed-mode ASIC market. And universities must realize that the time for purely digital designers has passed; their engineering graduates must be technically versed in mixed-mode design methodology.

Today's designers must be conversant in both digital logic and analog design. They also must be aware of the problems and/or techniques of mixing both technologies on the same substrate. Once the basic principles are understood, the tools are essential to improve efficiency. Until this occurs, each mixed-mode design will be a costly and time-consuming event.

Jerry Banks

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Research *Bulletin*

ASIC TRENDS OF THE 1990s

Application-specific integrated circuits (ASICs) are transforming the IC industry. System designers now can incorporate the microprocessor, memory, and logic on a single chip, thus reducing the size and cost of the system while improving its performance and reliability.

This research bulletin highlights the most important potential ASIC trends of the 1990s and presents a new ASIC forecast. Each of the following ASIC trends will be explored in depth by Dataquest analysts in subsequent ASIC newsletters:

- BiCMOS ASICs will be the new frontier for future ASICs; they blend the speed of bipolar with the density and low power consumption of CMOS.
- Complex PLDs such as field programmable gate arrays (FPGAs) and programmable multilevel logic devices (PMDs) will be viewed as low-risk entries into ASICs as well as nice prototyping tools. We believe that complex PLD pricing will continue to decline at a rapid rate, closing the gap on gate array pricing and thus increasing their cost-effectiveness in low- to medium-volume applications.
- System designers are demanding on-board cache memory and increased performance, which will fuel the growth for embedded arrays (megacells embedded in a gate array base wafer) and cell-based ICs.
- RISC will be the ASIC microprocessor of choice as system designers tailor their system designs to specific applications.
- As system designers strive toward single-chip system solutions, 100,000-gate ASICs will become popular.
- Reducing on-chip interconnect delays will increase in importance as ASIC suppliers move toward submicron geometries.
- ASIC suppliers will need to support open-architecture electronic computer-aided engineering (ECAE). System designers have a long list of demands including multilevel simulation (VHDL combined with gate level), seamless integration across all ECAE products (common databases), and top-down hierarchical design tools (logic synthesis in combination with logic optimization).
- Test will become a critical issue as densities climb, and we believe that JTAG will become an industry standard.
- Packaging also will be a critical issue for high-density products. We believe that suppliers must exploit state-of-the-art packaging technology now or they will not be well positioned for the 1990s.

Table 1 shows Dataquest's new ASIC forecast. The forecast includes NRE revenue, CAD software revenue, intracompany revenue (internal sales), and device production revenue. This forecast does not include the captive manufacturing of companies such as Digital Equipment, IBM, and Unisys that do not sell to the merchant market.

This list of trends proves that ASIC suppliers and users, as well as Dataquest analysts, have many issues to address in the 1990s. The ASIC market has rewards for those who effectively address the issues in a timely manner.

Bryan Lewis
Brand Parks
Jerry Banks

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TABLE 1
Estimated Worldwide ASIC Consumption by Technology (Millions of Dollars)

	1987	1988	1989	1990	1991	1992	1993	1994	CAGR 1989-1994
Total ASIC	$6,173.4	$7,453.7	$8,736.8	$9,371.7	$11,450.4	$14,130.1	$17,353.7	$19,647.0	17.6%
MOS	4,362.7	5,367.9	$6,435.5	6,899.9	8,432.2	10,365.3	12,517.6	13,818.7	16.5%
Bipolar	1,769.7	1,998.0	2,122.7	2,140.4	2,389.1	2,599.2	2,785.9	2,941.2	6.7%
BiCMOS	41.0	87.8	178.6	331.4	629.1	1,165.6	2,050.2	2,887.1	74.5%
Gate Arrays	$2,274.9	$2,992.5	$3,766.0	$4,303.6	$ 5,573.4	$ 7,187.4	$ 9,198.5	$10,641.9	23.1%
MOS	1,408.8	1,940.5	2,500.4	2,798.2	3,634.6	4,612.9	5,716.8	6,400.0	20.7%
Bipolar	825.1	965.2	1,092.0	1,193.0	1,360.7	1,533.9	1,712.8	1,889.2	11.6%
BiCMOS	41.0	86.8	173.6	312.4	578.1	1,040.6	1,768.9	2,352.7	68.4%
Programmable Logic	$ 483.0	$ 670.0	$ 816.0	$ 872.0	$ 1,119.0	$ 1,463.0	$ 1,871.0	$ 2,098.0	20.8%
MOS	79.0	163.0	301.0	419.0	600.0	927.0	1,344.0	1,595.0	39.6%
Bipolar	404.0	507.0	515.0	453.0	519.0	536.0	527.0	503.0	(0.5%)
Cell-Based ICs	$ 949.5	$1,266.2	$1,551.0	$1,753.1	$ 2,298.9	$ 3,094.4	$ 3,994.3	$ 4,731.7	25.0%
MOS	912.9	1,214.4	1,481.5	1,659.4	2,153.9	2,843.1	3,553.8	4,015.8	22.1%
Bipolar	36.6	50.8	64.5	74.7	94.0	126.3	159.2	181.5	23.0%
BiCMOS	0	1.0	5.0	19.0	51.0	125.0	281.3	534.4	154.6%
Full-Custom ICs	$2,466.0	$2,525.0	$2,603.8	$2,443.0	$ 2,459.0	$ 2,385.3	$ 2,289.9	$ 2,175.4	(3.5%)

Source: Dataquest
October 1989

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Research Newsletter

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ASIC
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DRAMs AND ASICs AS TECHNOLOGY DRIVERS

The topic of "DRAMs and ASICs as technology drivers" was presented at Dataquest's annual SEMICON/West '89 seminar. This newsletter presents the highlights of the presentation, which are as follows:

- Memory and ASIC markets
- Industry structure
- Semiconductor technology drivers
- DRAM technology and process equipment
- ASIC technology and process equipment
- Special ASIC process innovations
- Fab configuration
- Synergy and convergence

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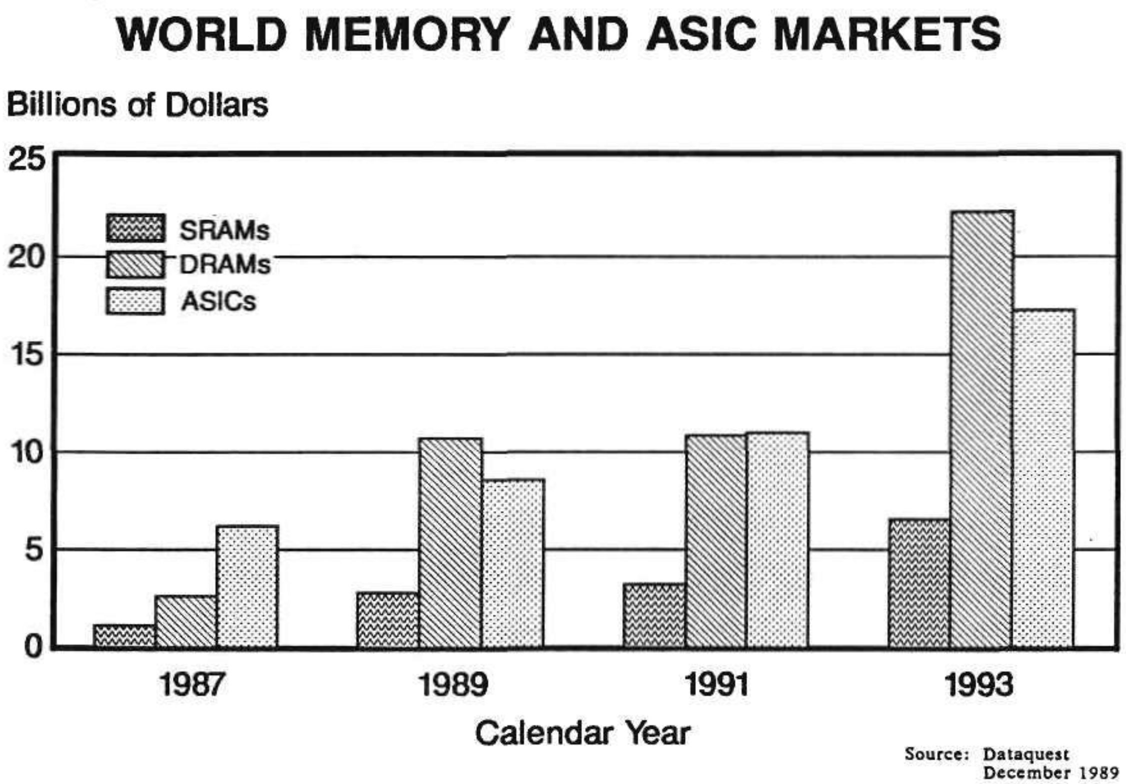


Key Points:

- The world markets for DRAM, SRAM, and ASIC products are substantial and are expected to grow rapidly.

- The worldwide DRAM market is expected to grow to $22.3 billion by 1993. It is fueled by high-performance computers' insatiable demand for memory. Also, new applications for DRAMs such as fax machines, laser printers, copiers, and high-definition television (HDTV) are expected to broaden the use of DRAMs.

- Because of their ability to reduce system cost and improve system performance, ASICs will continue to gain broad acceptance in various industry segments such as computers, telecommunications, transportation, industrial, and consumer applications. The worldwide ASIC market is projected to grow to $17.3 billion by 1993.

Industry Structure

DRAMs	ASICs
Capital intensive	Customer-service intensive
Oligopolistic structure	Numerous competitors
Low product differentiation	High product differentiation
Vertically integrated companies	Small merchant companies and large captive companies
One product per technology generation	Hundreds of low-volume products for each technology generation

Source: Dataquest
December 1989

Key Points:

- The DRAM industry is characterized by high capital costs, which pose formidable barriers to entry for small, new companies. Only vertically integrated companies with deep pockets can absorb the huge development and plant set-up costs associated with megascale DRAM factories. DRAM manufacturers need to ramp up production quickly to gain market share and recoup their investments, so that they can migrate to the next generation of DRAM technology.

- In contrast, the ASIC industry is characterized by small to medium-size merchant companies that focus on products that are driven by time-to-market and customer-service considerations. Low entry barriers imply a proliferation of ASIC vendors that are geographically dispersed in order to be close to the customers.

Technology Drivers

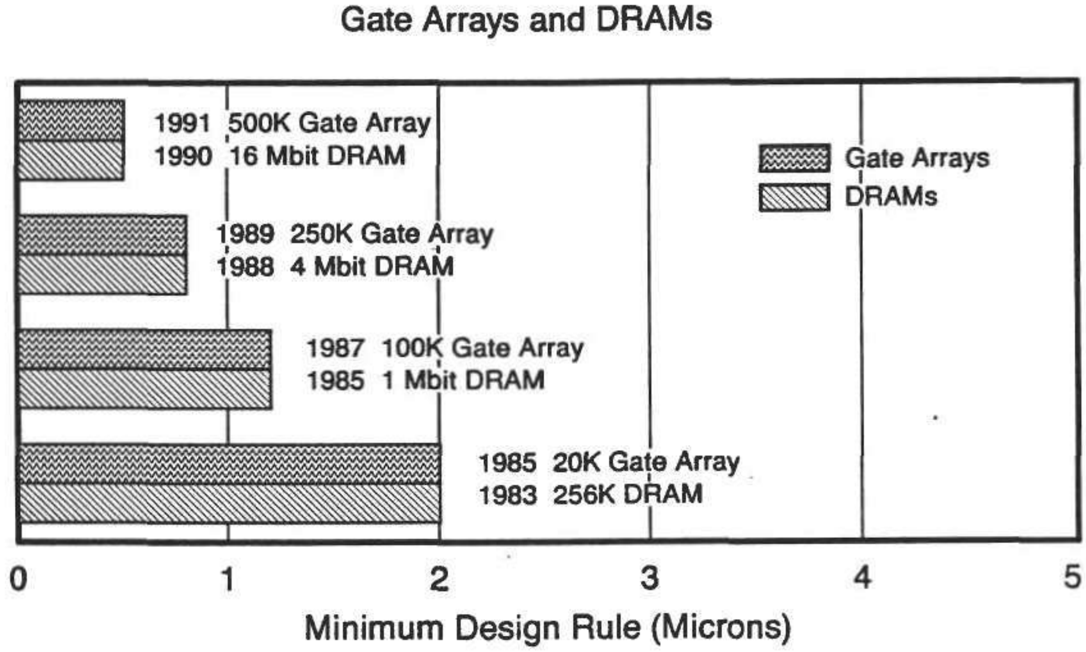
DRAMs	ASICs
High volume/low cost	Low-volume/time to market
Advanced device structures	Design automation
Submicron lithography	Multilevel interconnect
"Hardwired" automation	"Flexible" automation

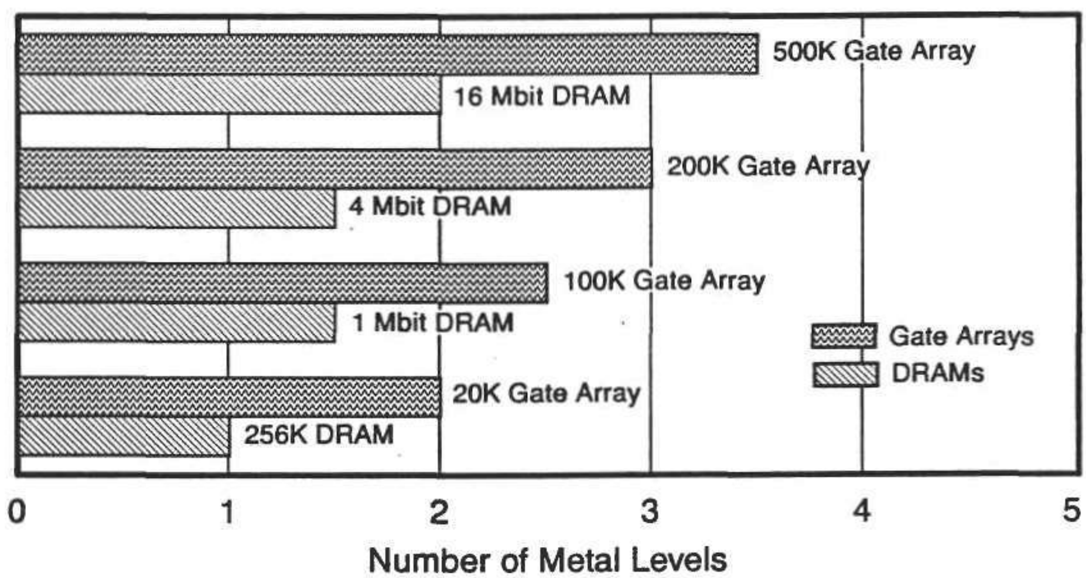
Source: Dataquest
December 1989

Key Points:

- DRAM technology drives the development of silicon device structures such as trench and stacked capacitors and submicron gate transistors with high packing density.
- ASIC technology drives multilevel interconnect technology because of the intensive random logic routing requirements of system-on-a-chip products.

Minimum Design Rules and Metal Levels





Source: Dataquest
December 1989

Key Points:

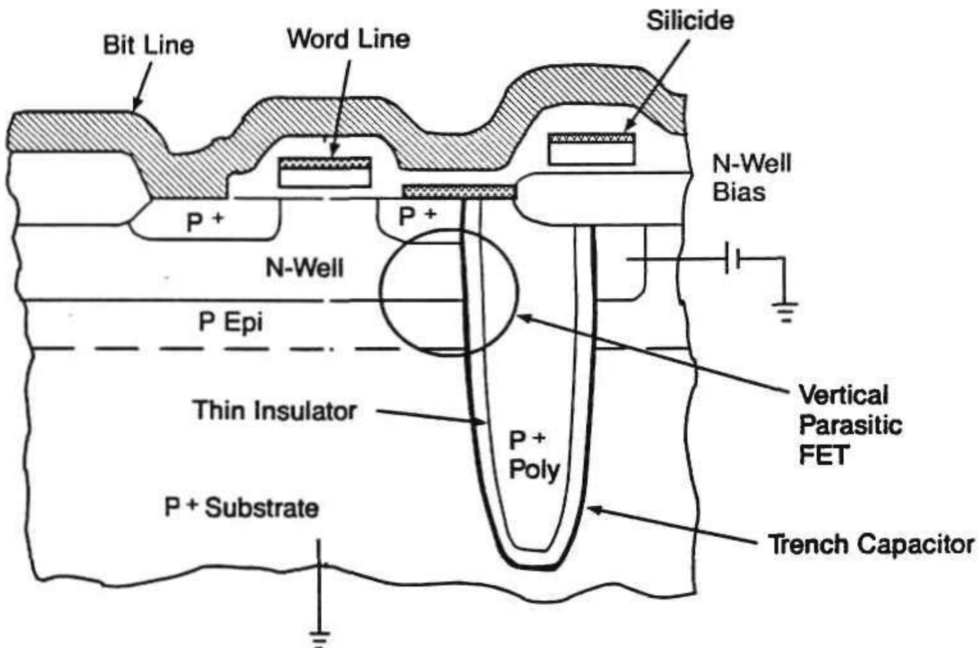
- DRAMs continue to have a two-year lead over ASICs in minimum feature size. Submicron lithography processes are first applied to DRAMs and then transferred to ASICs.

- Even though ASICs lag behind DRAMs in minimum feature size, they lead in the use of multiple levels of interconnect. ASIC technology drives advances in planarization, CVD oxides, and refractory metals such as tungsten plugs.

Typical 4Mb DRAM Technology and IBM's 4Mb DRAM

Features	Process/Equipment Needs
⬭ High-quality EPI	Economical EPI process?
⬭ Retrograde wells	High-dose/high-energy implants
⬭ Deep capacitor trenches	High throughput, low RIE damage
⬭ Stacked capacitor	Conventional etch process
⬭ Oxide-nitride-oxide dielectric	Vertical furnace or RTP
⬭ Trench refill CVD oxide	TEOS conformal CVD reactors
⬭ 0.8-micron gate length	Submicron capability steppers

Source: Dataquest
December 1989



Source: IEDM

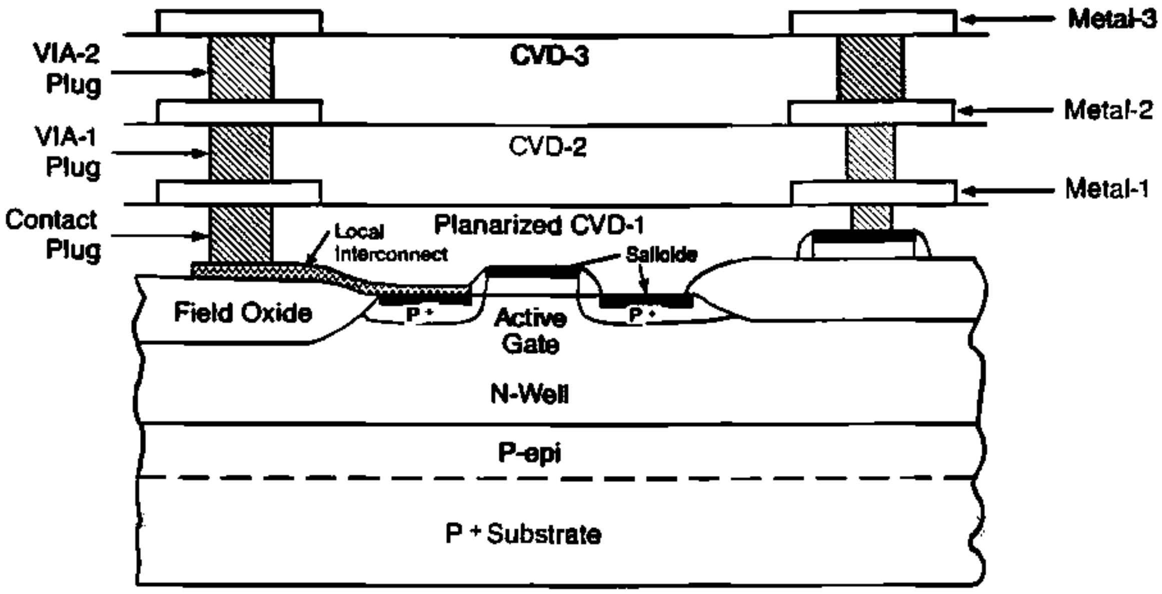
Key Points:

- DRAM technology has spurred the development of 3-D silicon structures such as trench capacitors and stacked capacitors. The etch and deposition technologies for trench formation and refill are unique to DRAM processes.
- The 4Mb and 16Mb DRAM technologies will lead in the use of high numerical aperture (NA) g-line and i-line steppers. Submicron imaging techniques, resist technology, and metrology tools will be paced by DRAM technology.

Technology for 200K Triple-Metal Gate Array

Feature	Process/Equipment Need
Salicide	RTP titanium silicide
Local interconnect	RTP titanium nitride
Planarized CVD between metals	Spin-on-glass planarization or in-situ PECVD planarization
Contact and VIA plugs	Tungsten CVD
Triple-metal interconnect	High-resolution, defect-free interconnect patterning
Custom metallization option	Flexible photoetch process
Many product configurations	Quick-turn maskmaking; good reticle management

Source: Dataquest
December 1989



Source: Dataquest
December 1989

Key Points:

- ASIC technology will lead in the use of local interconnects such as titanium nitride and self-aligned silicides such as titanium silicide. The need for multiple levels of interconnect in ASICs will drive advancements in planarization technology and new CVD processes.

- The trend toward hundreds of low-volume ASICs for each technology generation will demand quick-turn maskmaking and flexible steppers with low setup times.

ASIC Process and Equipment Innovations

- Laser-based interconnect patterning; quick-turn ASICs
- Focused ion beam tungsten direct-write interconnects
- E-beam lithography for maskless, direct-write ASICs
- Single-wafer etching and deposition systems
- Steppers with elaborate reticle management
- Multiproduct, computer-integrated manufacturing

Source: Dataquest
December 1989

Key Points:

- Companies such as LASA Industries and Lasarray are pioneering the use of laser beams for low-volume prototype ASIC manufacturing.

- Hitachi, JEOL, Micrion, and Seiko Instruments are marketing systems for prototype ASIC repair using focused ion beams to selectively deposit and etch local interconnect patterns.

- To improve throughput time and reduce costs for low-volume products, ASIC companies such as European Silicon Structures and United Silicon Structures are using e-beam systems for direct-write patterning.

Fab Configuration

4Mb DRAM Fabs	ASIC Fabs
Maxifabs ($200M-$300M)	Metallization fab ($30M-$50M)
	Full ASIC fab ($100M-$150M)
High-volume, single product	Low-volume, multiproduct
Dedicated automation	Programmable automation
Serial "assembly line"	Autonomous lines in parallel
Fab organized by function	Fab organized by product
High throughput, dedicated steppers for each layer	Flexible steppers with low setup time
Mix of batch and single-wafer processing	Single-wafer processing equipment

Source: Dataquest
December 1989

Key Points:

- DRAM fabs use hardwired automation to produce huge volumes of a single product economically, whereas ASIC fabs use programmable automation to respond to the needs of a dynamic, low–volume, multiproduct market.

Synergy and Convergence

- ASIC products with increasing on-chip SRAM memory
- Custom DRAMs and SRAMs for video, graphics applications
- Universal BiCMOS process for ASICs and high-speed SRAMs
- DRAM process trend toward 3-D silicon structure
- Multilevel interconnect technology now standard for ASIC and memory products
- Memory producers getting into ASIC manufacturing to balance fab capacity and offer one-stop shops
- Modular, reliable, flexible architecture equipment needed

Source: Dataquest
December 1989

Key Points:

- Several major U.S. and Japanese memory producers are setting up multipurpose fabrication plants for manufacturing DRAMs and ASICs in the same location. The objective is to balance capacity utilization by responding rapidly to changing market needs. It is important that process and equipment designs be modular and reliable so that the semiconductor manufacturer can mix and match standard modules for varying applications.

Conclusions

- DRAMs drive silicon device innovations and low-cost/high volume manufacturing
- ASICs drive design automation, multilevel interconnect technology, and flexible manufacturing
- Evolving synergy between memory (especially SRAMs) and ASIC processes
- Equipment design needs to be modular, highly reliable, and offer a "systems solution" to IC manufacturing
- Equipment and processes need to offer "open systems architecture"

Source: Dataquest
December 1989

Jerry Banks
Krishna Shankar

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Research Newsletter

SIS Code: 1989 Newsletters
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SIS MEMORY QUARTERLY EVENTS NEWSLETTER
JANUARY 1989

This newsletter is the fourth to be issued by Dataquest's Semiconductor Industry Service (SIS) Memory Product Group. It contains a synopsis of detailed memory product news events gathered from the trade press and company releases over the third quarter (July, August, and September of 1988.) SIS assumes no responsibility for the accuracy of the contents.

The following is a key to the publications reviewed during research for this issue:

Advanced Technology	AT	Electronic Components	EC
Asian Electronic Components	AEC	Electronic Design	ED
Company News Release	CNR	Electronic Engineering Times	EET
EDN	EDN	Engineering Times	ET
Electronic Buyers News	EBN	JEE	JEE

The new products for the third quarter of 1988 are as follows:

Company	Density	Speed
SRAM Developments		
Cypress Semiconductor	64K	20ns
Electronic Designs	256K	60, 70ns
Hitachi	64K	15ns
Honeywell	16K	
IDT	64Kx8, 64Kx9	25ns
Mitsubishi	64K	15ns
Mitsubishi	256K	25, 30, 35ns
Saratoga Semiconductor	256K, 512K	20 to 35ns
Toshiba	64K	15, 20, 25ns
Triad Semiconductor	64K	25, 35, 45ns
VLSI Technology	4K	20, 25ns
VLSI Technology	64K, 256K	25, 35ns
ECL I/O-Level RAM Developments		
Hitachi	256K	15ns
IDT	64K	10ns

(Continued)

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Company	Density	Type	Speed
Nonvolatile Developments			
Asahi Kasei	32K, 64K	EPROM	35 to 55ns
Exel	64K	EEPROM	35ns
Exel	16K, 64K	EEPROM	25, 60, 300ns
Macronix	1,2,4Mb	ROM	150, 200ns
MemTech	512KB	Bubble	
Mitsubishi	512K	EPROM	100, 120, 150ns
Mitsubishi		OTP/SRAM	
Mitsubishi	1Mb	ROM	200ns
NEC	4K	EEPROM	200, 250ns
NEC	4Mb	EPROM	150, 170, 200ns
Rohm	1,4,16,64K	EEPROMs	
Sharp	8Mb, 16Mb	ROM	200ns
Sierra	256	EEPROM	
Toshiba	256K	EEPROM/EPROM	170, 200, 250ns
Waferscale	126K	EPROM	40 to 70ns
Waferscale	256K, 512K, 1Mb	EPROM	90, 100, 120, 150ns
Xicor	16K	EEPROM	
Specialty Memories			
AMD	512x9	FIFO	
Brooktree		RAMDAC	
IDT	1Kx9, 2Kx9, 4Kx9	FIFO	35ns
IDT	2Kx9, 4Kx9	FIFO	35ns
IDT	64K	Cache	25ns
Saratoga	2Kx9	Cache	17 to 30ns
Saratoga	512x9, 1Kx9	FIFO	15ns

SRAM DEVELOPMENTS

Cypress Semiconductor

Cypress Semiconductor has remodeled its lineup of 64K static RAMs into 20ns versions. Two new devices, the CY7C161 and the CY7C162 (organized 16Kx4), feature separate I/O. Other parts introduced are two 16Kx4 common I/O devices, the C164 and the C166, which are offered in 22-pin and 24-pin DIPs. Also issued is the CYC187, a 64Kx1 SRAM with a 22-pin DIP, and two 8Kx8 SRAMs, the CYC185 and the CYC186, in a 28-pin DIP. (EBN, August 22, 1988, pg. 23)

Electronic Designs

Electronic Designs' ED18M1664C CMOS SRAM is organized 16Kx16 with commercial access times of 60ns and military access times of 70ns. The part comes in a 600-mil-wide, 40-pin DIP. (EDN, July 7, 1988)

Hitachi

Hitachi has developed three new 64K-bit SRAMs: the HM6787, HM6788, and HM6789. All of the models have an access time of 15ns and a maximum power consumption of 280mW. The series is organized 16Kx4 and 64Kx1, and packaged in either an SOIC or a 300-mil DIP. These devices are produced with Hitachi's "Hi-BiCMOS" process, utilizing a minimum linewidth of 1.3 microns. (AEC, May 1988, pg. 337)

Honeywell

Expansion of Honeywell's military product line comes with the introduction of two radiation-hardened 2Kx8 SRAMs. The devices come in JEDEC-compatible, 24-pin flatpack and DIP and are geared to such military systems requiring radiation hardness as space-based applications, avionics, and missiles. (EBN, August 8, 1988, pg. 8)

Integrated Device Technology

Integrated Device Technology (IDT) has introduced two new synchronous SRAM modules to accommodate the increasing demand for pipelined architectures. They are the IDT7M6028, organized 64Kx8, and the IDT7M6029, organized 64Kx9. They feature internal pipeline registers and an access time of 25ns. Both of these modules are 42-pin ceramic DIPs. (EET, September 26, 1988, pg. 69)

Mitsubishi

Mitsubishi plans to release a series of 64K CMOS SRAMs. The M5M6187B, 5188B, and 5189B have access times of 15ns, and their organization is 64Kx1 and 16Kx4. The parts are available in 300-mil DIP and SOJ packages. (JEE, June 1988, pg. 96)

Mitsubishi has introduced three fast SRAMs: the M5M5257A, (256Kx1); M5M5260A, (256Kx1); and M5M5258A, (64Kx4). All three are CMOS; have access times of 25, 30, and 35ns; and consume 300mW in active mode and 11mW in standby mode. They are available in two package types: a 24-pin, 300-mil plastic DIP and a 24-pin, 300-mil (SOJ) (CNR, September 12, 1988)

Saratoga Semiconductor

Offered by Saratoga Semiconductor are a series of 256K and 512K BICMOS SRAM modules. The SSMM91256 is organized 32Kx8; the SSMM91257, SSMM91258, and SSMM91259 are organized 16Kx16. The modules come in 28-pin ZIPs or DIPs and 38-pin ZIPs. The SSMM91512, SSMM91513, and SSMM91514 are organized 16Kx32 and are available in 60-pin ZIPs. All modules have access times of 20, 25, 30, and 35ns. (EET, July 4, 1988, pg. 52)

Toshiba

Toshiba has started production of two high-speed 64K SRAMs. The TC5588 has an organization of 8Kx8, and the TC5589 is organized as 8Kx9. These products are available with access times of 15, 20, and 25ns. Their maximum power consumption is 5.5mW during standby time and 550mW during operation. They are packaged in a 28-pin DIP and a 28-pin SOJ. (JEE, August 1988)

Triad Semiconductor

Triad Semiconductor has introduced the TR9C1640 and TR9C1643. They are 16Kx4 SRAMs with access times of 25, 35, and 45ns. The TR9C1643 is offered in a 24-pin DIP, and the TR9C1640 comes in a 22-pin DIP. (EDN, September 15, 1988, pg. 24)

VLSI Technology

Announced by VLSI Technology is the VT20C50, a 4K clearable SRAM. The 1Kx4 SRAM clear capability allows all memory cells to be set to logic "0" and eliminates the need for a software reset. The part is available in 15, 20, and 25ns speeds and is offered in 24-pin DIP, SOIC, and SOJ packages. (CNR, July 18, 1988)

In December, VLSI is going to begin marketing Hitachi static RAMs. Already scheduled are a 25ns, 16Kx4 device and a 35ns, 64Kx4 device. (EET, September 26, 1988)

ECL I/O LEVEL RAM DEVELOPMENTS

Hitachi

Development of a 15ns 256K ECL I/O RAM, the HM100500, has been completed by Hitachi. The part is offered with a power consumption of 400mW and 550mW. It is organized 256Kx1 and is packaged in a 24-pin DIP, flat package, and leadless chip carrier. (EC, April 1988, pg. 340)

Integrated Device Technology

Integrated Device Technology (IDT) has introduced the 10ns IDT10490 and the IDT100490. These devices are organized 64Kx1 and are manufactured with IDT's BICMOS process. They have an operating current consumption of 130mA and are available in 22-pin 300mil CERDIP packages. The IDT100490 is offered in a plastic DIP also. (CNR, July 18, 1988)

NONVOLATILE DEVELOPMENTS

Asahi Kasei Microsystems

Asahi Kasei Microsystems has plans to utilize International CMOS Technology's process to produce a 32K and a 64K EPROM. These UV-EPROMs will be packaged in a 24-pin ceramic DIP and will have access times of 35 to 55ns. (JEE, June 1988, pg. 97)

Exel

Introduced by Exel is the XL46HC64 EEPROM. The part is organized 8Kx8 and has an access time of 35ns. It is pin compatible with many EPROMs and bipolar PROMs and typically draws 40mA while operating at 10 MHz. (EDN, July 7, 1988, pg. 124)

Exel has added six EEPROMs to its existing military product line. They include one CMOS 2Kx8, two NMOS 2Kx8s, and two NMOS 8Kx8s. The CMOS 2Kx8 EEPROM, the XLM46C15J, has an access time of 60ns and a power consumption of 90mA. The 2Kx8 NMOS EEPROMs (the XLM2816AL and XLM2817AY) and the two 8Kx8 devices (the XLM2864AY and XLM2865AY) all have access times of 300ns and a 50mA power consumption. (EET, September 26, 1988)

Macronix

Macronix has begun supplying secure mask ROMs to prohibit unwanted access at 1, 2, and 4Mb. They are available as follows: the 1Mb MX23CS1024 housed in 28- and 32-pin packages, the 2Mb MX23CS2048 in a 32-pin package, and the 4Mb MX23CS409 in 32-pin packages. The ROMs are available at 150 and 200ns access times. (EET, September 26, 1988, pg. 77)

MemTech Technology

MemTech Technology has made available its 512K bubble memory devices. These devices come in a 40-pin module and can be stacked to supply up to 4 megabytes of nonvolatile memory. (ED, July 14, 1988, pg. 162)

Mitsubishi

Mitsubishi has plans to introduce 512K CMOS EPROMs, offered in 28-pin DIP packages and with access times of 100, 120, and 150ns. They will be manufactured using a 1.2-micron CMOS process and have a die size of 4.38mm x 6.72mm. (JEE, June 1988, pg. 96)

Mitsubishi Electric has begun sample shipments of its multifunction ROMs, M6M72561J and M6M72561J-1. These new devices integrate a 256K one-time PROM and a 16K SRAM onto a single chip. They are targeted for use as external memory for a microcomputer. (JEE September 1988, pg. 84)

Mitsubishi has begun sample shipments of its M5M27C100VP/RV, a one-time programmable 1Mb ROM. This device has an access speed of 200ns; is packaged in a 40-pin, 12.4mm x 10mm x 1mm low-profile plastic package; and is organized as either a 128Kx8 or as a 64Kx16. (EBN, August 29, 1988, pg. 6)

NEC

Two new EEPROMs have been released by NEC. The uPD28CO4C/G and the uPD28C05C/G (with an added address latch function) are organized 512x8 and are offered in 24-pin DIP or SOP packages. They both have access times of 200 and 250ns. (JEE, June 1988)

NEC has begun sample shipments of its 512Kx8 CMOS EPROM, the PD27C4001DZ. The EPROM has access times of 150, 170, and 200ns. Its die measures 5.48mm x 14.79mm and comes packaged in a 32-pin DIP conforming to JEDEC specifications. (JEE, September 1988, pg. 84)

Rohm

Rohm has started mass production of a line of EEPROMs using wafers supplied by Excel, its American subsidiary. The company plans to produce NMOS 4K, 16K, and 64K density devices plus CMOS 1K, 4K, and 16K density devices. (JEE, August 1988, pg. 37)

Sharp

Sharp is now accepting orders for its new developments: a CMOS 8Mb mask ROM, the LH538000, and a CMOS 16Mb mask ROM, the LH5316000. The chip size of the 8Mb mask ROM is 11.73mm x 5.96mm, and that of the 16Mb mask ROM is 11.96mm x 11.10mm. Both of these have an access time of 200ns. The LH538000 is offered in a 42-pin DIP package, and the LH5316000 is offered in a 128-pin quad flat package. (JEE, June 1988)

Sierra Semiconductor

Introduced by Sierra Semiconductor is the SC22100, a high-endurance 5-volt programmable 32x8-bit EEPROM, processed with 2-micron CMOS floating-gate technology. The part offers an endurance specification of 1 million write/erase cycles and is housed in an 18-pin DIP. (CNR, June 27, 1988)

Toshiba

Toshiba has released samples of two 256K-bit nonvolatile devices utilizing a 1.2-micron CMOS process. One is an EEPROM, the TC58257AP/AF, and the other is an EPROM, the TC57H256D. Both are available at 170, 200, and 250ns access times, and the EPROM is also available at 80ns. These two devices will be offered in DIP and flat packages. (JEE, August 1988, pg. 84)

Waferscale Integration

Waferscale is now shipping the WS57C51B, a 16Kx8 CMOS EPROM. The device is available in 40 to 70ns access times and comes in a 28-pin 300-mil and 600-mil CERDIP and a CLLCC. This 128K EPROM is available also in a military version. (CNR, July 11, 1988)

Waferscale announced three fast EPROMs—1Mb, 512K, and 256K. The 128Kx8 WS27C010L has an access time of 100ns and is available in the JEDEC-standard 32-pin DIP and a ceramic leadless chip carrier for surface mounting. The WS27C512L 64Kx8 and the WS27C256L 32Kx8 EPROM feature access times of 90, 100, and 120ns and are available in the JEDEC-standard ceramic leadless chip carrier and a 28-pin CERDIP package. (CNR, July 18, 1988)

Xicor

Xicor has introduced the MIL-M-38510/227, a 5-volt JAN-qualified 16K EEPROM. This is the military version of its X2816s and is available in a 24-lead ceramic side-braze DIP. (CNR, July 5, 1988)

SPECIALTY MEMORIES

Advanced Micro Devices

A bidirectional FIFO has been created by Advanced Micro Devices. The part combines two 512x9 FIFOs on one CMOS die, resulting in a single chip with two FIFOs that can be read and written to simultaneously. This device, the Am67C4701 BiFIFO, will be packaged in a 28-pin DIP, with surface-mount packages coming later. (EET, August 8, 1988, pg. 71; EBN, August 15, 1988, pg. 24)

Brooktree

Brooktree announced two new RAMDACs, the Bt492 and the Bt459. The Bt492 is ECL compatible and combines a 256x8 palette and a 360-MHz DAC. The Bt459 integrates a 256x8 color palette with three 8-bit, 135-MHz DACs. (EET, August 8, 1988, pg. 277)

Integrated Device Technology

Integrated Device Technology (IDT) has improved the performance of three of its CMOS FIFOs. The IDT7202, organized 1Kx9, now offers a 25ns access time. The IDT7203, organized 2Kx9, and the IDT7204, organized 4Kx9, both now have an access time of 35ns. The IDT7202 is available in a 28-pin plastic and ceramic 300-mil DIP package, plastic SOIC, and flatback. All of the FIFOs are available in 28-pin plastic and ceramic DIP 600-mil packages, 32-pin PLCCs, and ceramic leadless chip carrier (CLCC). (CNR, July 25, 1988)

Announced by IDT are new serial-to-parallel CMOS FIFOs: the IDT72132 (organized 2Kx9) and the IDT72142 (organized 4Kx9) plus two parallel-to-serial CMOS FIFOs, the IDT72131 (organized 2Kx9) and the IDT72141 (organized 4Kx9). All of these FIFOs are in a 28-pin plastic and ceramic DIP, 32-pin PLCC, and 32-pin leadless chip carrier. The FIFOs have a 35ns access time and 50-MHz serial shift rate. (CNR, July 25, 1988)

IDT has introduced the IDT71586, a 4Kx16 35ns SRAM optimized to interface with Intel's 82385 cache controller in a 25-MHz 80386 system. The IDT 71586 is packaged in a 40-pin plastic or ceramic DIP and a 44-pin PLCC. (CNR, August 23, 1988)

Saratoga Semiconductor

Available now from Saratoga Semiconductor are two 2Kx9 BICMOS cache-address comparators, the SSL2152 and SSL2154. The SSL2152 offers a totem-pole match output, and the SSL2154 offers an open-drain match output. The devices have access times from 17 to 30ns and are packaged in 28-pin 600-mil side-brazed DIPs, along with plastic DIPs and PLCCs. (EET, August 22, 1988, pg. 38)

Saratoga Semiconductor has expanded its BICMOS product line with two new FIFOs. They are the SSL7210, with 512x9-bit organization, and the SSL7202, organized 1Kx9 bits. Both have 15ns access times. These FIFOs come in 28-pin plastic DIPs, 32-pad ceramic LCCs, and 32-lead PLCCs. (EBN, August 22, 1988, pg. 10)

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Research Newsletter

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SIS MEMORY QUARTERLY EVENTS NEWSLETTER
April 1989

This is the fifth newsletter issued by Dataquest's Semiconductor Industry Service (SIS) Memory Product Group. It contains a synopsis of detailed memory product news events gathered from the trade press and company releases over the fourth quarter (October, November, and December) of 1988. SIS assumes no responsibility for the accuracy of the contents.

The following is a key to the publications reviewed during research, which are included in the issue:

AEU	AEU	Electronic Buyers' News	EBN
Company News Release	CNR	Electronic Design	ED
EDN	EDN	Electronic Engineering Times	EET
		Journal of Electronic Engineering	JEE

Listed below are the new products for the fourth quarter of 1988:

Company	Density	Speed
DRAM Developments		
NMB Technologies, Inc.	1Mb	60, 70, 80ns
Siemens	1Mb	70ns
SRAM Developments		
Cypress Semiconductor	4K	12ns
Cypress Semiconductor	256K, 512K, 1Mb, 4Mb	20, 70ns
Harris	16K	90, 100ns
Hitachi	1Mb	35, 45ns
Hitachi	256K	20, 25ns
Micro Electronic Technology	1Mb	100, 120, 150ns
Mitsubishi	64K	15, 20ns
Motorola	64K	20ns
Motorola	64K	35ns
National Semiconductor	64K	30 to 70ns
Performance Semiconductor	64K	10ns
S-MOS	256K	35 to 70ns
White Technology	4Mb	100, 120, 150ns

Company	Density	Type	Speed
Nonvolatile Developments			
Exel	1K	EEPROM	250ns
Fujitsu	128K	PROM	45ns
Harris	16K	PROM	100ns
National	64K, 128K, 256K	EPROM	200 to 450ns
NEC	4Mb	EPROM	150, 170, 200ns
Oki Electric	256K	EPROM	55ns
Samsung Semiconductor	64K	EEPROM	200, 250ns
SGS-Thomson	64K, 256K	EPROM/OTP	
Siemens	4K, 8K	EEPROM	
Sierra Semiconductor	256K	EEPROM	
Xicor	1Mb	EEPROM	200 to 350ns
Speciality Memories			
Advanced Micro Devices	512x8	FIFO	
IDT	256x9	FIFO	25ns
IDT	8-bit	Color lookup table	80, 110, 125, 132 MHz
Inmos	8-bit	Color lookup table	40, 50, 65, 80 MHz
Saratoga Semiconductor	2Kx9	Cache RAM	17ns
Saratoga Semiconductor	512x9, 1Kx9	FIFO	15, 20, 25, 30ns
Vitelic	8Kx16	Cache RAM	20, 25 MHz
Vitelic	512x9, 1Kx9	FIFO	12, 16, 22 MHz

DRAM DEVELOPMENTS

NMB Technologies, Inc.

NMB Technologies has begun sampling the AAA1M200 1Mb DRAM series. It is offered in 1Mbx1 and 256Kx4 versions. The devices are available with maximum access speeds of 60, 70, and 80ns. Available are the enhanced-page and static column mode versions, with access speeds of 40ns for the enhanced-page and 35ns for the static column. The devices will be available in plastic DIP, ceramic DIP, ZIP, SOJ, and SIMM packages with JEDEC standard pinouts. (CNR, November 1, 1988)

Siemens

Siemens has reduced the dimension of its 1Mb DRAM and is now able to offer a high-speed version of the device. The new HYB511000A has an access time of 70ns. The device utilizes a 1.0um double-well CMOS technology, which yields a 47-square-millimeter die. (CNR November 7, 1988)

SRAM DEVELOPMENTS

Cypress Semiconductor

Cypress Semiconductor has introduced a 1Kx4 separate I/O high-speed SRAM, the CY7C150. It has an access time of 12ns for its commercial specifications and 15ns for its military. It is available in a plastic 24-pin, 300-mil DIP; and CERDIPs are available for commercial temperatures. Also, it is available in 24-pin, 300-mil CERDIPs and 28-pin rectangular LCCs for the military temperature range. (CNR, September 30, 1988)

Cypress Semiconductor has introduced a new SRAM module line. The line includes the 256K (16Kx16) CYM1610 and CYM1611; the 512K (16Kx32) CYM1822; 1Mb (128Kx8) CYM1421 and (64Kx16) CYM1621; and a 4Mb (512kx8) CYM1461. The CYM1610, CYM1611, CYM1822, and CYM1621 have access times of 20ns, whereas the CYM1421 and CYM1461 have access times of 70ns. (CNR, December 12, 1988)

Harris

Introduced by Harris are two radiation-hardened 16K SRAMs. The HS-65C162RH, with CMOS-compatible input, and the HS-65T162, with TTL-compatible input, are both 2Kx8 CMOS SRAMs. The 65C162 has a maximum access time of 90ns; the 65T162 has an access time of 100ns. They are offered in 24-pin CERDIPs and flatpacks, and 34-pin LCCs. (EET November 21, 1988)

Hitachi

Hitachi has released the HM624256, a 1Mb SRAM. It is 256Kx4, has access times of 35 and 45ns, and its die size is 5.2 x 8.5um square. It is packaged in a 400-mil, 128-pin SOJ. (JEE, November 1988, p. 90)

Hitachi has introduced a BiCMOS 256K SRAM with TTL-level I/O. The device has access times of 20 and 25ns, and is available in two versions, the HM6707 (256Kx1) and the HM6708 (64Kx4). Both versions are available in 24-pin, 300-mil DIP and SOJ. (CNR, October 24, 1988)

Micro Electronic Technologies

Micro Electronic has announced the MS12808, a 128Kx8 static RAM. It is made up of four 32Kx8 SRAMs in SOG packages mounted on a substrate that fits into a standard 32-pin, 600-mil wide socket for the 1Mb. It has access times of 100, 120, and 150ns. (EBN, October 10, 1988, p. 24)

Mitsubishi

Mitsubishi has three new members of its static RAM series—a 64Kx1, the M5M5187B; and two 16Kx4, the M5M5188B and M5M5189B (which offers an output enable). All three are available in 15 and 20ns, and typically require 300mW of power in active mode and 5mW in standby mode. The M5M5187B and M5M5188B are available in 22-pin lead plastic DIP or SOJ; the M5M5189B is available in 24-pin lead plastic DIPs or SOJs. (EDN, November 24, 1988, p. 250)

Motorola

Motorola has introduced two new synchronous 16Kx4 fast SRAMs, the MCM6293 and MCM6294. Both have cycle times of 20ns. The 6293 and 6294 are available in 28-lead, 300-mil wide plastic DIPs, and the 6393 is also packaged in a 28-lead plastic SOJ. (EET, December 19, 1988, p. 79)

Motorola has introduced the MCM6264, a 8Kx8 fast SRAM. It has an access time of 35ns utilizing a 1.5um double metal CMOS process. It is available in 300-mil plastic DIPs or 400-mil SOJs. (CNR, October 4, 1988)

National Semiconductor

National Semiconductor has announced three military CMOS 64K SRAMs--the 1600A/1601A devices, which are 64Kx1, and the 1620/1621 and 1624/1625 devices, which are 16Kx4. The 1624/1625 offer an output-enable feature, and the 1601, 1621, and 1625 have data-retention current specs of 5uA at 2 volts VCC. All of these SRAMs are available with access times from 30 to 70ns. The 1600A/1601A and the 1620/1621 devices are available in 22-pin packages, while the 1624/1625 devices are available in 24-pin DIPs and 28-pin LCCs. (CNR, October 31, 1988)

Performance Semiconductor

Performance Semiconductor has announced the release of the P4C187-10PC, a 64Kx1 SRAM. This device is manufactured from Performance's Pace II, a 0.7-micron gate length process, and has an access time of 10ns. It is available in plastic DIPs and CERDIPs, 22-pin LCCs, and 24-pin, 300-mil SOJs. (CNR, October 3, 1988)

S-MOS

S-MOS announced the availability of two 256K CMOS SRAMs utilizing its 0.1u process. The first is a 64Kx4, the SRM21256, which has an access times of 35, 45, and 55ns, and is packaged in a 24-pin DIP. The second device is a 32Kx8, the SRM22256, having access times of 55 and 70ns, and is housed in a 28-pin DIP or SOP. (CNR, October 3, 1988)

White Technology

White Technology has introduced the M4194, a 4Mb SRAM memory module. The hybrid consists of 16 32Kx8 memory devices and 19 ICs for buffers, latches, decoders, etc. It can be configured as a 512Kx8, 256Kx16, or 128Kx32 SRAM. Maximum access times for all configurations are 100, 120, and 150ns. (EDN, December 8, 1988, p. 146)

NONVOLATILE DEVELOPMENTS

Exel

Introduced by Exel is the XL93C46. It holds 1,024 reprogrammable bits of information, can endure 10,000 erase/write cycles per register, and has an access speed of 250ns. The XL93C46 is available in an 8-pin DIP or an 8-pin SOIC. (EDN, October 27, 1988, p. 339)

Fujitsu

Fujutsu has released the MB71C46, a 128K PROM that uses bipolar circuits for its memory cell and BiCMOS for its peripheral circuitry. It has a configuration of 16Kx8 and an access time of 45ns. (JEE, November 1988, p. 60)

Harris

Introduced by Harris is a radiation-hardened 16K PROM. The HS-6617RH is a 2Kx8 CMOS PROM that is able to withstand a total dose of 100 krads (Si) without degradation and features a maximum access time of 100ns. It is offered in a 24-pin CERDIP and flatpack, and a 34-pin LCC. (EET, November 21, 1988)

National Semiconductor

National Semiconductor has introduced three new military CMOS EPROMs. They include a 64Kb device, the 27C64, which is organized as an 8Kx8 and has access speeds of 200 to 450ns; a 128Kb device, the 27CP128, which is 16Kx8 and has access times of 250 to 350ns; and a 256Kb device, the 27C256, which is 32Kx8 and has access times of 250 to 350ns. All three are available in 28-pin CERDIPs and 32-pin LCCs, and operate over the full military temperature range. (CNR, October 31, 1988)

NEC

NEC has introduced sample shipments of the uPD27C4001DZ, a 512Kx8 CMOS 4Mb EPROM. The EPROM has access speeds of 150, 170, and 200ns. Its die measures 5.48 x 14.79mm and is packaged in a 32-pin DIP. (AEU, No. 5, 1988, p. 102)

Oki Electric

Oki Electric has introduced the MSM27C256H, a 256K EPROM. It has an access time of 55ns. (JEE, November 1988, p. 91)

Samsung Semiconductor

Samsung Semiconductor has introduced the KM28C64 and the KM28C65, two 8Kx8 EEPROMs. Both are available with access times of 200 and 250ns. They come in two package types, 28-pin plastic-DIP or a 32-pin PLCC. (EBN, October 24, 1988, p. 33)

SGS–Thomson

SGS–Thomson has added three new EPROMs to its family, one of which is a CMOS UV–EPROM, the 27C256. It is 32Kx8 and is packaged in a JEDEC 28–pin CERDIP with a quartz window. The 27C64/P and 27C64/FN are 8Kx8 and are one–time–programmable (OTP). The 27C64/P is packaged in a 28–pin plastic DIP, and the 27C64/FN is packaged in a JEDEC 32–pin PLCC. (EDN, November 24, 1988, p. 249)

Siemens

Siemens has introduced two serially accessed EEPROMs, the 512x8 SDA2546 and the 1Kx8 SDA2586. Both EEPROMs feature an I2C bus interface and are available in 8–pin DIPs. (EDN, November 10, 1988, p. 329 and 331)

Sierra Semiconductor

Sierra Semiconductor has introduced the SC22100, a 256K EEPROM with a 1 million write/erase–cycle endurance capability. It has power dissipation of 0.5mW and is packaged in an 18–pin DIP. (ED, December 8, 1988, p. 141)

Xicor

Xicor has introduced the X28C010, a 1Mb EEPROM organized 128Kx8. It has access times of 200 to 350ns and runs on 5V. The EEPROM is manufactured from a 1.2um CMOS process and its die measures 359mm square and dissipates 250mW of power. It is packaged in 32–pin CERDIPs or 44–pad CLCCs. (EET, November 28, 1988, p. 73)

SPECIALTY MEMORIES

Advanced Micro Devices (AMD)

Advanced Micro Devices has introduced a 512x8 bidirectional FIFO buffer, the 67C4701. This FIFO can exchange data bidirectionally between devices that use different data rates. It is packaged in a 28–pin plastic DIP. (EDN, December 8, 1988, p. 122)

Integrated Device Technology (IDT)

Introduced by Integrated Device Technology is the IDT7200, a 256x9 CMOS FIFO. It offers three option flags outputs: full, half–full, and empty. The FIFO features an access time of 25ns and is available in a 32–pin PLCC, a 32–pin CLCC, or a 28–pin, 300–mil DIP. (EDN, October 13, 1988, p. 292)

IDT now offers an 8–bit color lookup table with speeds of 80, 110, 125, 132, and 165 MHz. The IDT75C458 allows flicker–free displays to 1,600 x 1,200 pixels and is housed in an 84–pin PGA or PLCC. (EET, December 19, 1988)

Inmos

Now available from Inmos is an 8-bit color lookup table, the IMSG178. This device offers a 16 million-color palette and features speeds of 40, 50, 65, and 80 MHz. The IMSG178 comes in 32-pin PLCCs. (EBN, December 5, 1988)

Saratoga Semiconductor

Saratoga Semiconductor has introduced the SSL2152 and SSL2154, which are 2Kx9 cache address comparators. They have address compare-to-match output times of 17ns. The 2152 offers a totem-pole output, and the 2154 features an open-drain output. Both are available in DIPs and PLCCs. (EDN, October 13, 1988, p. 290)

Introduced by Saratoga Semiconductor are two high-speed FIFOs, SSL7201 and SSL7202. The SSL7201 is 512x9, and the SSL7202 is 1Kx9. Both FIFOs are offered in grades of 15, 20, 25, and 30ns, and are packaged in 28-pin DIPs or 32-pad CLCCs and PLCCs. (EDN, November 10, 1988, p. 323-324)

Vitelic

Vitelic has introduced the V63C328, an 8Kx16 cache data RAM. It currently functions to match microprocessor systems operating at speeds of 20 and 25 MHz, and it also offers direct interface with the Intel 82385 Cache Controller. It is available in a 52-pin PLCC. (CNR, November 7, 1988)

Introduced by Vitelic are two new FIFOs—the V61C01, a 512x9, and the V61C02, a 1Kx9. Both devices are available in operating speeds of 12, 16, and 12 MHz, and are housed in 600-mil or 300-mil, 28-pin DIPs or PLCCs. (CNR, November 7, 1988)

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Conference Schedule

1989

Semiconductor User/ Semiconductor Application Markets	February 27-28	Le Meridien Hotel San Francisco, California
Japanese Components	April 20-21	Tokyo Bay Hilton International Tokyo, Japan
Computer Storage	April 26-28	The Doubletree Hotel Santa Clara, California
Document Processing	May 16-18	Monterey Sheraton Hotel Monterey, California
Copiers	May 16-17	
Printers	May 16-17	
Electronic Publishing	May 18	
Imaging Supplies	May 18	
Color	May 18	
SEMICON/West Seminar	May 24	The Dunfey Hotel San Mateo, California
Telecommunications	June 5-7	Silverado Country Club Napa, California
European Components	June 7-9	Park Hilton Munich, West Germany
Asian Semiconductor and Electronics Technology Seminar	June 28	Radisson Hotel San Jose, California
Financial Services	August 22-23	The Doubletree Hotel Santa Clara, California
Technical Computing and Applications	September 11-13	The Doubletree Hotel Santa Clara, California
European Copying and Duplicating	September 18-19	Majestic Hotel Cannes, France
Western European Printer	September 20-22	Majestic Hotel Cannes, France
Taiwan Conference	September 25-26	Grand Hotel Taipei, Taiwan
Distributed Processing	September 26-28	The Doubletree Hotel Santa Clara, California
SIA/Dataquest Joint Conference	September 27	Santa Clara Marriott Santa Clara, California
Information Systems	October 2-6	Tokyo American Club Tokyo, Japan
Semiconductor	October 16-18	Monterey Sheraton Hotel Monterey, California
Asian Semiconductor and Electronics Technology	November 2-3	Kunlun Hotel Beijing, China
European Telecommunications	November 8-10	Grand Hotel Paris, France
European Personal Computer	December 6-8	Athens, Greece

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Research Newsletter

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THE BARE FACTS ABOUT FLASH

INTRODUCTION

Flash technology, first announced by Toshiba in 1985, represented a $2.1 million market in 1988. Flash is an emerging nonvolatile memory technology currently supported by six entrants, with four potential suppliers on the horizon. Flash architecture is built around a single transistor cell with electrical programming and fast bulk/chip erase, in plastic and surface-mount packages.

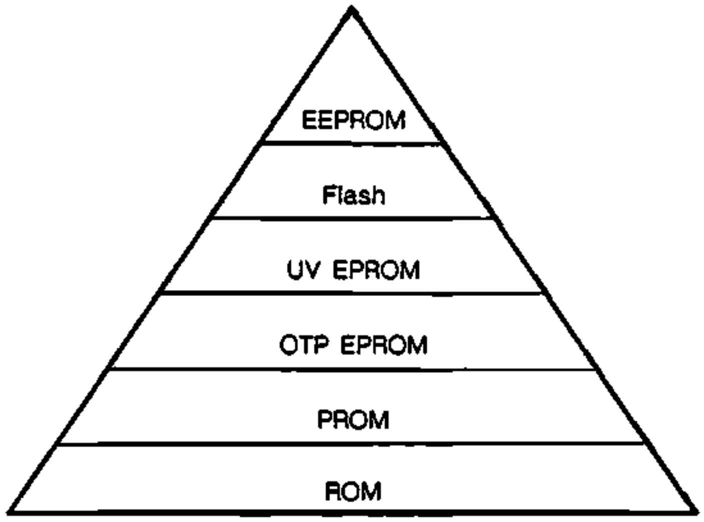
This newsletter compares the performance trade-offs of flash in comparison with other nonvolatile products, discusses price-per-bit comparisons to other MOS memory products, and looks at current and potential applications for flash technology. A learning curve and life cycle analysis have been used to develop Dataquest's flash market forecast for the next five years. During that time frame, the assumed growth of the flash is based on its ability to compete successfully in the nonvolatile memory market. To remain competitive and gain market share, flash suppliers must strengthen their products' performance relative to competing technologies. The price will have to drop from its current level for the products to be competitive. A form of standardization in place of the current functional differentiation must be established in order for second-source availability to evolve and user acceptance of a new and emerging product area to develop.

PERFORMANCE TRADE-OFFS

Already a fragmented market in terms of density, speed, and price, the nonvolatile memory hierarchy, with the addition of flash, now has multiple product offerings. Each nonvolatile memory technology in Figure 1 is shown in ascending order of performance, with each member offering a significant advantage over the other technology. In this hierarchy, the most desirable memories have the highest prices and lowest bit shipments, as would be expected. The respective revenue shares for all nonvolatile products shown in the figure represented $3.2 billion in 1988.

Figure 1

Nonvolatile Hierarchy



0004256-1

Source: Dataquest June 1989

It has been speculated that hierarchical cannibalism is possible when one memory technology usurps the market of a technology next to it in the hierarchy. This can occur when a new technology is introduced at near price parity with an older technology, but at much lower bit shipments. The new technology then needs to garner only a small fraction of the bit shipments of the older technology to double and redouble its bit shipments. Through the economies of scale, the new technology can run rapidly down its learning curve and lower its relative price substantially, until eventually it captures the bulk of the older technology's market.

In the late 1970s, cannibalism occurred when bipolar PROMs replaced bipolar ROMs. The one-time programmable (OTP) EPROM also was projected as the ultimate replacement to the UV EPROM. However, it never quite gained acceptance as a viable technology replacement to the strongly entrenched UV EPROM product. The OTP's reputation is permeated with black marks and obstacles, including questionable reliability, manufacturer inability to support the product with second-sourcing, poor customer acceptance, and declining EPROM prices. The full-featured EEPROMs, often the preferred system memories with 5-V system power and byte-alterable features, also were projected as EPROM replacements in the early 1980s. Although the EEPROM market experienced strong growth in 1983 and 1984, the price recessions of the early 1980s pushed EPROM prices down the learning curve, and the EEPROM growth generated was not substantial enough to drive the process technology that would allow prices to drop faster than they actually did. There also was very little if any standardization in EEPROM devices, with each vendor functioning as its customers' sole source. As a result, device prices were not as tightly coupled to one another for EEPROMs as were the prices for the commodity-type EPROM products.

As Figure 1 shows, flash is sandwiched between the EEPROM and UV EPROM family of products. Vendors of their respective flash EPROM/EEPROM products currently speculate that flash could erode some portion of both the UV EPROM and the EEPROM families during the mid-1990s. As the largest supplier of flash products at present, Intel currently has positioned the price of its flash EPROMs far above the UV EPROM price, establishing a separate, defensible position for its flash EPROM and UV EPROM market niches. In this type of situation, the majority of users will buy the superior technology only when the relative performance of the product (programming reliability and application compatibility) is absolutely required.

The maximum performance features and functionality trade-offs of the various technologies currently being shipped in the nonvolatile hierarchy are described in Table 1. Although reprogrammability always has been one of the major strengths of the superior nonvolatile products, reliability (endurance and data retention), and cost per bit have become strong criteria for the user selection process.

Table 1

Nonvolatile Memory Trade-offs

	Mask ROM	Bipolar PROM	Fast EPROM	OTP ROM	UV EPROM	Flash EPROM	Flash EEPROM	EEPROM
User-Programmable	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Reprogrammable	No	No	Yes	No	Yes	Yes	Yes	Yes
Programming Voltage	5V	21V	12V	12V	12V	5V/12+V	5V/12+V	5V
Programming Algorithm	-	-	Required	-	Required	Required	Required	-
In-Circuit	No	No	No	No	No	Yes	Yes	Yes
Write/Erase Options	No	No	Chip	No	Chip	Bulk	Bulk	Byte
Endurance Cycles	-	-	-	-	-	100-10K	1K-10K	10K-100K
Performance	120ns	35ns	35ns	150ns	150ns	90ns	170ns	35-200ns
Highest Density	16Mb	128K	1Mb	4Mb	4Mb	1Mb	1Mb	4Mb
Plastic Package	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Transistor	-	-	1-T	1-T	1-T	1-T	1-T	1&2-T

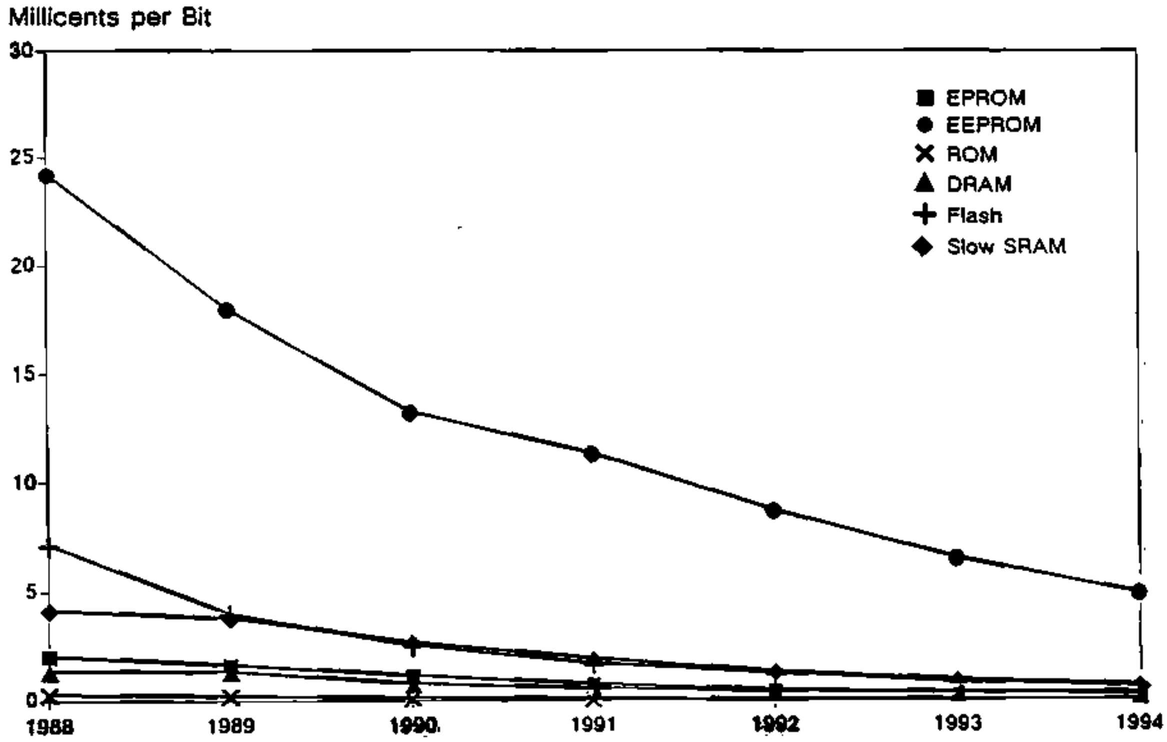
Source: Dataquest
June 1989

Relative price performance, in terms of price-per-bit changes over time, is also a measure of the relative superiority of one technology over another. Figure 2 illustrates the estimated price-per-bit changes for all MOS memory devices. Price-per-bit information for 64K and above densities only has been used to get a fairly sound representation of how the flash might position itself over time against other memory alternatives. A critical factor for growth and end-user stimulus for product selection of the flash will be driven by vendors' abilities to price their flash products competitively against other alternative technologies.

Figure 3 gives Dataquest's estimated total revenue trend line through 1994 for flash technology compared with the EPROM and EEPROM markets. Figure 4 illustrates estimated respective revenue shares of the total nonvolatile market by 1994, along with specific flash EPROM and EEPROM share by density, during that time frame.

Figure 2

MOS Memory Price-Per-Bit Comparisons

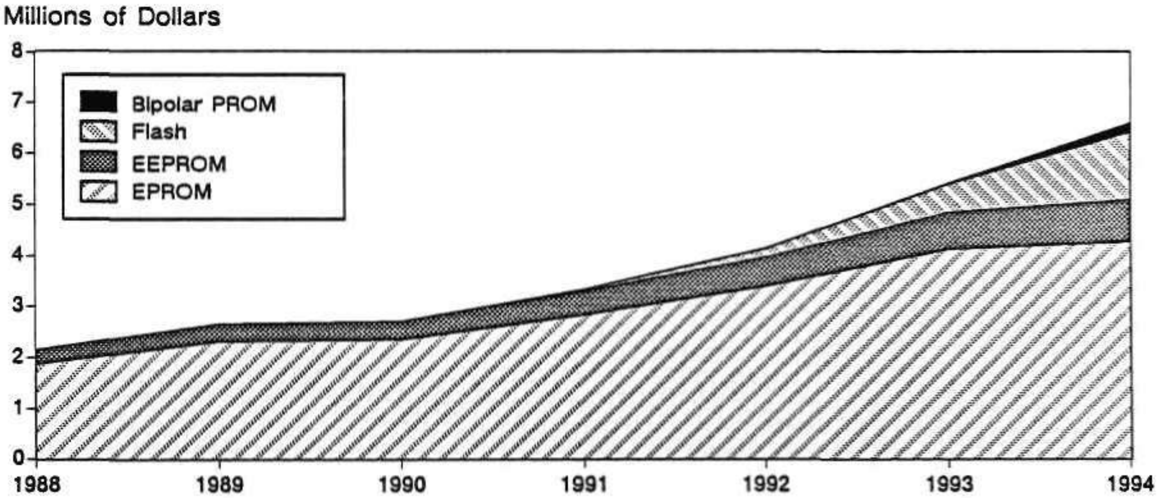


0004256-2

Source: Dataquest June 1989

Figure 3

Flash versus EPROM and EEPROM Total Revenue

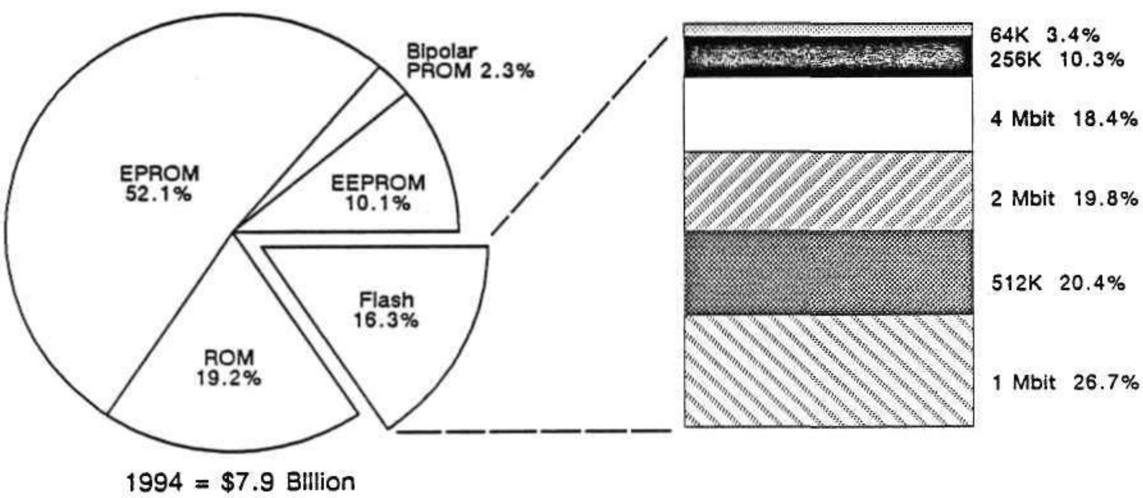


0004256-3

Source: Dataquest June 1989

Figure 4

Nonvolatile Market Revenue



0004256-4

Source: Dataquest June 1989

TECHNOLOGY DEVELOPMENTS

From the first 256K flash EEPROM, introduced by Toshiba, flash developments have appeared from both the EPROM and EEPROM sectors, with densities ranging from 64K through 1Mb, with 2Mb and 4Mb designs in the development stages. Flash construction implements an EPROM-like process design. The cell is programmed via hot electron injection. The erasure is accomplished using the Fowler-Nordheim tunneling of electrons between the floating gate and the drain. Typically, it takes one second to erase the entire memory.

Table 2 lists all available data by companies that are currently offering flash devices or have announced participation in the flash market. Two major announcements have been made during the last six months. Texas Instruments (TI) and Waferscale Integration (WSI) have introduced flash devices that offer 5V power supply, which is typical of the power supply required by the EEPROM. This is a distinct path away from other flash EPROM/EEPROM device announcements, where 12V power supplies, typical to the EPROM, are required for programming and erasure. Intel, TI, and WSI also have announced that their flash products can achieve maximum endurance capabilities of 10,000 program cycles, which is typical of the minimum write cycles for EEPROMs. An industry definition of endurance is the ability of a nonvolatile memory to withstand repeated data alteration while all parameters remain in specification. The end of endurance life is when any parameter fails specification as a result of data alteration.

Table 2

Flash Technology Developments
1985 through 1989

Parameter	Intel	Intel	Intel	Intel	National	SEEQ
Process	1.5u CMOS	1.5u CMOS	1.0u CMOS	1.0u CMOS	1.5um NMOS	2.5u NMOS
Poly Levels	2	2	2	2	2	2
Density	64K	256K	512K	1M	512K	128K
Cell Size	1T	$36um^2$ 1T	1T	$15.2um^2$ 1T	$25um^2$ 1T	$40um^2$ 1T
Chip Size	$123mils^2$	$23mils^2$	N/A	$60mils^2$	N/A	N/A
Address Access Time	150ns	170ns	120ns	90ns	200ns	140ns
Programming Time	1ms/byte	1ms/byte	10ms/byte	10ms/byte	1ms/byte	1ms/byte
Endurance Cycle	100	100-100K	10K-100K	10K-100K	100-1K	100-1K
Programming Voltage	12+V	12+V	12+V	12+V	12+V	21V
Programming Mechanism	Hot channel Electron Injection	Hot channel Electron Injection	Hot channel Electron Injection	Hot channel Electron Injection	Hot channel Electron Injection	Hot channel Electron Injection
Erase	Tunneling	Tunneling	Tunneling	Tunneling	Tunneling	Tunneling

(Continued)

Table 2 (Continued)

Flash Technology Developments 1985 through 1989

Parameter	Intel	Intel	Intel	Intel	National	SEEQ
Package	28-pin CERDIP	28-pin DIP 32-pin DIP 32-pin PLCC 32-pin CERQUAD	32-pin CERDIP 32-pin PLCC	32-pin CERDIP 32-pin PLCC	32-pin P/CDIP 32-pin P/CLCC	N/A
Estimated Price	$8	$19.9	$16-$21	$29-38	N/A	$7.00
Shipping Status 1988	20K	50K	-	-	Sampling	Low volume

Parameter	SEEQ	SEEQ	TI	Toshiba	Toshiba	WaferScale
Process	1.5um CMOS	1.5u CMOS	1.5u CMOS	2u NMOS	1.2u CMOS	1.2u CMOS
Poly Levels	2	2	2	3	3	2
Density	512K	1M	256K	256K	256K	256K
Cell Size	$25um^2$ 1T	$25um^2$ 1T	$40.5um^2$ 1T	$64um^2$ 1T	$36um^2$ 1T	$18um^2$ 1T
Chip Size	N/A	N/A	$46mils^2$	$33mils^2$	$22mils^2$	N/A
Address Access Time	200ns	120ns	170ns	200ns	170ns	N/A
Programming Time	1ms/byte	1ms/byte	10ms/byte	1ms/byte	1ms/byte	1ms/byte
Endurance Cycle	100-1K	100-1K	10K	N/A	100	10K
Programming Voltage	12+V	12+V	5V	21V	12+V	5V
Programming Mechanism	Hot channel Electron Injection	Hot channel Electron Injection	Hot channel Electron Injection	Hot channel Electron Injection	Hot channel Electron Injection	Hot channel Electron Injection
Erase	Tunneling	Tunneling	Tunneling	Tunneling	Tunneling	Tunneling
Package	32-pin P/CDIP 32-pin P/CLCC	32-pin P/CDIP 32-pin P/CLCC	N/A	28-pin PDIP	28-pin PDIP 28-pin SOIC	N/A
Estimated Price	$33	$78-$90	N/A	N/A	$50-$55	N/A
Shipping Status 1988	15K	-	-	-	32K	-

N/A = Not Available

Source: Dataquest
June 1989

APPLICATIONS

The ultimate success of the flash depends on the vendor's ability to create a demand for the flash products by defining new applications, and/or the performance ability of the flash to displace other alternate nonvolatile products in existing applications. To date, most flash products have been designed into new applications. Some of these new applications are as follows:

- Automotive – Power train–for in–system code programming and reprogramming
  – Data/fault logging–for system analysis

- Telecom – Switching equipment databases
  – Portable telephones/radios

- Industrial – Test and medical instruments

STRATEGIC ISSUES

The nonvolatile memory industry currently is a mature industry with an overabundance of producers. As such, it comprises two very distinct types of companies with varying abilities to sustain new product development. Very large companies such as Intel, TI, and Toshiba (with potential development from AMD and Hitachi) all have abundant capital and engineering resources and sufficient market dominance to permit significant new product development, such as the flash, that will extend the nonvolatile product horizon. Many smaller companies, such as SEEQ, WSI, and, possibly, Atmel, are very single–product directed, and they could leverage off basic technology developments of the major companies for their market growth. If flash EPROMs and EEPROMs offer significant performance and price advantages as a competing technology, they may jeopardize other nonvolatile product markets over time.

In polling some of the very large U.S. and European nonvolatile users, Dataquest has found that two major user concerns have yet to be addressed by flash EPROM and EEPROM vendors: standardization and cost of upgrade. The only standard for the flash at this time is the JEDEC standard (32–pin) pinout. Standardization of the electrical features (programming algorithm) will be a major difference between all manufacturers of the various flash EPROM and EEPROM devices. Because flash technology is still emerging and all participants are offering flash EPROMs and EEPROMs in different programming algorithms, standardization could develop in two ways. As more vendors enter the market and vie for market share, they will compete in a price and performance arena, eventually combining forces with other competitors and displacing multiple–functional differentiation with second–source availability. Standardization can also occur when and if large–scale producers such as Intel, TI, or Toshiba ramp up their flash lines into full–scale production and force standardization by volume produced and shipped. At this point in the flash EPROM and EEPROM neophyte stage, current producers will have to lock in their users to their specific product because of the varying programming algorithms. The second area of user concern is cost of upgrade. Users currently view flash EPROMs and EEPROMs as yet another nonvolatile memory. Although their design engineers see some potential for design–in of flash, its value as an EEPROM replacement at the electronic data processing (EDP) sector is minimal. Although flash also has potential as an EPROM replacement at the EDP and instrumentation sectors, the current cost (time and expenses) of requalification is prohibitive.

Ultimately, we believe that the largest end-use segments for the flash will come from the automotive and telecommunications sectors. This may or may not come at the risk of UV EPROM displacement over time. The automotive market is expected to be the largest consumer of nonvolatile devices through the early 1990s. This is timed exactly at the point of development and ramp up of the flash EPROM and EEPROM market. Although there are other potential high growth sectors in the EDP segment, the growth of flash technology should still come from the vendors' abilities to define new applications and new buying segments in their markets. As yet, the multiplicity of nonvolatile products only has added to buyer confusion regarding the relative advantages of one nonvolatile product over another. Technological advancement, price/performance ratio, and vendor support will determine the true success of the flash market.

Mary Olsson

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A new directory describing 30 Dataquest Research Publications is now available from Dataquest's Direct Marketing Group. The directory includes information on the following:

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Research Newsletter

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0004367

SIS MEMORY QUARTERLY EVENTS NEWSLETTER
June 1989

This newsletter is the sixth to be issued by Dataquest's Semiconductor Industry Service (SIS) Memory Product Group. It contains a synopsis of detailed memory product news events gathered from the trade press and company releases over the first quarter (January, February, and March) of 1989. SIS assumes no responsibility for the accuracy of the contents.

The following is a key to the publications reviewed during research for this issue:

Company News Release	CNR	Electronic Design	ED
Electronic Buyers News	EBN	EDN	EDN
Electronic Components	EC	JEE	JEE

Table 1 shows the new products for the first quarter of 1989.

Table 1

New Products for First Quarter 1989

Company	Density	Type	Speed
DRAM Developments			
Fujitsu	4Mb		80ns
Mitsubishi	4Mb		80, 100ns
NMB	1Mb		60ns
SRAM Developments			
Cypress	256K, 512K, 1Mb, 4Mb		25ns
Fujitsu	256K, 288K		25, 35ns

(Continued)

Table 1 (Continued)

New Products for First Quarter 1989

Company	Density	Type	Speed
SRAM Developments (Continued)			
Hitachi	256K		20ns
Hybrid Memory Products	256K		25, 35, 45ns
Motorola	64K		20ns
Performance	4K		6ns
VLSI Technology	256K		35, 45ns
ECL I/O-Level RAM Developments			
Integrated Device Tech.	64K		8ns
Nonvolatile Developments			
Intel	512K, 1Mb	Flash memory	120, 200ns
Mitsubishi	2K	EEPROM	
SEEQ	1Mb	Flash memory	
Toshiba	1Mb	EPROM	80, 100ns
Toshiba	512K	EPROM	150, 200ns
Specialty Memories			
Advanced Micro Devices	512x8	FIFO	
Fujitsu	8-bit	Dual port	
Integrated Device Tech.	64K	Cache RAM	25ns
Integrated Device Tech.	16K	Cache tag	12ns
Integrated Device Tech.	Module	FIFO	45ns
Integrated Device Tech.	Module	WCS	
Integrated Device Tech.	8-bit	Color-palette	165 MHz
Mosel	64K	Cache RAM	16, 20, 25 MHz
Vitelic	128K	Cache RAM	35, 45ns
Vitelic	512x9, 1Kx9	FIFO	12, 16, 25 MHz
VLSI Technology	512x8	Cache tag	20, 25, 30, 35ns

Source: Dataquest
June 1989

DRAM DEVELOPMENTS

Fujitsu Microelectronics

Introduced by Fujitsu is a 4Mb DRAM utilizing a CMOS stacked capacitor cell design, the MB814100. It is configured in a 4Mbx1 organization, has access times as low as 80ns, and is packaged in JEDEC standard 18-pin 300-mil dual in-line package (DIP), 20-lead zigzag in-line package (ZIP), and a 20- or 26-lead 300- or 350-mil SOJ. (CNR, February 8, 1989)

Mitsubishi Electric

Mitsubishi has begun shipments of 4Mb DRAMs utilizing a 0.8-micron process. The DRAMs have access times of 80 and 100ns, with a power consumption of 470mW. They are packaged in a 300-mil SOJ. (EC, December 1988, pg. 482)

NMB Technologies

Sampling of the AAA1M200, a series of high speed 1Mb DRAM, has begun from NMB. These new devices offer access speeds ranging from 60ns to 80ns and are available as 1Mbx1 and 256Kx4. They also will be available with enhanced page and static column mode cycle times of 40 and 35ns. (EBN, January 9, 1989, pg. 58)

SRAM DEVELOPMENTS

Cypress Semiconductor

Cypress has announced the release of six SRAM modules with access times as fast as 25ns. There are two 256K, 16Kx16, units available in a 40-pin DIP and a 36-pin vertical DIP. A 512K, 16Kx32 unit is available in an 88-lead vertical DIP. Two 1Mb units, organized as 128Kx8 and 64Kx16, are available in 32- and 40-pin DIPs. A 4Mb unit organized 512Kx8 in a 36-pin single-in-line module is also offered. (ED, January 26, 1989, pg. 138)

Fujitsu Microelectronics

Released by Fujitsu are a 256K and a 288K CMOS high-speed SRAM. They are fabricated from a 0.8-micron minimum-linewidth process and have maximum access times of 25 and 35ns. The 256K is organized as a 32Kx8 with a power consumption of 660mW, and the 288K is organized as a 32Kx9. Both are offered in two types of 32-pin package DIP and SOP. (EC, December 1988, pg. 474)

Hitachi Ltd.

Hitachi soon will begin sampling a BiCMOS 256K SRAM. It has an access time of 20ns and has a maximum power consumption of 350mW. The SRAM will be offered in 64Kx4 or 256Kx1 configurations, and there will be a choice of DIP and SOP packages. (EC, December 1988, pg. 475)

Hybrid Memory Products Ltd.

Hybrid Memory Products has introduced the MSM1256 and the MSM464 military-grade 256K static RAMs. They have access times of 25, 35, and 45ns and are organized in 256Kx1 and 64Kx4 configurations. They are available in 24-pin, 300-mil DIPs, 24-pin, vertical-in-line packages, or 28-pin ceramic LCCs. (EDN, February 2, 1989, pg. 203)

Motorola

Faster 16Kx4 devices now have been added to Motorola's fast SRAM family, all with access times of 20ns. The MCM6293P20 and MCM6294P20 are packaged in 28-lead, 300-mil-wide plastic DIPs. The MCM6293J20 is offered in a 28-lead plastic small-outline SOJ. (EBN, January 9, 1989, pg. 26)

Performance Semiconductor

Sampling has begun on Performance's 4K 6ns CMOS high-speed SRAM. The 4Kx1 and 1Kx4 are manufactured from Performance's PACE III, which utilizes a 0.75-micron linewidth and operates with a 3.3V power supply instead of the conventional 5.0V power supply. (CNR, January 24, 1989)

VLSI Technology

VLSI has introduced the VT62832, a high-performance 256K SRAM. The VT62832 is configured as a 32Kx8 and offers access times of 35 and 45ns. It has low power consumption for both standby and active modes—typically 300mW active, 100uW standby, and 15uW CMOS. The SRAM is available in a 28-lead, 300-mil plastic DIP and a 28-lead, 300-mil SOJ package. (CNR, April 6, 1989)

ECL I/O-LEVEL RAM DEVELOPMENTS

Integrated Device Technology

An 8ns 64K BiCMOS ECL I/O SRAM has been introduced by Integrated Device Technology (IDT). The IDT10494 and IDT100494 are both organized as a 16Kx4, have a typical current consumption of 600mW, and are available in 400-mil sidebraze DIPs. The IDT100494 also will be available in a 300-mil SOJ package. (CNR, February 13, 1989)

NONVOLATILE DEVELOPMENTS

Intel

Intel introduced two new flash memory devices, the 128Kx8 28F010 and the 64Kx8 28F512, manufactured from Intel's 1.0-micron CHMOS process. Both feature access speeds ranging from 120 to 200ns, and are both available in a 32-pin ceramic DIP (CERDIP) or a 32-lead PLCC. (CNR, March 27, 1989)

Mitsubishi Electronics

Introduced by Mitsubishi is a 2K serial CMOS EEPROM, the M6M80021. This device is organized 128x16 and is available in 8-pin plastic DIP (M6M80021P) or 8-pin plastic SIP (M6M80021L). (CNR, January 6, 1989)

SEEQ Technology, Inc.

SEEQ has introduced two new 1Mb flash memories. The 48F010 is a 1Mb flash EEPROM and is available in both military and commercial versions. It is packaged in a PLCC, ceramic DIP, and ceramic leadless chip carrier. The 27F010 is a 1Mb flash EPROM and is aimed at more cost-sensitive applications. It is available in plastic DIP. (CNR, February 16, 1989)

Toshiba Corp.

Sampling of a high-speed 1Mb EPROM manufactured from a 1.2-micron CMOS process and organized 64Kx16 has been started by Toshiba. The new device is available with an access time of 85ns or 100ns and is packaged in a 40-pin ceramic DIP. (JEE, February 1989, pg. 88)

Also introduced by Toshiba is the TC57512AD-15/20 CMOS EPROM, with an organization of 64Kx8. It has an access time of 150 or 200ns, as well as a power dissipation of 30mA at 6.7 MHz in the active mode and 100uA in the standby mode. (EDN, March 2, 1989, pg. 184)

SPECIALTY MEMORIES

Advanced Micro Devices

AMD announced the 67C4701, a device that is a 512x8 CMOS FIFO featuring an asynchronous, full-duplex operation. It has the ability to interface bidirectionally between devices with different data rates. This FIFO is packaged in a 28-pin plastic DIP. (ED, January 26, 1989, pg. 172)

Fujitsu Microelectronics

Fujitsu has introduced two new 8-bit dual-port high-performance SRAMs, the MB8431 and MB8432. Both SRAMs are CMOS and TTL compatible. They are available in 48-pin and 52-pin plastic DIPs, and in 64-pin plastic flat packages. (CNR, January 17, 1989)

Integrated Device Technology

Integrated Device Technology (IDT) has announced the IDT71586, a cache RAM designed to work with 33-MHz microprocessor systems. The IDT71586 is a 4Kx16 static RAM with on-chip address latch, which is optimized to interface with Intel's 82385 cache controller. It has an access time of 25ns and is offered in 40-pin plastic and ceramic DIP as well as 44-pin PLCC. (CNR, March 6, 1989)

IDT also introduced the IDT6178, a 4Kx4 cache tag RAM. The IDT6178 has an address to match time of 12ns and is available in 22-pin 300 mil plastic and hermetic DIP packages, as well as a 24-pin SOJ package. (CNR, March 6, 1989)

Announced by IDT are two bidirectional FIFO modules, the IDT7MB2002 configured 4Kx36 to 16Kx9 bidirectional, and the IDT7MB2001, configured 8Kx18. They are targeted to meet the needs of processor-to-peripheral communication. Both FIFOs are offered in an quad-in-line package. (CNR, February 17, 1989)

IDT has introduced a family of writable control store subsystems. The three members include the IDT7M6052, configured in 4Kx80 with an access time of 35ns and available in a 128-pin 900-mil ceramic quad-in-line package; the IDT7MB6042, configured in 8Kx112 with an access time of 35ns and available in 164-pin QIP; and the IDT7M6032, configured in 16Kx32 with an access time of 30ns, available in 64-pin, 600-mil ceramic DIP package. Both the IDT7M6032 and the IDT7M6052 are available in military versions. (CNR, February 21, 1989)

Also to begin sampling from IDT is an 8-bit color palette, the IDT75C458. This device enables color CRTs to display 1,600 by 1,200 pixels. The color palette has a maximum operating frequency of 165 MHz and is available in 84-lead, pin-grid array packages. (ED, January 26, 1989, pg. 137)

Mosel Corporation

Mosel has started sampling a high-speed cache data RAM, the MS82C308. It is organized as a 4Kx16 and is optimized to operate as two independently controlled 2Kx16 banks. Versions of the MS82C308 are available to support 16-MHz, 20-MHz, and 25-MHz systems. It is packaged in a 44-pin PLCC. (CNR, January 30, 1989)

Vitelic Corp.

The V63C328 CMOS cache data RAM has been introduced by Vitelic. The device is organized 8Kx16 and is tailored to interface with the Intel 82385 cache controller for use in 20- and 25-MHz systems. The V63C328 has an access time of 35 or 45ns and an output-enable access time of 10 or 11ns. It is available in a 52-pin plastic leaded chip carrier. (ED, January 26, 1989, pg. 172)

Vitelic has released two FIFO memories, the V61C01, in a 512x9 configuration, and the V61C02, in a 1Kx9 configuration. Both FIFO memories are available in 12-, 16-, and 22-MHz versions. (ED, January 26, 1989, pg. 172)

VLSI Technology

The VT7150, 512x8 CMOS cache tag RAM has been introduced by VLSI. The VT7150 has address to match access speeds of 20, 25, 30, and 35ns. It is available in 300-mil, 24-pin plastic DIPs, 24-pin small outline integrated circuit gullwing (SOIC) packages, and 24-pin SOJ packages. (CNR, March 27, 1989)

Bart Ladd
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Research Newsletter

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SIS MEMORY QUARTERLY NEW PRODUCTS NEWSLETTER: SEPTEMBER 1989

This newsletter is the seventh to be issued by Dataquest's Semiconductor Industry Service (SIS) Memory Product Group. It contains a synopsis of detailed memory product news events gathered from the trade press and company releases during the second quarter of 1989 (April, May, and June). SIS assumes no responsibility for the accuracy of the contents.

The following is a key to the publications reviewed during research for this issue:

Company News Release	CNR	Electronic Engineering Times	EET
Electronic Buyers News	EBN	High Performance Systems	HPS
Electronic Design	ED	JEE	JEE

The new products announced during the second quarter of 1989 are as follows:

Company	Density	Type	Speed
	DRAM Developments		
Fujitsu	4Mb		80ns
Hitachi	1Mb		35, 40, 45ns
Mitsubishi	1Mb	VRAM	100, 120ns
Toshiba	1Mb	VRAM	100, 120ns
	SRAM Developments		
Hitachi	256K		35, 45ns
Hitachi	64K		12ns
ICI Array Technology	256K, 512K		15 to 90ns
Logic Devices	16K		12 to 85ns
Micron Technology	1Mb		30, 35, 40ns

Company	Density	Type	Speed
SRAM Developments (Continued)			
Mitsubishi	4Mb		136ns
Motorola	64K		30ns
Motorola	64K		10, 20ns
Toshiba	256K, 288K		20, 25, 35ns
United Technologies	64K		55, 60ns
Vitelic	64K		25ns
ECL I/O-Level RAM Developments			
Cypress Semiconductor	1K, 4K		3, 5ns
Siemens	4K		5, 6ns
Nonvolatile Developments			
Catalyst Semiconductor	4K	EEPROM	
Cypress Semiconductor	16K	PROM	20ns
Fujitsu	256	EPROM	
Mitsubishi	4K	EEPROM	
Mitsubishi	1Mb	EPROM	120, 150, 200ns
National Semiconductor	512K	EPROM	250ns
Rohm	1K	EEPROM	
Simtek Corporation	64K	SRAM/EEPROM	35, 45, 55ns
Toshiba	4Mb	EPROM	150, 200ns
Toshiba	1Mb	EPROM	85, 100ns
Xicor	1K	EEPROM	
Specialty Memories			
Integrated Device Technology	512, 1K	Bidirect FIFO	35ns
Integrated Device Technology	1Kx8, 2Kx8	Four-port RAM	25ns
VLSI Technology	16K	Cache tag	25, 35ns

DRAM DEVELOPMENTS

Fujitsu Microelectronics

Fujitsu launched its 4Mb CMOS DRAM, the MB814100. This device is configured as a 4Mbx1 and offers an access time as low as 80ns. The 4Mb memory is available in an 18-pin DIP, a 20-lead ZIP, and a 20- or 26-pin 300- and 350-mil SOJ. (HPS, April 1989)

Hitachi

Hitachi began sample shipments of the HM571000JP, a BiCMOS 1Mb DRAM with access times of 35, 40, and 45ns. The device is manufactured from a 1.3-micron BiCMOS process and is available in a 28-pin SOJ. (JEE, May 1989)

Mitsubishi

Mitsubishi introduced a new CMOS 1Mb video RAM (VRAM). The VRAM has a maximum access time of 80ns as well as 100 and 120ns. The company's 1Mb VRAM is available in two configurations. The M5M482128 has a 128Kx8 DRAM port combined with a 256x8 serial access memory (SAM) port, and the M5M442256 has a 256Kx4 DRAM port combined with a 512x4 SAM port. The M5M482128 comes in a new 40-pin SOJ package and the M5M442256 comes in 28-pin SOJ and ZIP packages. (CNR, June 5, 1989)

Toshiba

Introduced by Toshiba, are its second-generation 1Mb VRAMs, the TC24256A and TC24258A. These VRAMs offer a variety of new features such as block write, flash write, split-read transfer, and fast-page mode. The VRAMs are organized as a 512x512x4 with a 512x8 SAM or a 512x256x8 with a 256x8 SAM. Both are available in 100ns or 120ns and fast-page cycle times of 60 or 70ns. The x4 version is packaged in 28-pin 400-mil ZIP or SOJ and the x8 version is packaged in a 40-pin 400-mil SOJ. (EET, April 3, 1989)

SRAM DEVELOPMENTS

Hitachi

The HM62832, introduced by Hitachi, is a high-speed 256K SRAM. It is organized as a 32Kx8 and has an access speed of 35ns. The SRAM is a result of a VLSI/Hitachi design cooperation and is available in both a plastic 28-pin 300-mil DIP and SOJ. (CNR, May 16, 1989)

Hitachi released two new BiCMOS 16Kx4 SRAMs, the HM6788H and the HM6789H. Each has an access time of 12ns and offers an output enable as an option. They are designed for use with 33- and 40-MHz processors and are available in a 22-pin DIP or a 24-pin SOJ. (CNR, May 16, 1989)

ICI Array Technology

ICI Array Technology announced three new CMOS SRAM modules with access speeds as fast as 15ns in order to focus on the cache market. The Mempak AT212SZ is organized 16Kx32, has an access time of 15ns, and is offered in a 94-pin ZIP. The Mempak AT612CP and AT656CP are available as either 32Kx16s or 16Kx16s. Both have access times ranging from 35 to 90ns and are available in 40-pin DIPs. (EET, April 17, 1989)

Logic Devices

Logic Devices introduced a family of three high-speed SRAMs that have organizations of 16Kx1, 4Kx4, and 2Kx8. Each of these new devices operates with a 3-volt power supply to facilitate low power consumption and higher-speed operation. They are available with access times that vary from 12 to 85ns. (ED, June 22, 1989)

Micron Technology

Micron released its first 1Mb fast CMOS SRAM module. This module is organized as 128Kx8 and has access times of 30, 35, and 40ns. It is available in a 32-pin 600-mil DIP. (CNR, June 30, 1989)

Mitsubishi Electric

Mitsubishi began marketing the MH51208PNA, a 4Mb 512Kx8 "pseudo-pseudo" SRAM module. The module is manufactured with DRAMs, but is compatible with the 4Mb SRAM standards. The hybrid is made from four 1Mb DRAMs, an address buffer, and a DRAM controller. It has an access time of 136ns and is available in a 40-pin 600-mil DIP. (JEE, April 1989)

Motorola

Motorola added a 30ns 8Kx8 CMOS RAM to its family of SRAMs. The MCM6264P30 is packaged in a 28-pin 300-mil plastic DIP and the MCM6264J30 is packaged in a 28-lead SOJ package. (EBN, April 17, 1989)

Motorola also introduced the MCM6288 and the MCM6290, each with an access time of 10ns. The MCM6290 has the added feature of a 10ns output enable access time. Both are configured as 16Kx4, are manufactured from a 1.2-micron CMOS process, and are available in the standard plastic DIP as well as the 24-lead SOJ packages. (EET, April 17, 1989)

Toshiba

Toshiba announced a series of new high-speed 256K/288K CMOS SRAMs. Now available are the TC55464 (64Kx4), the TC55465 (64Kx4 with output enable), TC55328 (32Kx8), and the TC55329 (32Kx9). All of the devices are offered with 20, 25, and 35ns access times. The 20 and 25ns parts have a maximum operating current of 120mA, and the 35ns version has 100mA for low-power operation. All four of these devices are packaged in 300-mil plastic DIPs and SOJs. (CNR, April 11)

United Technologies Microelectronics Center

Introduced by United Technologies Microelectronics Center (UTMC) are two radiation-hardened 8Kx8 SRAMs, the UT67614 and UT7164. Both SRAMs are hardened to a total dose of 1.0E6 Rads(Si). The SRAMs feature 55, 60, and 100ns access times, TTL-compatible I/Os, and operation over the full military temperature range. The products are available in 28-pin ceramic side-brazed DIP packages. (CNR, June 5, 1989)

Vitelic

Vitelic launched its V63C64, which is an 8Kx8 SRAM. This SRAM has an access time of 25ns and an output enable time of 9ns. This device is targeted for use as a cache memory in high-end 80386-based PCs and workstations and is available in a 300-mil plastic DIP. (CNR, May 22, 1989)

ECL I/O-LEVEL RAM DEVELOPMENTS

Cypress Semiconductor

Cypress introduced a new family of high-speed ECL I/O RAMs that utilize the company's 0.8-micron bipolar and BiCMOS technologies. The new family includes standard and low power products, the CY10/100E474 and CY10/100474L, both of which are organized 1Kx4, and the CY10/100E422, and CY10/100E422L, both of which are organized 256x4. These products are available with access times of 3 and 5ns. (ED, June 22, 1989)

Siemens

Siemens announced a high-speed 4K bipolar ECL RAM, the GXB100474A, intended for use in high-performance computers. The RAM operates in two modes: standard SRAM mode and a self-timed mode. Access times are available at 3.5ns typical and 5.0ns maximum at a power dissipation of approximately 1.4W, and 4.5ns typical and 6.0ns maximum at a power dissipation of 1.0W. The GXB1000474A has a configuration of 1Kx4 with ECL 100K-compatible I/O levels and a -4.5V supply voltage. This device is available in three packages: The standard versions are available in 24-pin ceramic DIP, flatpack, or LCC, and the self-timed versions are available in 28-pin ceramic LCC. (CNR, May 8, 1989)

NONVOLATILE DEVELOPMENTS

Catalyst Semiconductor

Catalyst released two 4K serial-interface EEPROMs, the CAT33C104 and CAT33C204. These devices are suitable for use in laptop computers, hand-held computers, smart cards, and pagers. Both draw a maximum of 2mA and draw 50mA in standby mode; they are available in plastic DIPs. (EBN, May 22, 1989)

Cypress Semiconductor

Introduced by Cypress are three 16K PROMs: the CY7C291A, CY7C293A, and CY7C245A. All three are manufactured from a 0.8-micron CMOS technology, have access times of 20ns, and feature a current drain of 120mA operating at their fastest speed. The 293A is differentiated from the 291A by its automatic power-down mode, and the 245A offers edge-triggered registers. The PROMs are available in 300-mil DIP 24-pin plastic packages. (EET, May 8, 1989)

Fujitsu

Fujitsu added the MB8541, a 256-bit CMOS sequential-access EPROM, to its EPROM line. The EPROM features an on-chip address counter, a wide voltage supply that ranges from 3 to 8 volts, and a wide operating temperature range, of -40° to +85°C. This device is targeted for use in the citizen band radio, cellular telephone, and cordless phone markets and is available in a standard 8-pin plastic DIP and 8-pin plastic flatpack. (CNR, April 18, 1989)

Mitsubishi Electric

Mitsubishi developed the M6M80041P, a 4K CMOS EEPROM that is fully compatible with 1K and 2K products. The M6M80041P is organized as a 256x16, uses a 5V single power supply, has a programming time of 7 seconds, and offers an error-correction circuitry. The device is targeted for small-capacity channel selector memory for use in TV sets and VCRs. The M6M80041P is available in an 8-pin DIP. (JEE, May 1989)

Mitsubishi also started shipping three 1Mb CMOS EPROM products. The products are sealed in ceramic leaded-chip carrier (CLCC) packages with glass windows. The M5M27C100JK is organized 128Kx8 and is packaged in a 32-pin mask ROM compatible pinout. The M5M27C101JK has the same organization but is packaged in a 32-pin JEDEC standard pinout. The third EPROM, the M5M27C102JK, is organized 64Kx16 and is packaged in a JEDEC standard 44-pin package. All three have access times of 120, 150, and 200ns. (EET, May 22, 1989)

National Semiconductor

National Semiconductor expanded its line of UV EPROMs with the NMC27C512A. It is manufactured from a 1.5-micron CMOS process, organized 64Kx8, and has an access time of 250ns. This UV EPROM is packaged in a 28-pin DIP. (EBN, April 10, 1989)

Rohm

The BR93C46, a 1K CMOS serial EEPROM, has been introduced by Rohm. It is available in either surface-mount or 8-pin DIP packaging. Possible applications for this EEPROM include alarm devices, appliances, computer terminals, smart cards, electronic locks, meters, robotics, and telephones. (JEE, April 1989)

Simtek Corporation

Introduced by Simtek are two high-speed nonvolatile 8Kx8 SRAMs, the STK10C68A and STK11C68A. The memory cell for these parts is a combination of an SRAM and an EEPROM cell. The SRAM portion can be read and written a number of times while the independent nonvolatile data reside in the EEPROM portion of the cell. Both memories are available in three speed versions with access times of 35, 45, and 55ns. These devices are housed in the JEDEC standard pinouts for 8Kx8 SRAMs: the 28-pin 600-mil DIP, the 32-pin LCC, and the 28-pin 300-mil DIP. (CNR, June 5, 1989)

Toshiba

Toshiba announced a 4Mb EPROM, the TC574000D. The product is organized as a 512Kx8 and is available in either 150ns or 200ns access times with power dissipation of 50mA at 6.7 MHz in active mode and 100uA in standby mode. It is available in 32-pin ceramic DIP (CERDIP). The chip size is 5.86mm x 14.92mm and is manufactured from a 0.8-micron CMOS process. (CNR, June 16, 1989)

Toshiba also released its TC57H1024, a CMOS high-speed 64Kx16 EPROM. This EPROM is available in 85 or 100ns access times, with power dissipation of 40mA maximum at 6.67 MHz in active mode and 100mA in standby. The TC57H1024 is packaged in a 40-pin CERDIP. (CNR, June 30, 1989)

Xicor

Introduced by Xicor is the X24C01, a 1K serial CMOS EEPROM. This new device is compatible with existing 2K, 4K, and 16K serial devices in the 8-pin mini-DIP. The part is designed for applications in the consumer, communications, computer, and automotive markets for data storage in microcontroller designs. (CNR, June 26, 1989)

SPECIALTY MEMORIES

Integrated Device Technology

Integrated Device Technology (IDT) announced a family of 35ns bidirectional FIFOs optimized to facilitate microprocessor communications. The family is divided into those with sides organized as x9 and x18, and those with both sides organized as x18. The first group has the IDT7252 and IDT72520, which are 1K in density and the IDT7251 and IDT72510, which are 512-bit in density. The second group offers the IDT72521 at 1K and the IDT75211 at 512 bit. The IDT7252 and IDT7251 are packaged in 48-pin plastic DIPs, the IDT72520 and IDT72510 are packaged in 52-pin PLCCs and 68-pin PGAs, and the IDT72521 and IDT72511 are packaged in 68-pin PLCCs and 68-pin PGAs. (CNR, June 5, 1989)

IDT also launched two four-port SRAMs, the IDT7050 (1Kx8) and IDT7052 (2Kx8). Both RAMs have access times of 25ns and are aimed to help solve the bandwidth and processor connectivity problems in DSP, radar, LAN, and graphics processing systems. They are available in 108-pin ceramic PGAs and 132-pin plastic and ceramic quad flatpacks. (CNR, June 15, 1989)

Micron Technology

Released by Micron is an 8Kx16 cache data SRAM that also can be configured as a dual 4Kx16 SRAM. It has access times of 25, 35, and 45ns. This device is targeted for use as a cache memory along with 33-MHz microprocessors and a cache controller, such as the Intel 82385. (CNR, June 20, 1989)

VLSI Technology

Introduced by VLSI are two new cache tag RAMs, the VT7152 (with totem-pole match output) and the VT7154 (with open-drain match output). The 2Kx8 cache tag RAMs have access times of 25 and 35ns, and both versions are available in 28-pin DIPs or PLCCs. (EBN, March 6, 1989)

Bart Ladd
Kimberlie Southern

Semiconductor Industry Service
GATA Newsletters

Title	Date
Progress in GaAs-On-Silicon Technology	February
ISSCC Features Advances in GaAs ICs	March
The Decline of GaAs SRAM Costs	March
GaAs ICs Lead 1988 Growth in Compound Semiconductors	April

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Research Newsletter

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PROGRESS IN GaAs-ON-SILICON TECHNOLOGY

INTRODUCTION

Gallium arsenide layering on silicon substrates (GaAs-on-Si) experienced broadened interest during 1988. Since the introduction of this technology in 1981 by MIT researchers, GaAs-on-Si has offered the potential rewards (with respect to GaAs substrates or wafers) of increased mechanical strength and significantly lower manufacturing costs. Companies and universities in the United States have led the development of this technology since its inception. In some countries, government-sponsored programs are under way to support the timely solution of the remaining problems. This newsletter examines many of the ongoing activities and the progress being made in this exciting technology.

This newsletter also includes data on indium phosphide-on-silicon (InP-on-Si) technology. InP-on-Si is closely related to GaAs-on-Si in several respects, and it may be more beneficial for applications such as high-frequency amplifiers and optoelectronics.

RESEARCH DEVELOPMENTS

GaAs-on-Si offers the prospects of improved performance and a more efficient speed-power product of GaAs semiconductor technology, coupled with the low cost and efficiencies of scale of silicon wafer technology. Since the outset, a primary source of problems has been the lattice mismatch of Ga and As atoms with Si atoms as the layer formation begins.

InP has electro-optical properties that make it even more desirable than GaAs for such applications as fiber-optic communication, but it has lattice mismatch problems during formation that are similar to those of GaAs. Many of the companies with expertise in compound semiconductors are in a race to resolve the technical problems involved and thus gain competitive advantages in the semiconductor marketplace.

U.S. companies such as AT&T, Bellcore, Ford, Kopin Corporation, and Texas Instruments, along with U.S. universities such as MIT and the University of Illinois, continue to lead the world in GaAs-on-Si and related compound semiconductor materials research, followed by Japanese companies and universities. Tables 1 and 2 attest to the depth and breadth of these efforts. In addition to the work listed in Tables 1 and 2, Dataquest has noted that significant research in this technology is under way in China, Canada, and other countries.

Table 1

Company-Supported GaAs-on-Si and InP-on-Si Developments

Company	Location	Area(s) of Research
AT&T Bell Labs	Murray Hill, NJ	MOCVD growth of GaAs-on-Si and InP-on-Si
Ford Aerospace Corporation	Newport Beach, CA	Development of LSI-complexity GaAs-on-Si gate array
Ford Micro-Electronics Corporation	Colorado Springs, CO	MOCVD growth of LSI-density GaAs-on-Si; processing of E/D circuits on GaAs-on-Si wafers; III-V and II-VI materials on Si wafers of up to 200mm (8 inches) diameter
GTE Labs	Waltham, MA	OMVPE growth of GaAs-on-Si
Kopin Corporation	Taunton, MA	Large-diameter, GaAs-on-Si wafers
Matsushita	Osaka, Japan	Low-temperature MOMBE processing of GaAs-on-Si
Mitsubishi Electric Corporation	Hyogo, Japan	AlGaAs-on-Si LEDs
NTT	Musashino, Japan	Combining growth interrupt and thermal cycling (in situ TC) in InGaAs/GaAs strained-layer superlattices to lower etch-pit density (EPD) of GaAs-on-Si; development of GaAs-on-Si solar cells

(Continued)

Table 1 (Continued)

Company-Supported GaAs-on-Si and InP-on-Si Developments

Company	Location	Area(s) of Research
Oki Electric Industry Co. Ltd.	Tokyo, Japan	MOCVD growth of GaAs-on-Si
Spire Corporation	Bedford, MA	MOCVD growth of InP-on-Si
Texas Instruments	Dallas, TX	GaAs SRAMs on Si substrates; cointegration of GaAs MESFET and Si CMOS ICs on Si wafers

Source: Aztek Associates

Table 2

University Research in Compound Semiconductors on Silicon Substrates

University	Location	Area(s) of Research
California Inst. of Tech.	Pasadena, CA	GaAs/AlGaAs PNP and NPN HBTs on Si
Hiroshima University	Hiroshima, Japan	Low-temperature MOMBE processing of GaAs-on-Si
MIT	Cambridge, MA	Superlattices
MIT Lincoln Labs	Lexington, MA	ALE growth of GaAs/InGaAs layers
National Sun Yat-Sen University	Taiwan	MOCVD growth of heteroepitaxial GaInP/GaAs-on-Si
Nippon Inst. of Tech.	Saitama, Japan	MBE formation of AlGaAs-on-GaAs, GaAs-on-Si
Solar Energy Res. Inst.	Golden, CO	AlGaAs alloys; MOCVD-grown InP-on-Si
University of California at Los Angeles	Los Angeles, CA	MOCVD-grown InP-on-Si

(Continued)

Table 2 (Continued)

University Research in Compound Semiconductors on Silicon Substrates

University	Location	Area(s) of Research
Univ. of Illinois	Urbana, IL	Fabrication of LSI digICs on MOCVD-grown GaAs-on-Si; MBE formation of layered GaAs/AlGaAs PNP and NPN HBTs on Si; CW lasers using GaAs-on-Si
Univ. of Tokyo	Tokyo, Japan	Novel quantum well devices; GaAs-on-Si growth by MOCVD

Source: Aztek Associates

Kopin Corporation is the leader in supplying GaAs-on-Si wafers. In 1987, the company demonstrated 3-inch and 4-inch material suitable for prototype runs. In 1988, Kopin and GigaBit Logic jointly published comparative results of performance, yield, and reliability tests of an MSI-density chip. The device, a synchronous programmable counter, was processed on both LEC-grown GaAs wafers and MOCVD GaAs-on-Si wafers, with functional yields of 34 percent and lifetimes in excess of 2 million hours at 100° Celsius. Kopin recently has demonstrated 6-inch GaAs-on-Si substrates, further indicating that its process is production worthy.

Researchers at NTT's Applied Electronics Laboratory, Musashino, Japan, have determined that the etch-pit density (EPD) of GaAs-on-Si can be reduced significantly by combining growth interrupt and thermal cycling (in situ TC) with the growth of InGaAs/GaAs strained-layer superlattices. Last year, NTT achieved EPD of $1.4 \times 10^6/cm^2$ in 3.5u GaAs epilayers using this approach, a substantial improvement over the company's previous results.

NTT researchers have developed GaAs-on-Si solar cells for use in power generators on Japanese satellites to be launched in the 1990s. The approach uses a sandwich of alternating InGaAs and AlGaAs layers to provide relief from the stress caused by the 4 percent lattice mismatch of GaAs atoms and silicon atoms. GaAs-on-Si offers a 50 percent weight reduction compared with the use of GaAs-only wafers.

Hiroshima University and Matsushita physicists have used hydrogen plasma to lower the temperature of cleaning GaAs surfaces to 200 to 300°C, as compared with 700 to 1,000° C for previous processes. This allows MOMBE (metalorganic molecular beam epitaxy) growth of GaAs-on-Si at 400°C, using triethyl gallium (TEGa) and triethyl arsenic (TEAs) without inducing thermal cracking. The deposition apparatus was prepared by Dianippon Manufacturing Company, and the MO sources were supplied by Trichemical Company. The researchers expect this development to lead to the three-dimensional integration of III-V compound optoelectronic devices with silicon VLSI.

A study supported by the National Science Council of the Republic of China (ROC) has resulted in successful growth of heteroepitaxial GaInP/GaAs-on-Si substrates. The intermediate buffer layer of GaAs was grown by low-pressure MOCVD. This work is under way at National Sun Yat-Sen University, Kaohsiung, Taiwan, ROC.

EUROPE TRAILS IN GaAs-on-Si SEMICONDUCTOR RESEARCH

Almost every country in Western Europe is known to have corporate and/or university research under way to understand and advance compound semiconductor materials, devices, and applications. However, reports of progress in GaAs-on-Si technology in Europe were conspicuously absent from the major 1988 conferences that included sessions for this purpose. Apparently, European companies and universities are lagging in their efforts to master this technology.

DATAQUEST CONCLUSIONS

GaAs and other III-V compound semiconductor technologies have moved from the laboratory to volume production levels. Development of silicon as an alternate substrate to GaAs has progressed rapidly and has achieved preproduction status in the United States. InP-on-Si technology appears to be lagging by many months or perhaps years behind GaAs-on-Si. U.S. companies and universities remain the leading innovators in these compound semiconductor materials, closely followed by Japanese researchers. So far, this leadership remains unchallenged by European efforts.

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Research Newsletter

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THE DECLINE OF GaAs SRAM COSTS

SUMMARY

Gallium arsenide static random-access memories (GaAs SRAMs) are key ingredients in the development of today's high-performance digital systems. For this technology to continue its rapid growth, GaAs SRAMs must now compete head-on with silicon ECL technology on a cost-performance basis. Dataquest's Semiconductor Industry Service's GaAs Technology Analysis Segment has developed a GaAs SRAM cost model for its clients. This cost model is updated herein to reflect improvements in the GaAs industry's capabilities in producing cost-effective SRAMs.

GaAs SRAM APPLICATIONS

GaAs SRAMs now are used in at least three market segments. The first and oldest of these is military applications, where radiation hardness or some other unique quality of GaAs is required for maximum performance in hostile environments. Here, GaAs SRAMs have achieved production density of 16K bits per chip. In a second application, GaAs RAMs are used as cache RAMs in supercomputers, where maximum speed is essential. Third, there is a growing demand for GaAs SRAMs with ECL interface to allow implementation of air-cooled, high-performance main memory in computers. In this usage, GaAs SRAMs are displacing their higher-power, slower silicon counterparts.

COST ANALYSIS

Of these three applications, ECL main memory has the most stringent cost requirement. Silicon ECL SRAMs comprise the major share of the bipolar read/write RAM market, which exceeded $300 million in 1988. Dataquest's analysis shows 4K silicon ECL RAMs at a performance level of 5ns cycle times selling in volume for less than $10 each (<0.5 cents/bit) and 3ns chips (if available) priced considerably higher. Dataquest's SIS GATA Segment binder includes a GaAs SRAM cost model, which was recently updated to show late-1988 production figures at the 4K density level. The bottom line was a variables cost per packaged, tested, shippable unit of approximately $41, sellable at a break-even price of $93 (at 125 percent overhead). This figure is not competitive with silicon ECL SRAMs.

Dataquest believes, however, that these figures will improve dramatically over the next few months, for several reasons. First, several wafer suppliers are making substantial yield and quality improvements in starting material. Recent volume price quotes for high-quality 3-inch wafers have been less than $150/wafer for near-term deliveries, with further declines expected. Second, die sizes continue to shrink by relayout and process scaling, with one vendor claiming a 4K GaAs SRAM die size near 11,000 square mils. Third, the increased fab area volumes at GaAs prducers' factories, driven by gate array and other ASIC business, have fostered improved yields throughout the fab sequence.

The result is availability of 3ns and faster GaAs SRAMs at supplier costs that allow pricing of less than $30 in volume. While impressive, this remains a factor of several times ECL SRAM pricing. Table 1 summarizes the parameters of Dataquest's cost model for an efficient supplier at 2,500 3-inch GaAs wafer starts/month and includes a sample calculation.

Table 1

GaAs 4K Static RAM Cost Model
(Mid-1989)

Wafer Sort	Cost
3-inch wafer cost = $150, fab cost = $400, fab yield = 80% good wafers; therefore, the fab cost per gross die (fab wafer cost/450 die locations) is:	$ 1.53
Wafer sort cost per gross die:	$ 0.20
Cost per gross die through wafer sort:	$ 1.73
Therefore, cost per net die at wafer sort yield of 40% is:	$ 4.33
Assembly	
Cost of die through wafer sort:	$ 4.33
Assembly cost per wafer sort die (incl. pkg. cost):	$ 4.00
Therefore, cost per assembled die at 95% assembly yield is:	$ 8.76

(Continued)

Table 1 (Continued)

GaAs 4K Static RAM Cost Model
(Mid-1989)

Final Test	Cost
Assembled die cost:	$ 8.76
Test time/device = 20 seconds	
Test cost/unit (Cost/hr/devices tested/hr):	$ 0.67
Final test yield = 85%	
Therefore, cost per final tested unit is:	$11.09
Mark, Pack, Ship	
Operation cost at 99.9% yield:	$ 0.75
Therefore, total variables cost per net unit is:	$11.85
Assume overhead* = 125%	
Therefore, breakeven cost per unit is:	$26.66

*The term "overhead" as used here includes all other costs of growing a viable business, e.g., R&D, marketing, selling, accounting, management and other costs and expenses.

Source: Dataquest
March 1989

DATAQUEST CONCLUSIONS

The costs of high-quality NDF (near-defect-free) wafers, facilities amortization, packaging and testing, and yields associated with modest efficiencies of scale (compared with the silicon industry) are the primary cost-limiting factors in producing GaAs SRAMs. Although Japanese companies have been involved in GaAs SRAM R&D for several years and have built 16K and projected 64K chips, this technology has been reduced to volume production practice by United States companies such as GigaBit Logic, Rockwell, Vitesse, and others. Dataquest expects U.S. suppliers to continue their significant cost improvements in 1989.

Progress in cost reduction, while evident, has been limited by a lack of aggressive pursuit of this market by U.S. suppliers (attributed by some to resource limitations). These companies apparently fear the possibility of Japanese competition causing a never-ending spiral of price wars and product obsolescence (as in silicon DRAMs). This reticence is presently causing a major limitation to supercomputer designers who cannot get GaAs SRAMs at the costs they need to support their GaAs CPU designs, and who are compromising performance by using Si ECL SRAMs. The first GaAs chip supplier to take a leadership role and apply sufficient resources to 4K and larger GaAs SRAM production has a unique opportunity to capture a significant share of an emerging market.

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Research *Bulletin*

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ISSCC FEATURES ADVANCES IN GaAs ICs

SUMMARY

GaAs ICs moved farther into the major leagues during the thirty-sixth International Solid-State Circuit Conference (ISSCC). Presentation of an ASIC chip designed jointly by IBM and Rockwell has created major interest across the GaAs industry infrastructure. This Research Bulletin highlights this and related compound semiconductor topics presented during the conference.

DISCUSSION

The ISSCC, a technology conference concerned predominantly with silicon, included five papers on GaAs technology that were of special interest to the electronics community. Two of these relate to high-performance computing and digital signal processing, two to digital and high-speed analog communications, and one to microwave signal processing. These advancements are discussed in the following paragraphs.

IBM/Rockwell Gate Array Uses HBT Technology

IBM and Rockwell have developed a 5,090-transistor gate array with the logic equivalent of 1,100 logic gates, using AlGaAs/GaAs heterostructure bipolar transistors (HBTs). Performance of 43 GHz frequency was achieved on coarse-tolerance transistors having emitters of 1.4 x 3.0 microns^2. Differential outputs from each gate assure 800mV of noise margin, and gate delays of 71ps were measured at fanouts averaging 2.5. The paper was prepared jointly by IBM personnel at facilities in Los Gatos, California, and Yorktown Heights and East Fishkill, New York, and by Rockwell personnel in Thousand Oaks, California, and Dallas, Texas.

Honeywell's 16x16 Multiplier Is World's Fastest

Researchers at Honeywell's Sensors and Signal Processing Laboratory used a modified Booth's algorithm to develop a 16x16 complex multiplier of 4,500-gate complexity. The 7.8 x $8.5mm^2$ chip was fabricated on 3-inch LEC GaAs wafers using MBE to form the 1-micron gate-length heterostructure FETs. Vector rotations have been performed on the chip at 520 MHz clock and 4 watts P_D. This corresponds to 96ps per gate and 0.89mW per gate and is believed to be the fastest multiplier reported to date for any IC technology.

NTT Describes GaAs MESFET Macrocell Array

NTT's LSI Laboratories and Communications Switching Laboratory, Atsugi, Japan, have demonstrated a GaAs MESFET 250-gate array constructed of 50 macrocells. Short-channel effects were minimized by 10-keV Si+ implantation and rapid optical annealing at 950° C for two seconds to form a 450-angstrom active layer. Gate delays of 50ps were achieved in a 10-element critical path of a 2-Gb/s asynchronous transfer switch implementation. Die size is 2.5 x $2.8mm^2$ using minimum gate lengths of 0.4 microns.

ETRI Develops GaAs 16x8 Crosspoint Switch

Korea's Electronics and Telecommunications Research Institute (ETRI) reported satisfactory testing of its 2.2-Gb/s 16x8 crosspoint switch built using a 1.0-micron GaAs MESFET process. The 700-gate, 4.06 x $5.25mm^2$ die is packaged in 132-pin LCC. Crosstalk at 2.2 Gb/s was measured at 140mV.

Hughes Advances the Art of Op Amp Design

Hughes Research Laboratories has overcome the problems of light sensitivity and excessive backgating to develop a 10-GHz operational amplifier using 0.2-micron gates, MBE-grown channel layers, and air-bridge interconnects. The frequency of the GaAs D-MESFETs is approximately 80 GHz. This device has the highest op amp bandwidth reported to date.

DATAQUEST CONCLUSIONS

Dataquest believes that bipolar GaAs technology represents another increment in speed that is available to designers of future supercomputers, achievable at relatively "loose" manufacturing process rules. The building blocks for 500-mips processing speeds have been demonstrated. We also acknowledge that Korea has joined Japan and other countries as a source of 2.2-Gb/s communications technology.

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Research Bulletin

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GaAs ICs LEAD FORECAST GROWTH IN COMPOUND SEMICONDUCTORS

SUMMARY

Fueled by significant growth in almost all electronic equipment market segments, consumption of GaAs and other compound semiconductors increased to more than \$2.6 billion in 1988; consumption is now expected to exceed \$4 billion by 1993. Discrete optoelectronic and other discrete devices constituted 89 percent of 1988 shipments and will account for less than 75 percent of 1993 shipments. GaAs ICs (excluding NRE charges) now account for more than 16 percent of the compound semiconductor market and are expected to exceed 25 percent of this market by 1993.

DATAQUEST ANALYSIS

Dataquest's forecast of the GaAs and related compound semiconductor device markets is summarized in Table 1. As in last year's forecast, we continue to show a compound annual growth rate (CAGR) of more than 15 percent. In fact, Dataquest expects the adoption of fiber optics by the automotive and other industries, coupled with computer and communications equipment market recovery and with very high growth rates in the IC categories, to pull the growth rate of the overall market to more than 18 percent through 1993.

However, we have reduced the IC forecast growth rates to 45 percent for digital ICs and 28 percent for analog/linear (including microwave) ICs, for two reasons. First, several suppliers have withdrawn from this market, the most recent being Siemens (MSC) and GAIN Electronics. This reduces total market development effort, particularly in the digital arena, where GAIN's arrangement with NTT was intended to accelerate SRAM applications and availability. Second, the number of Phase 1 MIMIC awards was reduced from the anticipated six to a total of four primes, causing several major participants to revise their market entry strategies.

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Table 1

Worldwide GaAs and Related Compound Semiconductor Market Consumption* (Millions of Dollars)

	1987	1988	1989	1990	1991	1992	1993	CAGR 1987-1993
Total	$2,183	$2,691	$3,149	$3,454	$4,082	$4,928	$5,897	18.1%
Analog/Linear ICs	138	157	201	269	377	486	621	28.5%
Devices	85	107	153	224	339	451	586	38.0%
NRE	53	50	48	45	38	35	35	(6.7%)
DigICs	71	86	127	188	315	512	656	44.9%
Devices	35	51	92	158	285	482	626	61.7%
NRE	36	35	35	30	30	30	30	(2.5%)
Optoelectronics	1,752	2,205	2,558	2,709	3,072	3,585	4,244	15.9%
Discrete Opto	1,709	2,143	2,461	2,558	2,885	3,342	3,916	14.8%
OEICs	43	62	97	151	187	243	328	40.3%
Microwave/mm Wave Discretes	222	243	263	288	318	345	376	9.2%

*Data include intracompany consumption for merchant suppliers (e.g., AT&T), and exclude intracompany consumption of full captives (e.g., IBM).

Source: Dataquest
May 1989

Potential upsides in the analog/linear IC markets are in the automotive, GPS navigation equipment, VCRs, and several other end equipment markets. Federal legislation for mandatory collision-avoidance hardware on vehicles would increase demand for MMICs by an estimated $100 million annually. The probable impact of HDTV applications is longer term—mid- to late-1990s.

There are upsides to the GaAs digital IC segment of this forecast for the early 1990s, related to the rates of buildup required by end users such as Cray, IBM, Prisma, Unisys, and other potentially high-volume users. The possibility for explosive demand growth for GaAs ICs is evidenced in the late-1988 contract between Cray Research and GigaBit Logic (total 1988 sales by GBL were less than $13 million), which calls for $29 million in digICs, deliverable in 1989.

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Research *Bulletin*

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GaAs ICs LEAD 1988 GROWTH IN COMPOUND SEMICONDUCTORS

The 1988 worldwide market for GaAs semiconductors was characterized by double-digit growth in almost all categories and approached $2.7 billion in total sales. Discrete optoelectronics continued as the dominant factor, although GaAs ICs now account for more than 13 percent of the total. Record GaAs device sales in all categories resulted from the substantial growth in computers, telecommunications, instrumentation, and related electronic equipment markets. Table 1 shows worldwide GaAs semiconductor shipments for 1984 through 1988.

GaAs IC devices, including OEICs, led 1988 growth, exceeding 20 percent in all categories. NRE (nonrecurring engineering) costs leveled in 1988, indicating a maturing of GaAs ASICs and certain developmental programs that have been under way since the early 1980s. During 1988, GaAs IC growth was somewhat lower than expected, primarily due to the withdrawals of Ford, GAIN Electronics, and Microwave Semiconductor Corporation (Siemens) from the merchant marketplace. Although Gazelle started shipping in 1988, its quantities were very limited and did not offset the loss of three suppliers. The Ford withdrawal is said to be temporary; the company is expected to reenter with analog/linear products within 12 months.

Major announcements in 1988 included a contract for more than $29 million in GaAs digICs to be delivered by GigaBit Logic to Cray Research in 1989. A host of new product introductions in the last several months include optoelectronic transmitter and receiver functions from Rockwell and several other suppliers, high-density (12,000+) gate arrays from Vitesse, and TTL-compatible factory-programmable logic from Gazelle. These developments have set the stage for an acceleration in growth of GaAs ICs in 1989–1990.

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The acceptance of GaAs IC technology at AT&T, IBM, and other industry giants has heightened the interest in this approach to hardware design across the data processing industry. Dataquest expects new system products containing thousands of GaAs ICs per system to be shipped by major industry participants within calendar year 1989.

Gene Miles

Table 1

Worldwide GaAs Semiconductor Shipments (Millions of Dollars)

Category	1984	1985	1986	1987	1988	Percent Change 1987-88
Total GaAs Semiconductors	$1,410	$1,517	$1,902	$2,183	$2,691	23.3%
Optoelectronics	$1,229	$1,233	$1,514	$1,752	$2,205	25.9%
Discrete Opto	1,221	1,213	1,486	1,709	2,143	25.4%
OEICs	8	20	28	43	62	44.2%
Analog/Linear ICs	$ 39	$ 80	$ 107	$ 138	$ 157	13.8%
Devices	19	40	56	85	107	25.9%
NRE Costs	20	40	51	53	50	(6.7%)
DigICs	$ 11	$ 26	$ 51	$ 71	$ 86	21.1%
Devices	2	6	21	35	51	45.7%
NRE Costs	10	20	30	36	35	(2.8%)
uw/mmw Discretes	$ 131	$ 178	$ 228	$ 222	$ 243	9.5%

Notes: Columns may not add to subtotals and totals shown due to rounding.
OEIC = optoelectronic integrated circuit
uw = microwave
mmw = millimeter wave
Dataquest's merchant shipment figures include intracompany transfers for merchant suppliers at estimated market value. No full-captive supplier data are included.
Optoelectronics data for 1984 through 1988 include silicon emitters and detectors.

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Research Newsletter

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GaAs ICs COMPETE FAVORABLY WITH ALTERNATE TECHNOLOGIES

SUMMARY

Recent developments in silicon and compound semiconductor technologies have intensified the competition for new designs in all product categories. To date, only one competitor, Texas Instruments, has introduced a broad range of products in both silicon and GaAs, although several silicon device suppliers, primarily Japanese companies, have developed GaAs advanced products for internal use. This newsletter examines recent advances and tradeoffs in both silicon and compound semiconductor technology.

HIGH-SPEED LOGIC EVOLUTION

As more and more TTL interface logic circuits have reached performance levels limited by the laws of physics at the I/O levels, many users have opted for ECL current-mode interfaces to extend performance into the subnanosecond range. This has led to a proliferation of ECL suppliers and to an evolution from conventional CMOS toward BiCMOS for many new logic and memory devices. Designing with ECL is becoming commonplace; the difficulty of using ECL is now usually a matter of perception rather than of reality. Table 1 summarizes recent developments in available logic technology and lists some of the suppliers active in these areas.

The data in Table 1 assume that the user is willing to tolerate silicon ECL power dissipation of 30 to 40 watts in order to take advantage of the available gate density. This power level necessitates liquid cooling for reliable operation. GaAs' unique properties allow the creation of speed/power products that are five to six times more efficient than silicon so that it can provide the characteristics listed in Table 1 in an air-cooled environment.

Process complexity eventually will be a limiting factor on the cost of each of the technologies discussed here. Table 2 compares data regarding the relative complexity of the processes used for the manufacture of logic ICs.

Table 1

Recent Developments in Logic IC Technologies

Process	Gates/Chip	Min. CDs	Gate Delay	Typical Suppliers
GaAs HBT	10,000+	2.0u	<100ps	Texas Instruments
GaAs MESFET	10,000-16,000	1.0u	50-60ps	GigaBit Logic, Vitesse
Si ECL	14,000-30,000	0.8u	150-350ps	AMD, AMCC, Fujitsu, Motorola, National, NEC, Plessey, Signetics, Sony
Si BiCMOS	To 200,000	0.8u	270-900ps	AMCC, Fujitsu, Hitachi, Motorola, NEC, Texas Instruments, Toshiba

Note: CD = critical dimension; u = micron; ps = picosecond

Source: Dataquest
May 1989

Table 2

IC Process Complexity Comparison

Process Type	Critical Masks	Total Masks	Process Steps
GaAs E/D	3	11	45
Si ECL	5	13-15	65
Si CMOS	5	13-15	63
Si BiCMOS	6-7	17-19	71

Source: Dataquest
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Regarding cost, silicon BiCMOS offers the lowest cost per gate of the technologies shown, although standard CMOS cost per gate is even lower. Both silicon ECL and GaAs MESFET gate arrays and standard cell arrays are priced at 3 cents to 5 cents per gate depending on volume, and NRE costs for the two technologies are similar. GaAs HBT is priced somewhat higher than silicon ECL/GaAs MESFET.

IMPROVEMENTS IN LINEAR TECHNOLOGIES

During the late 1980s, standard cell technology has been introduced to both GaAs and silicon analog/linear ICs. Pacific Monolithics now has more than 500 cells in its library for GaAs MMIC design. Silicon houses have followed suit, developing standard cell sets for linear circuit applications. Others have combined CMOS and bipolar linear processes to allow replacing complex, expensive hybrid designs with lower-cost monolithic ICs.

Texas Instruments has accomplished the first insertion of GaAs MMIC technology into a DOD hardware program. GaAs ICs designed by TI will be incorporated into the HARM missile program. TRW was the first company to deliver working prototype MMIC chips on Phase I of the DOD MIMIC program; TRW's chip consumes only 20 percent as much power and 5 percent as much space as its silicon counterpart. Other GaAs MMIC successes are expected to follow these breakthroughs.

While some industry sources maintain that certain functions are not integratable, the upper limit of integratability remains a moving target. For example, companies such as Avantek have fabricated monolithic silicon ICs with cutoff frequencies well beyond 10 GHz. Dataquest expects these trends to continue, with an increasing variety of high-performance analog/linear ASICs becoming available from a broad range of suppliers by the early 1990s.

DISCRETE DEVICE TECHNOLOGIES

GaAs discrete transistors are now available for operation to frequencies beyond 100 GHz from sources in the United States, Japan, and Europe. By applying fine-line lithography, critical dimensions are now controlled to values approaching 0.25 micron, with corresponding improvements in performance being introduced on a continuing basis.

Compound semiconductors based on II-VI technology have resulted in the development of blue LEDs for indicators, using such materials as ZnSe. GaAs-based LEDs may see increased competition from II-VI LEDs as materials and manufacturing costs are reduced.

InP is a promising substrate material for millimeter-wave operating frequencies. Development activity in this area is accelerating and may result in the eventual availability of linear ICs capable of operating above the 40-GHz carrier frequency.

DATAQUEST CONCLUSIONS

While CMOS continues to have the lowest cost per function of the available IC technologies, 1989 is the year of intercept and possibly of crossover of GaAs with silicon ECL gate pricing. Parity in pricing for these two technologies has been established.

The competition among processes and substrate technologies is more heated than ever. InP and certain II-V materials may represent new competition for GaAs discrete LEDs and for millimeter-wave ICs.

Recent developments in GaAs, together with the increasing process complexities of silicon bipolar, CMOS, and BiCMOS, indicate that the user base for GaAs ICs will expand on an accelerating basis for years to come.

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GaAs IC ACTIVITIES INCREASE DESPITE CONSOLIDATIONS

Presentations and discussions at the Microwave Technology Conference and other recent developments confirm the growing acceptance of GaAs ICs for new designs, although some supplier consolidation continues to occur. This newsletter highlights several current activities in the GaAs IC field that will be of interest to many Dataquest clients.

DARPA CONTRACTS BOOST GaAs DigIC INSERTION

The Defense Advanced Research Projects Agency (DARPA) is expected to award several contracts in the near future, all directed toward the assimilation of GaAs digital IC (digIC) technology by active defense programs. These programs include the following:

- Array processor—E-Systems (Greenville Division)
- Digital radio frequency memories (DRFMs)—ITT Avionics, KOR Electronics, and Sanders Associates
- Digital map computer—Honeywell
- Missile guidance DSP—Martin-Marietta (Electronic Systems)
- Portable modem and frequency synthesizer—E-Systems (ECI Division)
- Radar signal processor—Grumman
- Search radar upgrade—Texas Instruments
- Spacecraft on-board processor (replacing CMOS)—Martin-Marietta (Space Systems)
- Target-tracking processor—McDonnell Douglas

The fiscal year 1989 awards are expected to range from approximately $300,000 to more than $1 million. The projects were chosen from more than 40 industry proposals.

CHANGES IN THE COMPETITIVE LINEUP

As of mid-June 1989, several changes in the GaAs competitor lineup are under way. These involve both U.S. and European participants.

M/A-COM has offered to acquire Adams-Russell, reportedly for an exchange of shares. The future impact, if any, on the two companies' foundry services and other GaAs activities was unknown at press time.

Ford has backed away from the commercial GaAs MESFET IC market. However, its GaAs foundry support of projects continues on a case-by-case basis, as does its support of internal programs. Dataquest believes that Ford recently has increased its focus on heterojunction bipolar transistor (HBT) technology.

Plessey reportedly has de-emphasized commercial GaAs activities, although company representatives at MTT indicated a continuation of GaAs foundry services. Plessey is expected to reorganize its GaAs group and relocate certain operations.

Siemens is no longer a player in the GaAs IC and foundry business. The sale of MSC in late 1988 was accompanied by the shutdown of all GaAs standard MMIC, digIC, and custom/foundry operations and the layoff or transfer of all associated personnel at the Somerset, New Jersey, facility.

SILICON MMICs ACHIEVE 6-GHz OPERATION

Avantek has fabricated a set of fixed and variable gain amplifiers with silicon technology that have a cutoff frequency of 10 GHz, allowing functional operation of 6-GHz MMICs. The process uses interdigitated, 0.6-micron, arsenic-doped emitters; self-alignment; local oxide isolation; and ion implantation. Avantek expects to extend this technology to 10-GHz and 10-Gb/s operation. This development represents silicon technology's leading edge, which confirms the demand for GaAs and other compound semiconductors for microwave and millimeter-wave applications.

GATE WIDTHS ADVANCE BELOW 0.5 MICRON

Compound semiconductor technology rapidly is becoming a 0.25-micron world, at least where FETs and MMICs are involved. A growing number of suppliers, including AEG-Telefunken, Avantek, COMSAT, General Electric Company, Thomson-CSF, TRW, Varian, and Watkins-Johnson, have reported using 0.1- to 0.35-micron gate lengths to fabricate present GaAs IC designs. Matsushita has developed low-noise InGaAs HEMTs with a 0.68dB noise figure at 12 GHz that are grown by MBE and have 0.2-micron gates. Toshiba claims it has achieved 40-GHz operation of low-noise HEMTs using AlGaAs/GaAs structures with gate lengths of 0.1 micron.

HBT TECHNOLOGY ACHIEVES 42-GHz VCO FREQUENCY

TRW Inc. Electronic Systems Group has demonstrated a pair of GaAs HBT voltage controlled oscillators (VCOs) that span the 25- to 42-GHz frequency range. Active devices are 3-micron-emitter AlGaAs/GaAs self-aligned transistors with F_{max} that exceeds 50 GHz. Packaged in less than 0.5 cubic inch, the devices eliminate the need for post multiplication, amplification, and filtering in today's lower-frequency VCOs. TRW expects this technology to have an important impact on the size, weight, and power of future wideband communications systems.

FIRST KILOWATT GaAs LASER ARRAY REPORTED

The David Sarnoff Research Center in Princeton, New Jersey, has reported the successful operation of the first one-kilowatt (peak power) GaAs laser array. Operating parameters included 32 percent overall efficiency, 808nm nominal wavelength, 15Hz repetition rate, and 60mA input current at 16° Celsius. Pulse width was 100 microseconds. The array structure is AlGaAs quantum wells (QWs) grown by MOVPE on a GaAs substrate.

DATAQUEST CONCLUSIONS

GaAs technology applications continue to diversify as yields increase and costs decline to new levels. Performance specifications for GaAs ICs and discretes are improving at a relentless pace, and we expect them to continue to remain well ahead of silicon technology improvements into the next century. We believe that semiconductor users, particularly those that supply leading-edge-performance electronic equipment, should not ignore the competitive advantages available through the appropriate application of GaAs technology.

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Research *Newsletter*

GaAs PLDs ATTACK THE SILICON TTL PLD MARKET

GaAs programmable logic devices (PLDs) that operate 65 percent faster than equivalent silicon parts are now available as a superset of more than 30 of the most popular silicon PLDs. These and other GaAs PLDs are expected to have a major impact on the silicon PLD marketplace as the 1990s unfold. This newsletter examines some of the important issues involved in this aspect of the evolution of IC technology.

AVAILABILITY AND PRODUCTION WORTHINESS OF GaAs

The history of GaAs development in many ways parallels that of silicon ICs. The reproducibility of GaAs VLSI technology already is established by the accumulated experiences of several major U.S. defense suppliers, as well as commercial suppliers of GaAs ICs. Available gate arrays, standard cell logic, and static RAMs now contain 25,000 to 100,000 transistors per chip. U.S. defense contractors supplying complex digital ICs (digICs) include McDonnell Douglas, Rockwell, and Texas Instruments. Commercial suppliers of GaAs VLSI chips include Gazelle, GigaBit Logic, TriQuint, and Vitesse.

The GaAs digIC production difficulties experienced in the early and mid-1980s were resolved by improvements in wafer technology and device worst-case design techniques and by the application of silicon volume production methodologies to GaAs chip fabrication and testing operations. GaAs gate array manufacturers now are offering volume deliveries of sub-100-picosecond, 10,000-gate arrays with emitter-coupled logic (ECL) interface at per-gate pricing at or below that of silicon ECL. Availability of GaAs is no longer an issue in new designs.

BENEFITS OF GaAs OVER SILICON

At a given set of design rules, GaAs E/D MESFET technology offers a superior speed-power product of approximately three to five times that of silicon. This allows IC designers to trade off speed and power to optimize circuit operation at a more efficient point than that achievable with silicon. In TTL-interface designs, speed improvements in silicon now dictate that faster input and output transitions be used, because internal gate speeds are rapidly approaching the limits of silicon technology. Silicon chip designers have taken this approach in some of the latest designs, which results in increased ground noise, I/O signal reflections, and crosstalk, each of which may cause logic malfunctions.

GaAs internal gates can operate several times faster than silicon at the same power level, allowing significantly faster chip throughput speeds. This gives the IC designer greater flexibility in maintaining the relatively slow I/O rise and fall times dictated by a transistor-transistor logic (TTL) or CMOS environment.

GaAs properties also allow the design of chips that can operate above 250° Celsius (versus 125° Celsius for silicon). GaAs circuits have the additional property of greater radiation hardness than that achievable in silicon. However, these properties are relatively unimportant compared with raw speed and speed-power product in the design of ICs intended for commercial computer, communication, and workstation applications.

GaAs PLDs

The first GaAs PLDs, the GA22V10-10 and GA22V10-12, were announced by Gazelle Microcircuits, Inc., in mid-1988. These devices are pin-compatible replacements for the popular 24-pin

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TABLE 1
PLDs Replaceable by the GA23SV8

Part Type	Array Inputs	Registers	Product Terms	Fixed Inputs	Fixed Outputs	Bidirectional I/Os
23SV8	23	14	135	9	0	8
23S8	23	14	135	9	0	8
18V8	18	8	72	10	0	8
18P8	18	0	72	10	0	8
16V8	17	8	64	10	0	8
16R8	16	8	64	8	8	0
16R6	16	6	64	8	6	2
16R4	16	4	64	8	4	4
16L8	16	0	64	10	2	6

Source: Gazelle Microcircuits, Inc.

22V10 PLDs, which have been available in silicon for more than five years. The Gazelle chips are produced from wafers supplied by TriQuint or some other foundry and are factory configurable by laser programming technology.

In June 1989, Gazelle announced the GA23SV8, a 20-pin superset of 32 of the most widely used silicon PLDs. The 166-MHz maximum clock frequency makes this device the fastest TTL sequencer presently available in commercial volume. Table 1 identifies several of the TTL PLDs included in the superset, most of which are pin compatible and all of which are functionally compatible with the GA23SV8.

THE PROGRAMMING ISSUE

The Gazelle PLDs are programmed at the factory at present. This programming probably is acceptable for most prototype situations and many production environments, but it restricts the user's control over design security. Factory programming by the chip vendor also increases turnaround time and cost when engineering changes or product improvements are made to the system design, although overnight mail may relieve some time constraints. In the silicon TTL world, bipolar masked ROMs were limited in popularity and acceptance for these reasons, and field-programmable PROMs served as the workhorse technology until field-programmable PLDs became available. This issue will be a constraining factor in determining the extent to which GaAs PLDs will penetrate the silicon TTL and CMOS PLD markets.

DATAQUEST CONCLUSIONS

The availability of GaAs PLDs with TTL interface is accelerating the insertion of GaAs technology into digital systems. Together with GaAs gate array and standard cell technologies, this technology will find broad applications in workstations and other high-performance hardware. The acceptance of GaAs PLDs presently is limited by the constraint of factory programmability. However, Dataquest believes that the solution to customer programmability of GaAs PLDs is only months away, and that introduction of such GaAs chips soon will have a significant impact on the growth rate of the $900 million silicon PLD marketplace.

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Research Newsletter

III-V ANALOG ICs POISED FOR NEW APPLICATIONS

INTRODUCTION

Linear and other analog ICs based on GaAs and related III-V compound semiconductor materials now are positioned to penetrate new markets, the result of major cost reductions in recent months. Two examples: Japanese GaAs analog IC chips are being used in VCRs and other consumer electronics, and Hewlett-Packard now uses GaAs ICs in at least 10 of its products for the instrumentation market. GaAs analog IC insertion into military electronics is accelerating as MIMIC Phase III awards are made. This newsletter briefly examines specific recent progress in this technology and explores some of the many new opportunities for the growth of III-V analog ICs.

III-V IC COSTS CONTINUE THEIR RAPID DECLINE

The traditional cost decline in silicon semiconductors is no less true for compound devices. In fact, because the market for III-V devices is experiencing a higher long-term growth rate than that of silicon ICs, unit costs of many III-V analog ICs are declining more rapidly than are silicon IC costs. Several factors have interacted to push GaAs and other III-V compound analog IC costs to new lows. These include materials progress, application of silicon IC CAD and production techniques, improvements in test equipment, and advances in packaging.

Materials progress in the 1986 to 1988 time frame resulted in the widespread availability of VLSI-grade 4-inch GaAs wafers, with correspondingly favorable impact on the quality of the 3-inch wafers used by many GaAs analog IC suppliers. Improved CAD models have allowed analog GaAs IC designers to accomplish worst-case analysis prior to production release more easily. Nonintrusive optical-test and RF-test technologies are making excellent progress, as is higher-frequency test equipment, which now exceeds 40-GHz capability. Improved packaging techniques are reducing the extent of customization required during the assembly process. All of these advances are tending to have a multiplicative rather than additive effect on cost reduction of compound semiconductor analog ICs.

MIMIC UPDATE

MIMIC (pronounced my-mik) is a seven-year, $575 million DARPA-sponsored initiative for development of affordable microwave and millimeter-wave ICs (hence the name, MIMIC) for United States DOD applications including radar, communications, smart weapons, and electronic warfare. As previously reported by Dataquest and others, Phase 0 of the MIMIC program, which involved studies by 12 prime contractors that are under the direction of either the army, the navy, or the air force, was completed in 1988. Phase I has been under way for more than a year, with awards ranging from approximately $49 million to $68 million each to 4 prime contractor teams (Hughes/GE, ITT/Martin Marietta, Raytheon/TI, and TRW). MIMIC Phase II will follow Phase I, with awards expected in mid-1991. A Phase III effort is running parallel to Phase I in order to accelerate modeling, testing, and other support programs.

MIMIC Phase III funding addresses support programs such as automatic testing; CAD modeling of devices, wafers and wafer processing, and packaging. DARPA received more than 100 proposals for Phase III funding. At press time, DARPA

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reportedly had made 12 MIMIC Phase III awards that ranged from $198,000 to more than $1.2 million each. Recipients and their respective projects are believed to be the following:

- AT&T—Nondestructive wafer characterization
- Ball Aerospace—RF probing of wafers
- Comsat Labs—Wafer characterization
- Gateway Modeling Inc.—CAD device models
- ITT Avionics—Multilayer multichip packaging
- M/A-COM—Pulsed-power wafer testing
- North Carolina State University—CAD and process yield models
- Spire—Process evaluation
- TRW—Focused ion beam (FIB) processing
- University of Colorado—CAD layout models
- Varian Research—Nonintrusive wafer testing
- Varian MBE Operations—MBE process enhancements

EUROPE MOVES AHEAD IN GaAs ANALOG ICs

European suppliers of GaAs analog ICs reported significant advances in products and applications at the 19th European Microwave Conference and Exhibition held in London on September 4 through 7, 1989. Presentations by persons from AEG, British Aerospace, CNRS, Plessey, Siemens, Thomson, several other companies, and numerous universities covered an array of advances in amplifiers, oscillators, convertors, multiplexers, testing, CAD techniques, and systems applications. Frequency capabilities now range to 348-GHz all-solid-state receivers for radiotelescopes and 200-GHz EM-field measurements for large-antenna systems.

The Europe 1992 initiative, which is aimed toward a single internal market among 12 (and possibly more) European Community (EC) countries, is expected to affect favorably GaAs IC applications in the commercial sector. Any lowering of tariffs and other trade barriers is expected to stimulate demand. However, the defense sector may be much less affected because nationalistic objectives such as the avoidance of technology transfer will remain. Furthermore, U.S. defense suppliers may lose market share to EC suppliers, especially as duplication of programs such as NATO requirements among allies is reduced.

JAPANESE COMPANIES DEVELOP GaAs ANALOG ICs FOR CONSUMER EQUIPMENT

While U.S. and European companies have focused most GaAs analog/linear IC developments on defense applications, Japan has redirected some of its attention—heretofore, almost exclusively devoted to communications applications—toward consumer applications. The following developments, first reported by Dataquest several months ago, illustrate this trend.

Hitachi has demonstrated a 3-band (VHF/CATV/UHF) GaAs IC tuner for TV and VCR receivers. The chip integrates a mixer, oscillators, and an IF amplifier, decreasing the size and improving the noise properties of the tuner circuit while reducing parts count by 30 percent compared with the silicon approach presently in use.

Matsushita's Discrete Device Division in Kyoto and its R&D Laboratory in Osaka reported developing a GaAs RF amplifier IC for UHF TV/VTR tuner applications in a 6-pin plastic package. The chip reduces the size of the amplifier section of the RF tuner by a factor of two and reduces its cost compared with the present silicon implementation.

The TV and VCR markets are well recognized as involving shipment levels of tens of millions of units per year. This demonstrates that Japanese companies are eager to exploit large-volume applications of GaAs analog ICs in order to gain efficiency of scale as early as possible, while their American and European competitors deal with yield issues at much lower volume levels. The ability of Japanese GaAs companies to compress time-to-market will reap for them an increased share of the world GaAs IC market as the industry progresses into the 1990s.

INSTRUMENTATION PRODUCTS USE ANALOG GaAs ICs

Cost and performance are major factors for successful participation in the instrumentation marketplace. Many suppliers of complex instrumentation are turning to analog GaAs ICs for upgrading existing designs and for new designs. These

Table 1
Applications of Analog GaAs ICs in Hewlett-Packard Products

Model	Unit Function	IC Function(s)	Benefit(s) of GaAs ICs
HP 5386A	Frequency counter	Preamp, scaler	Prescaling to 3 GHz; -23.5 dBm sensitivity
HP 54111D	Digitizing oscilloscope	Sample and hold	1 gigasample/second
HP 71400A	Lightwave signal analyzer	Broadband IF amplifier	22-GHz bandwidth
HP 8131A	Pulse generator	Output amplifier	5V p-p, <200ps rise/fall
HP 8347A	RF amplifier	Continuously variable attenuator	Broadband leveling
HP 85024A	RF probe	High-impedance input amplifier	0.7pF input capacitance, useful to 3 GHz
HP 8560 series	Spectrum analyzer	LO amplifier	Reduced component cost 30 percent
HP 8665A	Signal generator	Pulse modulator, freq. divider	Reduced phase noise
HP 8670 series	Signal generator	2- to 7-GHz amplifier	Replaced 269 parts with 52
HP 8770A	Waveform generator	Deglitcher	Reduced spurious level to -53 dBc
HP 8780A	Vector generator	Amplifier, modulation drivers	1.5 percent accuracy 350-MHz digital modulation

Source: Hewlett-Packard

companies include Boonton, Colby, Fluke, Hewlett-Packard (HP), Microwave Logic, Sciteq, Tektronix, Wavetek, and others. Chip suppliers include Anadigics, HP, M/A-COM, NEC, Teledyne, TriQuint, and others.

Starting in 1985, Hewlett-Packard has increasingly incorporated custom analog GaAs ICs into its instrumentation product line. Analog GaAs IC chips now are considered by HP to be a mainstream technology. Benefits cited by HP include reduced parts count, fewer interconnections, smaller space requirements, performance enhancements, less sensitivity to variations in manufacturing, and improved component reliability. Table 1 shows several HP products that use analog GaAs ICs and describes the benefits of GaAs over silicon and other alternatives.

Dataquest Conclusions

The analog GaAs IC market, which now exceeds $150 million annually, is enjoying steady growth as new applications emerge. Although several suppliers recently either shut down (e.g., Siemens' MSC), were acquired (e.g., Adams-Russell by M/A-COM), or de-emphasized products (e.g., Ford), others are enjoying the increased sales that result from careful niche marketing and product engineering. Dataquest expects continuing rapid growth of this marketplace, exceeding 30 percent per year, as defense, instrumentation, and telecom-oriented product insertions continue and as consumer-oriented and other analog GaAs IC products evolve.

Gene Miles

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Research Bulletin

FOUR-INCH WAFERS IMPROVE GaAs VLSI COSTS

GaAs IC producers now have several sources of high-quality four-inch wafers competing for business. Conversion of GaAs fabrication lines to take advantage of the cost reduction potential has been under way for several months. At least three GaAs digital chip companies, capable of producing arrays of 10,000 to 25,000 gates per chip, expect to be fully converted to four-inch wafers by the end of the next quarter. This newsletter examines the effects of this conversion on the economics of GaAs VLSI chip production.

COST ENHANCEMENTS OF GaAs FOUR-INCH WAFERS

For several years, GaAs production was restricted to the use of two-inch and three-inch wafers. In 1987, several wafer companies mounted a campaign to enhance their production of four-inch GaAs wafers. Changes to the wafer production process included using more nearly pure source chemicals, adding computer-controlled rotating magnetic fields within the crystal-growing equipment, and improving environmental control.

Competition in the GaAs wafer market has become very keen in recent months as quality and wafer size improved. Foundries may now rely on as many as four to eight sources of GaAs four-inch wafers. Raw near-defect-free (NDF) wafer pricing is less than $300 per four-inch wafer at 2,000-piece procurement levels. The suppliers of GaAs wafers are competing for a smaller dollar market than anticipated because overall yield improvements in some cases have outpaced the chip market's growth.

GaAs VLSI ARRAY COST ANALYSIS

To examine the expected cost of producing GaAs VLSI chips in early 1990, Dataquest modeled and analyzed the cost details for a GaAs logic device. Logic complexity is approximately 15,000 gates per VLSI chip, which is sufficiently complex to accommodate a 32-bit RISC microprocessor. NRE costs are not shown and are dependent upon foundry choice, number of engineering changes made to the design by the customer, and related factors. GaAs NRE costs are similar to those encountered in silicon ECL VLSI chip designs.

This model is based on all-implant processing of NDF, nonepitaxial four-inch wafers that were purchased in the merchant market. The topology used in the model is 1-micron E/D MESFET with three levels of metal for interconnections. Die size is estimated at 200 mils x 250 mils. The assumptions for yields, test costs, and several other parameters are shown in the model itself and are based on present experiences in the industry. Scaling to 0.8 micron offers some yield (usable dice per wafer) improvement over the figures shown. Table 1 summarizes the expected costs involved in the production of such devices at an efficient supplier's facility.

DATAQUEST CONCLUSIONS

GaAs VLSI arrays of digital logic have experienced dramatic cost decreases in 1989. Availability of high-quality, low-cost four-inch wafers has enhanced these cost reductions. GaAs foundries now can produce GaAs logic arrays of 15,000 gates per chip at break-even costs of less than $0.02 per gate if volume is sufficiently high.

Diligent engineering efforts at U.S. companies have resulted in the ability of this leadership technology to compete head-on with silicon ECL VLSI on a cost-per-gate basis and to approach BiCMOS

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TABLE 1
GaAs VLSI Array Cost Model (Early 1990)

Wafer Processing	Cost
4-inch wafer cost = $280, processing cost = $385, fab yield = 70% good wafers, therefore, the fab cost per gross die (processed wafer cost/82 die locations) is:	$ 11.59
Wafer sort cost per gross die:	$ 0.80
Cost per gross die through wafer sort:	$ 12.39
Therefore, cost per net die at wafer sort yield of 25% is:	$ 49.54
Assembly	
Cost of die through wafer sort:	$ 49.54
Assembly cost per wafer sort die (incl. pkg. cost):	$ 16.00
Therefore, cost per assembled die at 90% assembly yield is:	$ 72.82
Final Test	
Assembled die cost:	$ 72.82
Test time/device = 180 seconds	
Test cost/unit (Cost/hr. to devices tested/hr.):	$ 6.00
Final test yield = 75%	
Therefore, cost per final tested unit is:	$105.10
Mark, Pack, Ship	
Operation cost at 99.9% yield:	$ 1.50
Therefore, total variables cost per net unit is:	$106.71
Assume overhead* = 125%	
Therefore, break-even cost per unit is:	$240.09

*The term "overhead" as used here includes all other costs of operating a viable business, e.g., R&D, marketing, selling, accounting, other indirect labor, and related costs and expenses.

Source: Dataquest
October 1989

density level. Next-generation computers, workstations, and instrumentation all will benefit to the extent that their producers choose to incorporate GaAs VLSI chips into new designs. A major issue GaAs VLSI chipmakers now must face is accomplishing profitability (or minimizing losses) in a slow economy while new end-user system designs gestate.

Gene Miles

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Research *Newsletter*

GaAs IC SYMPOSIUM EMPHASIZES PRODUCTION AND APPLICATIONS

Seventy-three papers presented to more than 700 persons at the eleventh annual GaAs IC Symposium repeatedly demonstrated the increasing pervasiveness of GaAs into production systems. Many of the speakers offered specific details of their applications. Others described ongoing R&D efforts to advance the state of the GaAs IC art to encompass heterostructures and bipolar approaches. Achievement of VLSI reproducibility was reinforced by GigaBit Logic, TriQuint, Vitesse, and others. This newsletter examines some of the specific activities reported to the attendees.

COMMUNICATIONS SYSTEMS INSERTIONS

Bell-Northern Research (Ottawa, Canada) and several Japanese companies reported the successful application of GaAs ICs to communications systems that require 10-GHz and higher operating frequencies. The applications include logic for asynchronous transfer multiplexing (ATM) packet switches, prescalers for cellular radio/telephone hardware, and laser drivers for fiber-optic links.

The Bell-Northern Application utilized the GaAs components shown in Table 1. These components include four custom GaAs ICs and six commercial GaAs ICs. The chips were used to implement an eight-port switch operating at 10-GHz total throughput. The test boards were interconnected with fiber-optic links.

The Fujitsu multiplexer/demultiplexer chip pair was developed to replace an existing functional set in an optical communications system. The GaAs LSI approach reduces the mounting space that currently is required by a factor of 70 and decreases power consumption by a factor of 5. The characteristics of the GaAs chip pairs are given in Table 2.

Table 1
ATM Testbed Components

Chip Type	Quantity	Function	Vendor
10G010	3	Buffers	GigaBit Logic
Custom	1	Crosspoint switch	Not specified
1131	4	8-to-1 multiplexer	TriQuint
10G100	8	4-bit adder	GigaBit Logic
12G014	18	1K SRAM	GigaBit Logic
Custom	4	Clock recovery	Not specified
10G065	3	7-bit counter	GigaBit Logic
10G012	4	Comparator	GigaBit Logic
Custom	4	Demultiplexer	Not specified
Custom	4	Laser driver	Not specified

Source: Bell-Northern Research

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TABLE 2
Fujitsu MUX/DEMUX Chip Set

Feature	Characteristics Multiplexer	Demultiplexer
Functions	16:1, 12:1, 8:1, 4:1	1:16, 1:12, 1.8, 1:4
Transistor Gate Length	1 micron	1 micron
Logic Gate Count	430	480
Max Speed	3 Gb/s	3 Gb/s
Package Bandwidth	18 GHz	18 GHz
Output Rise Time	90ps	180ps
Output Fall Time	100ps	210ps
Internal Logic	SCFL	SCFL
Interface Levels	ECL	ECL
I/O Impedances	50 ohms	50 ohms
Supply Voltage	-5.2 volts	-5.2 volts
Die Size (mm x mm)	3.6 x 3.6	3.6 x 3.6
Package Size (mm x mm)	17 x 17	17 x 17

Source: Fujitsu Ltd.

Toshiba presented results of its development of a 12 Gb/s SONET chip set. Other companies that described their GaAs communications chip activities include Motorola, NEC, NTT's LSI Laboratories, Oki, and Sony. The chips were variously labeled as MUX/DEMUX, frequency dividers, laser drivers, and similar functions. The highest frequency of operation reported was a 34.8-GHz divider chip based on heterostructure bipolar transistor (HBT) technology, reported by NTT.

MMIC INSERTION ACTIVITIES

An interesting paper by Grumman Corporation's Electronics Systems Division described a control chip for a two-MMIC radar transmit/receive (T/R) module that was fabricated on a 1-micron all-implant GaAs process. The design was based on the requirement of scalability to higher-frequency operation and of interfacing with a power amplifier MMIC. The power amplifier MMIC was designed to eliminate the large circulator commonly used in L-band radar transceivers. The Grumman approach appears to refute Texas Instruments' position that 1 million GaAs-based radar T/R modules must be manufactured at a cost to the U.S. government of at least $400 million before the average cost of such modules can be reduced to less than $400 each.

The first production use of GaAs MMICs by Texas Instruments (TI) in a military program is the insertion of two matched amplifier pairs into the high-speed anti-radiation missile (HARM) electronics. TI has produced several hundreds of the amplifier pairs in the last 12 months and expects its production to exceed 14,000 such chips per year. Other insertions envisioned by TI are the advanced technology fighter (ATF) program, which requires several million T/R modules over the life of the program. TI projects a need for approximately 30 million MMICs for military system insertions during the 1990s.

Other companies reporting designs for MMIC insertions into military and aerospace programs include Avantek, General Electric, Hittite, Plessey, Raytheon, and TRW. Frequencies of operation were reported to and above 50 GHz.

ADVANCES IN DIGITAL VLSI

Notable presentations in the digital area were made by DARPA, GigaBit Logic, E-Systems, and Vitesse. Information released at the conference by TriQuint that described its 10,000-gate standard cell array with on-board ROM also stirred interest among the attendees.

TABLE 3
Vitesse GaAs Gate Arrays

Function	VSC3K	VSC5K	VSC15K
Total Gates	3,584	6,400	16,896
Input Cells	36	48	88
I/O Cells	52	68	100
Clock Drivers	4	4	8
Total Signal Pads	92	120	196

Source: Vitesse Semiconductor Corporation

The DARPA paper covered digital array processors, radar signal processors, digital map computers, DRFMs, and several other insertion activities funded by the U.S. government. Almost all of these programs were placed with large, well-established companies such as E-Systems, Honeywell, ITT, McDonnell-Douglas, and others. Unfortunately, the presentation left many of the listeners with the opinion that DARPA is taking the low-risk approach of selectively supporting major corporations of the defense industry establishment at the expense of the start-ups and entrepreneurs and that continuing budget battles between the Republican minority and Democrat majority in Congress will only worsen the situation.

The GigaBit Logic presentation on its conversion of wafer fabs from 3-inch to 100-mm (approximately 4-inch) production was well received. The company evaluated the changeover by making runs on material received from five 3-inch wafer producers and eight 100-mm wafer producers. The only manufacturing step that required major modification was the rapid thermal annealing (RTA), which required a major hardware upgrade. The company now has the world's only fully redundant 100-mm GaAs fab line capable of sustaining 2,000 wafers per month.

Vitesse described its VSC gate array family, which includes the VSC15K, a gate array containing 16,896 total gates and 196 signal pads. An applications paper by E-Systems of Garland, Texas, described the insertion of a Vitesse gate array into a digital sub-band tuner, which also uses GaAs 4K SRAMs in the delay and multiplier functions. The VSC15K die measures 280 by 335mm. Statistics for the Vitesse gate array family are shown in Table 3.

EXHIBITS

The annual GaAs Manufacturing Technology (MANTECH) conference was held overlapping the last day and immediately following the GaAs IC conference. The exhibits were open to attendees of either of the conferences. The emphasis of the exhibits was on materials, test hardware, and software, with very few IC suppliers present. GaAs wafers, GaAs epi wafers, and GaAs-on-Si products were displayed with much emphasis placed on availability.

DATAQUEST CONCLUSIONS

Dataquest observed a relative maturing of the GaAs IC technology in the presentations and exhibits at this conference. System designers are increasingly accepting the overall cost-effectiveness of GaAs ICs in their approaches to next-generation designs. The shakeout of IC chip houses is settling; Dataquest expects this to have an adverse ripple effect on the raw wafer and epi wafer suppliers by mid-1990.

Gene Miles

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Research *Bulletin*

GaAs COMPUTER TECHNOLOGY IMPACTS THE VLSI INFRASTRUCTURE

SUMMARY

The advent of GaAs VLSI at better specifications and pricing than silicon ECL is having an increasing impact on the market for digital computing (EDP) and signal processing (DSP) hardware. Recent reports indicate growing applications of GaAs VLSI in commercial and military systems. This research bulletin examines some of these developments and their potential impact on equipment designs.

FUJITSU ENTERS THE SCENE

The expected merchant market entry into GaAs ASICs of a major Japanese vertically integrated supplier occurred last month when Fujitsu and Vitesse Semiconductor Corporation (VSC) jointly announced an alternate-sourcing agreement for the Vitesse "Fury" series of GaAs gate arrays. The announcement ended speculation as to which of the Japan-based computer houses would be the first to enter the merchant market for GaAs VLSI chips. Other likely entrants were (and still are) Hitachi, Mitsubishi, NEC, Oki, and Toshiba, all of which have concerted R&D in this area. The Fujitsu/VSC agreement includes arrays of 3,000 to 30,000 gates and mixed logic/SRAM chips as well as joint development of additional GaAs VLSI products.

Some observers expect the Fujitsu entry to be a short-term gain to VSC and a longer-term, much greater benefit to Fujitsu. Initially, Fujitsu must rationalize the relative importance of its silicon ECL business, which will be eroded somewhat by GaAs VLSI. However, in the longer term, Fujitsu's computer efforts (both its FACOM series and its Amdahl connection) stand to benefit. In the meantime, VSC (as well as the other GaAs ASIC suppliers) may gain some sales as a result of the added credibility brought by the entry into GaAs ASICs of the high-performance chip market's biggest supplier of silicon ECL gate arrays.

CRAY MOVES TO RECAPTURE A FAB LINE

About three years ago, Cray Research became a significant stakeholder in Gigabit Logic (GBL), at which time Cray disassembled a captive GaAs fabrication line and shipped equipment to GBL. Cray Research now is negotiating to take GBL's 4-inch GaAs wafer fab line to Cray's Colorado Springs facility, where it will support the CRAY-3 computer operations. Each CRAY-3 supercomputer uses approximately 100,000 GaAs ICs. The move is expected to have multiple benefits: CRAY-3s will become less expensive to produce; GBL will start using foundries rather than support an internal fab in this age of overcapacity; and Rockwell, TriQuint, Vitesse, and other foundries will lose one of their competitors. Cray has been a stakeholder in GBL for some time. The move leaves observers wondering how Digital Equipment Corporation, another GBL stakeholder, is going to fare as a result of this development.

SPARC-COMPATIBLE WORKSTATION SUPPLIER ADOPTS GaAs CHIPS

Reports in October confirmed that Solbourne Computer (Longmont, Colorado) chose GaAs SRAMs for use in its Series 5 Workstations and Servers products. The approach was used to eliminate most of the overhead associated with maintaining consistent cache memory performance in a

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TTL multiprocessor environment. The company is using 256Kx4 SRAMs to implement a purely physical cache memory.

GaAs MICROPROCESSORS FACILITATE MILITARY SYSTEM UPGRADES

McDonnell Douglas recently reported on its use of GaAs VLSI to upgrade several military systems. Last year the company described its 32-bit GaAs RISC microprocessor, developed under DARPA contract. The 200-MHz pipelined device, designated the MD484, is based on the Stanford "mips" architecture and contains approximately 21,000 transistors. Using the MD484 as a control processor, the company has designated an all-GaAs vector processor for space systems applications. McDonnell Douglas is also using the MD484 in the design of a hybrid GaAs-Si sensor-signal processor for the U.S. army OH58D helicopter. The system will have a preprocessing rate of more than 1 billion operations per second as a result of using GaAs ICs.

Although Texas Instruments described a TI/CDC GaAs microprocessor chip that was developed more than two years ago, there have been no recent public statements by either company detailing specific progress and/or applications regarding this development. A similar effort by RCA a few years ago proved premature because of yield problems caused by materials and other problems. Thus, it appears that McDonnell Douglas has taken the lead in GaAs RISC microprocessor technology in military applications.

DATAQUEST OBSERVATIONS AND CONCLUSIONS

The commercialization of GaAs digital ICs (digICs) has entered a new stage with the adoption of GaAs into workstation architectures. A major Japanese company, Fujitsu, has assumed an open, active marketing role in the GaAs VLSI ASIC arena; time will tell whether or not still another U.S.-invented technology will become controlled by Japanese sources. Meanwhile, the military GaAs digIC market is evolving independently of commercial markets, supported largely by an almost totally different supplier base that is now led by McDonnell Douglas.

Gene Miles

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Research *Newsletter*

START-UPS THREATEN INTEL DOMINANCE: FIRST VOLLEYS IN THE COPROCESSOR WAR

SUMMARY

Dataquest believes that the PC math coprocessor market is ripe for competition and that the number of suppliers to this market is likely to double or triple in the next two years. This will drive prices down at a rate much faster than in the past. Along with trends in hardware and software, this increased competition and resulting price drop will have the effect of increasing the penetration of coprocessors into available sockets.

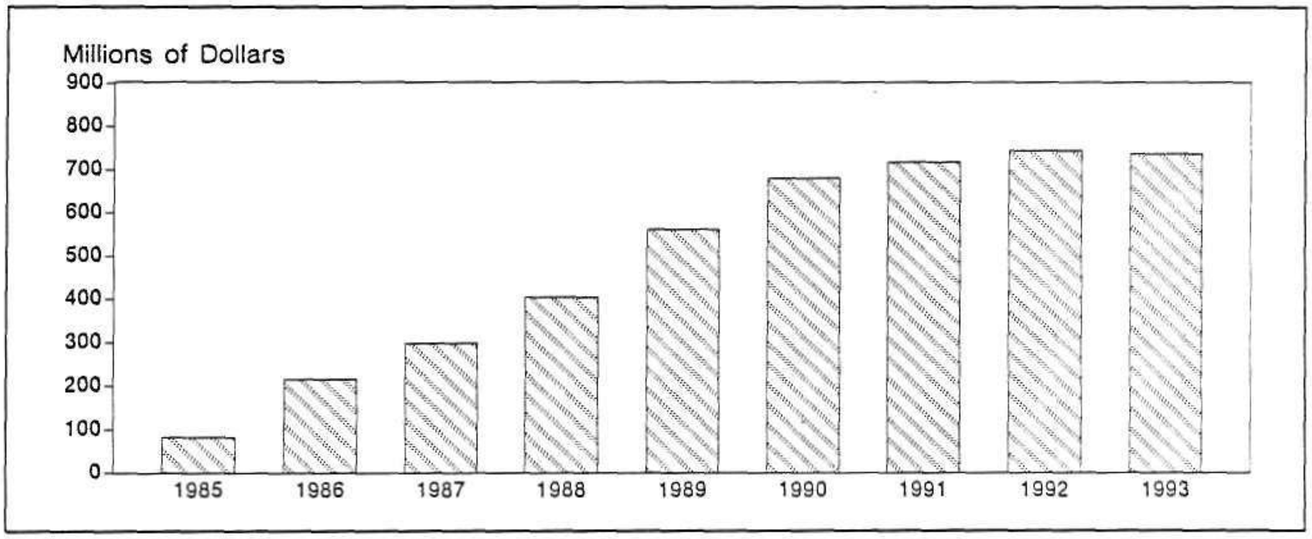
For suppliers choosing to enter this market, the challenge will be not only to sell products and gain market share, but to make a profit. In the last two years we have witnessed a large number of vendors entering the PC logic and graphics chip set markets, resulting in intense competition, rapidly falling prices and margins, and shrinking profits. The potential for a repeat of this scenario in the coprocessor market is very real.

The Dataquest revenue forecast for the PC and workstation math coprocessor market is shown in Figure 1.

PC MATH COPROCESSOR MARKET HEATING UP

Evidence of the first skirmishes in the floating-point coprocessor war already has appeared in the industry press. Intel, the company that has owned the DOS PC math coprocessor

FIGURE 1
PC and Workstation Math Coprocessor Revenue Worldwide History and Forecast



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market, has publicly announced the errors and incompatibility problems it has found in evaluating competitor Integrated Information Technology's (IIT's) 80287 plug-compatible device, the IIT 2C87. Intel claims that this device does not meet the ANSI/IEEE standard specifications for floating-point arithmetic. IIT claims that Intel tested a preproduction part and that the problems discovered have been fixed in the production version.

It is not unusual for chip manufacturers to offer information about potential problems with competitor parts during sales calls, but these issues are not usually made public. Intel's public criticism of IIT is an indication of the serious impact this product and others may have on Intel's near monopoly of the PC floating-point coprocessor market.

The PC math coprocessor market historically has been favored by high prices and margins, maintaining the perception that these products will sell into the high-end PC and workstation segments only. This fact has kept unit volumes low, and consequently, the penetration of these products into the total available sockets has been quite low. The result is a glaring invitation to talented chip designers and chip set vendors facing tough competition and saturated markets for PC-related chips and chip sets. Assuming that entry barriers are surmountable, the PC coprocessor market is ripe for competition. This means lower prices for coprocessors and higher penetration into PCs.

THE STAKES ARE HIGH

Dataquest divides the PC math coprocessor market into 80X87 (Intel) compatible and 68XXX (Motorola) compatible. Until recently, there were no 100 percent pin-compatible Intel 80X87 clones available, and Intel owned the DOS PC math coprocessor market. Motorola owned the 68XXX-based PC math coprocessor market except for a few specialty ASIC parts that are implemented as add-in boards. The workstation market, which is considered separately, comprises Motorola math coprocessors and other specialty high-end products.

The Dataquest revenue forecast for PC and workstation coprocessors is shown in Table 1. Intel's 80X87 products are believed to make up approximately 60 percent of the market in terms of revenue and about 55 percent in terms of units. Motorola's 68XXX products have approximately 25 percent of the revenue with about 30 percent of the units. These estimates are based on survey work that has been correlated with the Dataquest PC and workstation forecasts. The bottom line is that according to Dataquest estimates, math coprocessors make up approximately 10 percent of Intel's revenue.

FORECAST METHODOLOGY AND ASSUMPTIONS

The Dataquest PC math coprocessor forecast is derived from the Dataquest worldwide PC and technical workstation forecasts. The forecast for each type is derived from the Dataquest PC by microprocessor forecast. Historical data come from Dataquest survey work. The forecast unit shipment numbers are derived from assumptions of sales into the installed base, sales into new systems, and total saturation by coprocessor type. For the technical workstation segment, it is assumed that penetration is 100 percent.

The basic underlying assumptions of the Dataquest forecast are that the number of vendors in this market is going to increase, that this increase will drive prices down more rapidly than in the past, and that penetration into PCs will be higher than in the past. These assumptions are based on the following reasons and analysis.

Barriers to Entry

There do not appear to be any insurmountable technical or legal barriers to entry into this market. As long as new products are not direct copies, there is not likely to be any legal recourse for Intel. The argument for technical barriers is de facto. These products exist now, and there is every reason to believe that the talent and resources necessary to design and produce them are available to other potential entrants. This is not to trivialize the technical aspects of these products, but again, these aspects are surmountable.

Competition

There are currently four vendors in the Intel-compatible market: Cyrix (produces a pin-compatible 80387 clone), IIT (produces pin-compatible 80287 and 80387 clones), Intel itself, and Weitek (no pin-compatible products). Because of the saturation and strong competition in the PC logic and graphics chip set market and a softening of the domestic PC market, Dataquest believes that there is great incentive for some of the chip set

TABLE 1
PC and Workstation Math Coprocessor Market
Worldwide Forecast

	History			
	1985	1986	1987	1988
Unit Shipments (Thousands)	353	973.0	1,385.0	2,141.0
Growth Rate (%)		175.6	42.3	54.6
Weighted ASP	$232.29	$220.91	$215.73	$188.94
Growth Rate (%)		(4.9)	(2.3)	(12.4)
Revenue ($M)	$ 82	$ 215	$ 299	$ 405
Growth Rate (%)		162.1	39.0	35.4
Penetration (%)	10.3	15.3	15.3	15.9

	Forecast					CAGR	CAGR
	1989	1990	1991	1992	1993	1985-1993	1989-1993
Unit Shipments (Thousands)	2,830.0	4,156.6	5,929.9	7,922.8	9,541.2	51.0%	35.5%
Growth Rate (%)	32.2	46.9	42.7	33.6	20.4		
Weighted ASP	$198.51	$163.61	$121.17	$ 93.88	$77.29	(12.9%)	(21.0%)
Growth Rate (%)	5.1	(17.6)	(25.9)	(22.5)	(17.7)		
Revenue ($M)	$ 562	$ 680	$ 719	$ 744	$ 738	31.6%	7.0%
Growth Rate (%)	38.9	21.1	5.7	3.5	(0.9%)		
Penetration (%)	17.8	20.6	24.4	29.0	33.6		

Source: Dataquest
January 1990

manufacturers, as well as for other semiconductor houses, to consider entering this market. Companies with the incentive and the resources to produce a coprocessor product for the PC market include Acer, AMD, Chips and Technologies, Headland Technology, National Semiconductor, Texas Instruments, Trident, VLSI Technology, and Western Digital. These 9 companies, together with the 4 mentioned previously, make a total of 13 potential suppliers to this market.

In addition to having the incentive to enter this market, the chip set companies are especially well equipped to service it. These companies have capitalized on the trends of very large scale integration of logic and peripheral functions and the trend toward motherboard implementation of these functions. They have experience selling to motherboard and systems manufacturers and are in position to establish a trend toward increasing volumes by lowering prices and offering OEM motherboard and system vendors a means of differentiating their products.

Pricing

The model for the coprocessor forecast assumes that there will be between 6 and 12 vendors, with the new vendors entering in the next two years. Under this scenario, prices for each product type are forecast to drop at a compound annual growth rate (CAGR) of approximately negative 25 percent, giving a weighted average of negative 21 percent for the 1989 through 1993 period. This negative growth can be compared with the price declines of 30 to 40 percent that have been seen in the PC logic and graphics chip set markets or with the typical Intel pricing curve for microprocessors, which declines at a 30 to 32 percent CAGR.

Unit Volumes

For each compatible coprocessor type, assumptions are made as to unit sales into the installed base of PCs and unit sales into new PC shipments. These assumptions differ depending on the historical penetration levels of the product, the age of the product (where it is in the product life cycle), and the degree to which the product can be used effectively as an upgrade path. In all cases, the price decline assumptions lead to significantly higher penetration levels than have been seen historically.

Technology Drivers

Perhaps partly because of the potential threat to its coprocessor sales, Intel has brought the floating-point unit (FPU) on-chip with the new 80486 microprocessor. This fact may or may not prevent competitors from selling an 80487-type product, but it could induce software developers to develop programs that use the floating-point capabilities of the 80486. This possibility could accelerate the sales of coprocessors into the installed base of 80286 and 80386 systems as users upgrade to take advantage of new software. Just as memory upgrades have become mandatory for some PC users in order to effectively utilize new software products, coprocessor upgrades will become increasingly more common. As the rate of change in PC performance and technology increases, the role of performance upgrade products becomes more important.

DATAQUEST ANALYSIS

For potential entrants to the compatible coprocessor market, the current low level of penetration of these products into sockets, combined with artificially high prices and margins, is an attractive inducement to entry. Given certain assumptions regarding the hardware and software environments and pricing structures, the opportunity may exist to increase the saturation level of coprocessors in the PC market. This opportunity increases the potential for the market to support multiple suppliers.

The result of the forecast model, presented in Table 2, is that the penetration of math coprocessors into PCs almost doubles, from approximately 18 percent in 1989 to approximately 34 percent in 1993. Although overall unit shipments are expected to grow at a 35.5 percent CAGR for 1989 through 1993, overall revenue should grow at only 7.0 percent for the period. In fact, revenue is forecast to level off in 1992 and turn down slightly in 1993.

So what's the problem? The high growth rates and increased penetration are predicated on pricing assumptions. The average selling price (ASP) should decline at a 21 percent CAGR for the period (see Table 1). The ability of the rising volumes to offset these price declines should reach a crossover point in the 1993 time frame, partly because of the assumption that no new higher-priced product types will come into the market during the forecast period. The introduction of new products would slow the ASP decline and avert the flattening effect on revenue. An example of a new product that might extend the industry's revenue growth cycle would be a standalone 80487-type product.

With the first real competition just coming on-line and with the potential still existing for many technical, marketing, and legal barriers to appear, it is difficult to predict this market's future. The math coprocessor forecast model incorporates assumptions regarding technology, expected number of vendors, pricing curves, demand elasticities, market segmentation, and market saturation levels. These assumptions are based on historical data and trends for these and similar products and markets.

The high prices and margins on PC math coprocessors are an anomaly in the PC-related semiconductor business. This situation is not sustainable, and a number of vendors are both capable and motivated to expand the competition in this market. Unlike the logic and graphics chip set products, which are nearing saturation usage levels in PCs, the coprocessor market is far from saturated. This open field offers a tremendous near-term opportunity for the positioning of new entrants, but the potential exists for intense competition and oversupply if too many vendors elect to capitalize on the opportunity.

Ken Pearlman

TABLE 2
PC and Workstation Math Coprocessors by Type: Worldwide Forecast
(Revenue in Millions of Dollars, Units in Thousands)

	History					Forecast				CAGR	CAGR
	1985	1986	1987	1988	1989	1990	1991	1992	1993	1985-1993	1989-1993
8087 and Compatibles (Units)	240.0	430.0	320.0	315.0	260.0	225.0	200.0	185.0	160.0	(3.7%)	(11.4%)
ASP	$140	$ 130	$ 120	$ 110	$ 95	$ 72	$ 52	$ 41	$ 35	(16.1%)	(22.1%)
Revenue	$33.6	$ 55.9	$ 38.4	$ 34.7	$ 24.7	$ 16.2	$ 10.4	$ 7.6	$ 5.6	(19.2%)	(31.0%)
Penetration (%)	11.6	15.5	13.7	12.8	13.3	14.2	15.5	17.3	20.1		
80287 and Compatibles (Units)	90.0	420.0	600.0	600.0	775.0	985.0	1,230.0	1,410.0	1,450.0	41.5%	17.0%
ASP	$350	$ 300	$ 250	$ 200	$ 180	$ 135	$ 95	$ 70	$ 60	(19.8%)	(24.0%)
Revenue	$31.5	$126.0	$150.0	$120.0	$139.5	$133.0	$116.9	$ 98.7	$ 87.0	13.5%	(11.1%)
Penetration (%)	10.9	19.9	16.6	14.0	14.2	15.5	17.8	20.7	23.7		
80387SX and Compatibles (Units)	0	0	0	5.0	75.0	440.0	1,090.0	1,945.0	2,750.0	105.5%	146.1%
ASP	-	-	-	$ 300	$ 253	$ 195	$ 135	$ 100	$ 80	(20.6%)	(25.0%)
Revenue	0	0	0	$ 1.5	$ 19.0	$ 85.8	$147.2	$194.5	$220.0	63.2%	84.5%
Penetration (%)	0	0	0	5.4	6.0	12.4	18.0	23.3	27.3		
80387 and Compatibles (Units)	0	0	77.0	335.0	715.0	1,145.0	1,510.0	1,900.0	2,100.0	73.5%	30.9%
ASP	-	-	$ 425	$ 375	$ 310	$ 235	$ 165	$ 125	$ 100	(21.4%)	(24.6%)
Revenue	0	0	$ 32.7	$125.6	$221.7	$269.1	$249.2	$237.5	$210.0	36.3%	(1.3%)
Penetration (%)	0	0	26.9	29.4	29.4	32.6	37.1	42.9	48.1		
68XXX and Compatibles (Units)	10.1	50.0	247.0	500.0	702.0	895.0	1,200.0	1,540.0	1,865.0	92.0%	27.7%
ASP	$225	$ 190	$ 160	$ 140	$ 120	$ 95	$ 75	$ 60	$ 50	(17.1%)	(19.7%)
Revenue	$2.3	$ 9.5	$ 39.5	$ 70.0	$ 84.2	$ 85.0	$ 90.0	$ 92.4	$ 93.3	59.1%	2.6%
Penetration (%)	1.5	3.6	9.9	17.4	23.6	28.6	33.6	38.8	43.7		
Technical Workstations (Units)	32.5	62.8	119.2	191.8	303.0	466.6	699.9	942.8	1,216.2	57.3%	41.5%
ASP	$450	$ 375	$ 320	$ 275	$ 240	$ 195	$ 150	$ 120	$ 100	(17.1%)	(19.7%)
Revenue	$14.6	$23.6	$ 38.1	$ 52.7	$ 72.7	$ 91.0	$105.0	$113.1	$121.6	30.3%	13.7%
Penetration (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0		

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Research *Newsletter*

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MICROCOMPONENT NEWS: FOURTH QUARTER 1988

Microcomponent News is designed to inform the reader of key happenings in the microcomponent marketplace by providing short, informative abstracts for quick, easy scanning. Each issue will provide a synopsis of news events gathered from a variety of sources including company press releases and trade magazines. The abstracts are organized by key topics and will be listed in alphabetical order by company. This first issue summarizes the major events that occurred during the fourth quarter of 1988.

MICROPROCESSORS

Advanced Micro Devices (AMD)

AMD has been developing CMOS versions of the 80286 microprocessor with expected clock speeds of 12, 16, and 25 MHz. Anticipated samples of these devices will be available in the second half of 1989.

Fujitsu

Fujitsu has announced the newest members of the SPARC family, called the SPARC H products. These devices will operate at one cycle per instruction (CPI). SPARC H is scheduled for sampling in the second half of 1989. Additionally, Fujitsu announced the 25-MHz memory management unit, the MB86929, and the MB86911 floating-point controller to accompany the existing S-25 SPARC microprocessor, the MB86901. Production of these VLSI parts will occur in February 1989.

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Hitachi

Hitachi has begun to import the AMD Am29000 RISC processor for inclusion in measuring and medical equipment.

Inmos

Samples are now available of the 25-MHz T800-G25S transputer device. This MPU is claimed to execute a sustained 2.9 mflops rate. It has been developed in 1.5-micron CMOS and is available in an 84-pin PGA package. Inmos is also planning a 30-MHz version for future upgrades.

Intergraph

Intergraph APD announced two additional versions of the Clipper series of RISC-based 32-bit microprocessors. Along with the C300 15-mips product, there will be a 20-mips CMOS version and a 60-mips ECL version. Samples of the ECL version should be available in the first quarter of 1989. It will be completely software compatible with the C100 and C300 predecessors.

Mitsubishi-Fujitsu-Hitachi

The three G-micro product companies all building the TRON components announced samplings of the 32-bit floating-point controller for TRON CPUs. Hitachi developed the FPU, while both Fujitsu and Mitsubishi will use Hitachi's mask in making the FPU. The part numbers are Mitsubishi, M33281GS; Fujitsu, MB92811; and Hitachi, HD648132.

Toshiba-Motorola

Since May 1988, the joint semiconductor operation of Toshiba and Motorola, named Tohoku Semiconductor Co., Ltd., has been producing various products, one of which has been 32-bit microprocessors. Toshiba assembles MC68000 family devices for the domestic market at its factory in Iwate, Japan.

MICROCONTROLLERS

Fujitsu

Fujitsu has begun sample shipments of a new microcontroller called the MB89740B. This MCU is an 8-bit CMOS device incorporating a luminescent display driver and an A/D converter. The CPU core is the 16-bit FFMC-8 model with 16 Kbytes of ROM, 516 bytes of RAM, and 25 high-pressure output ports.

Matsushita

Matsushita is accelerating production of microcontrollers in both consumer and industrial product areas. In consumer, production is shifting to 8-bit models from 4-bit MCUs, with late 1988 volume increasing from 1 million units per month to 1.5 million units per month. In the industrial models, a new 16-bit architecture has been under development and will be available in 1989.

Mitsubishi

Mitsubishi has begun sample shipment of a new 16-bit microcomputer device called the M37700M4A. Built in 1.3-micron CMOS, this controller contains 32 Kbytes of mask ROM and 2 Kbytes of RAM. The sampled part will be available in an 8-MHz speed.

NEC

NEC has added four new models to the V series of processors. The uPD70325/335 and uPD70327/337 have been introduced to the V25/35 family. These parts are fully compatible with the existing V series structure and conventional software.

Sanyo

Sanyo Electric has begun to market the LC86104A 8-bit microcontroller with on-chip liquid crystal display driver. This device can display 8 characters at one time or a total of 160 characters and signs. The LC86104A contains 4 Kbytes of ROM, 128 bytes of computation RAM, and 40 bytes of display RAM.

PERIPHERALS/COPROCESSORS

Advanced Micro Devices (AMD)

AMD announced two new devices comprising a laser printer controller chip set. The Am95C75 Raster Printer Controller (RPC) and the Am95C76 Orthogonal Rotation Processor (ORP) are CMOS parts that function as coprocessors to a controlling CPU in a page printer design. The RPC can handle up to 45 pages per minute at 300 dots per inch; the ORP handles all character rotation for any font creation.

Intel

Intel has announced the 80C187 numeric coprocessor to mate with the 80C186 CMOS 16-bit embedded control microprocessor. The new 80C187 conforms to ANSI/IEEE standards for binary floating-point arithmetic. It is built in Intel's CHMOS-III process and is available in 12.5-MHz or 16-MHz versions.

Weitek

Weitek has announced the upgrade of the WTL3164 and WTL3364 64-bit arithmetic processors to three new speed levels. These devices were introduced at 100ns originally but are now being offered at 75, 60, and 50ns. This upgraded performance is the result of efforts between Weitek and Hewlett-Packard to produce these parts on HP's 1.0-micron CMOS line.

Brand Parks

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Research Newsletter

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EISA—WILL IT BE AN ALTERNATIVE FOR MCA?

SUMMARY

An alternative to IBM's microchannel architecture bus structure (MCA) was announced by a group of PC competitors on September 13, 1988. Support for the enhanced industry standard architecture (EISA) bus has been widely endorsed by PC vendors, hardware manufacturers, and software vendors.

This announcement has caused a strong reaction in the marketplace, with uncertainty as to which architecture to support. Businesses need to plan for the future, and the issue of whether to purchase MCA systems now or wait for EISA systems to become available is an important one. Dataquest believes that there will be some clear winners and losers with the EISA announcement and that the end result will be two "standards" playing to a confused customer base in the short term and a single MCA standard in the long term.

BACKGROUND

EISA was started by several PC manufacturers, led by Compaq, that did not want to pay the royalties that IBM demanded for using its microchannel architecture. They have argued that IBM developed MCA as a strategy to increase its market share and to limit the number of manufacturers of PCs by increasing the barriers to entry for low-cost manufacturers. IBM has denied this, stating that the MCA bus was developed because of its technical superiority and its ability to meet future computing demands.

At present, there is no product that uses the features of the MCA or EISA bus. The need is there, however, as speakers at Dataquest's last PCIS conference dramatically proved. The immediate requirement is for high-speed graphics, optical storage, scanners, distributed processing, LANs, and data base management to control the masses of paper that businesses must process in a single day.

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The present ISA, or AT bus, is not capable of solving this requirement. As Bill Lowe, president of IBM Entry Systems Division, stated at last September's PCIS conference, the introduction of the EISA bus simply proves that a new bus structure is essential.

Technically, both MCA and EISA can support the same applications. Although proponents of each group claim advantages for their own design, the real question is: Which bus structure will win or will they coexist?

EISA

EISA Delivery Time

The EISA bus is in its evolutionary phase. A technical synopsis has been developed with an outline and goals stated, and each member of the consortium has listed its input and needs. Agreement has been reached as to the design of the connector used. According to the company hired by the consortium to administer the details, the finished specification is on target to be published sometime in the first quarter of this year. Work still must be done to generate the silicon, build prototypes, test and benchmark the system, and obtain agency approvals, among other things.

Once PCs are introduced with the EISA bus, third-party manufacturers of add-in products will have a forum into which to sell their products. The board manufacturers' urgency to supply EISA boards will be limited to the size of this market. As EISA systems increase in the marketplace, third-party manufacturers will then allocate resources to service those systems. This delay in shipping EISA third-party boards can only boost MCA credibility.

EISA's success will depend greatly upon the perception of when an extended bus is required. The sooner the MCA bus can demonstrate that it can satisfy new demands, the fewer buyers will wait for the EISA bus to become available. Companies are balancing today's applications with tomorrow's advances and making risk decisions as to which bus structure to follow. If a company buys a PC without the extended bus today and an application that requires the new bus becomes available before the life of the newly purchased PC is over, then it has lost. On the other hand, why make higher expenditures for PCs if they will not provide a higher payback?

The average life of a PC is five years. Typically, older products are passed down to areas with no PCs, are discarded due to failure, or are sold to employees. A system purchased today, therefore, will perform the same tasks for its life. Dataquest believes that, perhaps as early as Fall 1989 Comdex, high-speed graphics cards, communications boards, and improved disk and I/O management products will be introduced. These products will use the MCA bus because it is the only extended bus architecture at present. This will immediately place the proponents of EISA in a catch-up mode.

EISA Backward Compatibility

According to its advocates, EISA's main advantage is its backward compatibility for the customer. Customers have large investments in LAN cards, communication boards, and peripheral products that can be moved to newly purchased systems.

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Research Newsletter

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88OPEN CONSORTIUM HELPS SET OPEN SOFTWARE STANDARDS

SUMMARY

There has been much speculation on whether or not Motorola's 88000 processor will be able to successfully compete with the SPARC and MIPS processors in the RISC arena. Although the 88000 is late to the market, we believe that it will be a viable RISC contender. So far, more than 40 corporations have joined 88open Consortium, a nonprofit organization of companies that support the 88000. Motorola has a well-established reputation and will be able to attract new RISC customers from its installed customer base of 68000 microprocessor users. More than 200 customers are evaluating the 88000 processor, and some significant design wins already have been made.

In addition, 88open has dedicated itself to the establishment of an industry-wide adoption of open system standards that are being embraced by all members of its organization. With so many companies agreeing to accept an open systems approach to system design, a significant amount of UNIX software applications and tools soon will be available for the 88000-based systems. We also believe that the increasing trend by so many companies to accept an open system approach will benefit software developers, hardware developers, and end users.

88OPEN AND THE CREATION OF THE 88000 BINARY COMPATIBILITY STANDARD

Formed in April 1988, 88open Consortium is a nonprofit organization of more than 40 companies that sell, manufacture, use, or develop products for the Motorola 88000 RISC chip set. Part of 88open's charter includes the establishment and promotion of the industry-wide adoption of open software standards and the creation of an environment that will permit software and hardware from different vendors to work together.

88open is governed by a board of directors who are elected from the general members. Seats on the board are dispersed as follows:

- Hardware vendors hold three seats.
- Software vendors hold two seats.
- The academic community has one seat.

- The membership at large has one seat.

- Motorola has one seat.

Daily operations are run by Bob Anundson, who is the executive director and a member of the board of directors. The bulk of the work of the Consortium is conducted by the following two committees:

- The Technical Committee proposes and develops definitions, standards, and extensions related to 88000 product use.

- The Business Committee deals with the business issues relating to the Consortium and promotes the 88000 product family in the market.

One of 88open's first priorities was the creation of the 88000 Binary Compatibility Standard (BCS), which insures that all code created for the 88000 is compatible at the binary level. The BCS specifies data types, file formats, signal handling, and installation for the BCS, thereby allowing any software written to its specifications to run on any BCS-compliant 88000-based system. BCS is based on AT&T's UNIX System V Interface Definition (SVID) and complies with X/Open and POSIX standards. Software compliance with BCS and these standards ensures that software developers will not have to port their applications to any other vendor's 88000-based platform. The 88000 BCS is a subset of AT&T's System V Release 4 Application Binary Interface (ABI), which specifies shared library support, network interfaces, and support for the X-Windows interface.

Additionally, because the BCS is implemented at the system call level, it can support any variant of the UNIX operating system. This capability is especially important because the subtle differences among various versions of UNIX notoriously have been the cause of problems that arise when porting applications from one system to another. The BCS also simplifies the porting of applications from one architecture to another. Developers with applications written for SPARC- or MIPS-based machines will be able to recompile their software using System V Release 4 and have their applications run on the 88000-based systems without any additional porting efforts. This means that hardware manufacturers will have a large selection of software available to run on their computers and that both users and software vendors will have a large selection of systems to choose from.

Developers that do not want to wait for Release 4 to become available can begin to work with Unisoft's UNIX. Unisoft has already incorporated BCS support as it exists today into System V Release 3.2 and is in the process of making BCS object code compatible.

88open Consortium recently announced the formation of an organization called the Software Initiative (SI) Committee to support the process of software development for the Motorola 88000. SI will be responsible for designing, implementing, and enforcing a compliance testing program to verify that hardware and software products are compatible with the BCS and, therefore, with each other. Although, the software vendors will conduct their own testing, SI will do the following:

- Supply free, on-site equipment to ISVs

- Provide senior-level consultation

- Provide technical assistance to software developers
- Monitor and administer the certification process
- Audit the execution of custom test suites
- Issue a seal of compliance after successful verification

DATAQUEST ANALYSIS

Many industry observers have speculated that Motorola may not be able to overcome the momentum built by its SPARC and MIPS competitors. Motorola's 88000 RISC chip is a latecomer to the market as a result of design and production problems. The majority of announced software packages to support the 88000 will not be available until either the third or fourth quarter of this year.

Although the 88000 has had a slow start, we believe that it is too soon to rule out Motorola and the 88open Consortium vendors as serious RISC contenders. Motorola has gained experience and a solid reputation as a leading chip manufacturer with its successful family of 68000 microprocessors. Motorola will be able to draw new RISC customers from its current 68000 installed customer base and through its established reputation. More than 200 customers currently are evaluating the 88000 processor, and some significant design wins already have been made. Forty-five companies are now members of 88open, and many other companies have expressed an interest in joining them. Although most of the announced software products are development tools and compilers, a variety of user applications are also under development.

It is particularly noteworthy that so many hardware vendors are continuing to gather together in consortiums or various organizations and work together to promote the adoption of open systems. 88open Consortium's dedication to open systems standards sends an encouraging message to the computer industry; the days of one vendor controlling the market with a proprietary solution are over.

Until recently, most hardware vendors have been ambivalent about open systems and open standards. If everything about the system is proprietary, the customer must come to the vendor for all the desired components and software. Since most vendors are not interested in sharing revenue with anyone else, least of all their competitors, they have done very little to encourage users to select multivendor solutions.

Software developers and users, on the other hand, have always encouraged the adoption of open systems. Software vendors want to see their products sold across a broad range of hardware platforms, but they have been constrained by the difficulties involved in porting their applications from one operating environment to another. Users want to have the luxury of being able to do business with different vendors without risking their software investments. Most users do not want to risk their future success by depending on one or two vendors to meet their requirements.

Open software standards benefit everyone. They eliminate the dependencies on particular vendors for a single solution and timely responses. They enhance software development efforts by ensuring that the current development environment will be stable and consistent. They encourage hardware manufacturers to compete on price, performance, and functionality, a strategy that directly benefits the user. They support the development of a wealth of general-purpose and application-specific tools by many different vendors. Finally, they allow companies to access a large base of trained computer system professionals.

In conclusion, open systems are the wave of the future, and Motorola will be one of those vendors with a surfboard. As we enter the next decade, RISC-based workstations will have to be sold on price, features, and performance rather than on total solutions. Companies that will not embrace this open approach to product development will find themselves left in the dust of users rushing to support the vendors that do embrace this technology. As an ever increasing number of vendors support open standards, the market will become more productive and competitive. The winners may very well be everyone.

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Research *Bulletin*

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CHIPS AND TECHNOLOGIES ENTERS THE MASS STORAGE CONTROLLER BUSINESS

Chips and Technologies' newly formed Mass Storage Organization has announced its first drive controller chip set, the Micro Channel Fixed Disk Adapter CHIPSet. Targeted toward OEM suppliers of PS/2-compatible computers, this chip set is capable of supporting ST506/412 (both MFM and RLL versions) and Enhanced Small Device Interface (ESDI) type drives using a single controller.

Consistent with Chips' general product strategy of combining high-level integration with an intelligent, systems-level architectural approach, the Disk Adapter CHIPSet will allow for a significant reduction in chip count, while imposing minimal architectural constraints upon system designers.

In entering this segment of the PC chip set market, Chips will not only be competing against established rivals Cirrus Logic and Western Digital, but also against former ally Adaptec. If successful, Chips is likely to become, by reputation as well as by market presence, a major player in setting future controller interface architectures as well.

Consisting of the 82C780 Micro Channel Hard Disk Controller and the 82C784 Data Separator, this new chip set represents the first step toward a complete line of chip set products aimed at integrating hard and floppy disk drives into AT-, PS/2-, and EISA-compatible personal computers that use AT and ST506/412 interfaces, the Small Computer Systems Interface, and the Enhanced Small Device Interface.

These chip sets will function as host adapters, controllers, and interfaces, not only in systems, but also in the embedded control portion of "smart" disk drives. This capability will expand Chips' current customer base of controller board houses, system houses, and OEMs to include drive manufacturers as well.

DATAQUEST ANALYSIS

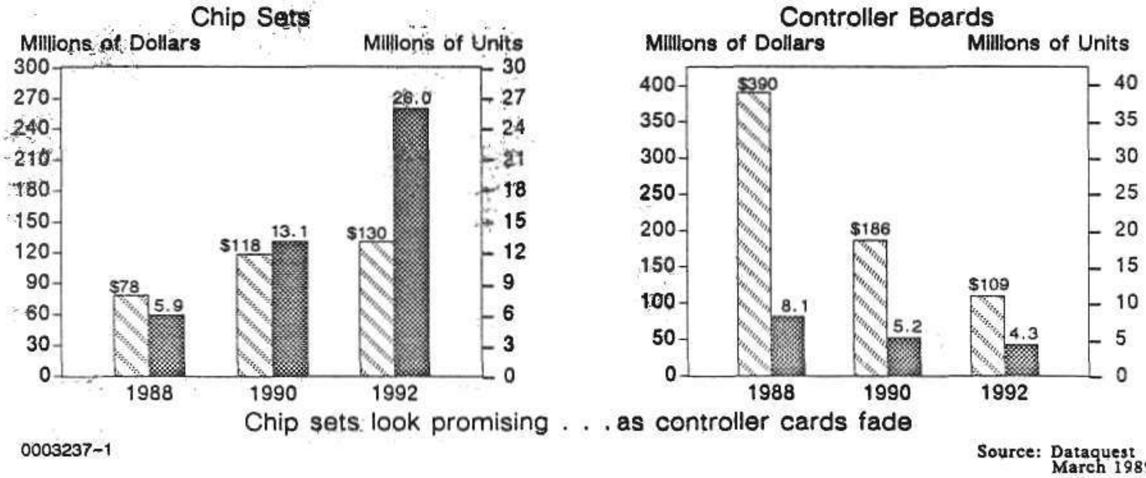
Dataquest views this announcement as a broadening of product and market scope for Chips, rather than a radical departure in corporate strategy. While the move will broaden Chips' customer base within the PC and peripherals industries, the company's fate remains inextricably tied to the health of the PC industry.

As it has in other markets, Chips can be expected to continue applying its strategy of offering system design flexibility through intelligent product architecture while lowering chip count, and therefore total system cost, through high-level integration. This may well serve as a wake-up call to those who still view peripheral control as a board-level industry and expect subsystem-level pricing and revenue.

Dataquest forecasts that by 1992, the percentage of hard drives qualifying as "smart" (i.e., containing embedded controllers and therefore not requiring controller cards) will grow from the present 42 percent to 85 percent. At the same time, we expect that the confusion surrounding the various versions of SCSI (a major roadblock in the transition of controller cards to chip sets) will soon be ironed out, accelerating the trend toward low-cost, standardized, chip set-implemented solutions. Figure 1 shows Dataquest's estimate of the controller chip set market and the controller board market through 1992.

Figure 1

Estimated Hard Drive Controller Markets



Source: Dataquest
March 1989

As a pioneer in the chip set industry, Chips and Technologies has run up an impressive track record by being first out of the gate. By offering unique, systems-level solutions, Chips has enjoyed the luxury of sole-source pricing while offering a reduction in system cost. In this respect, it faces a new set of challenges in playing catch-up with both Cirrus Logic and Western Digital. Many of the advantages that Chips usually enjoys could evaporate in this new market. We look for Chips to establish credibility early and to attempt to establish premium pricing in order to protect the comfortable margins it has enjoyed to date.

While most observers view this card-to-chip-set transition as inevitable and the process of PC consolidation as inexorable, Dataquest believes that the entry of a first-rate chip set vendor like Chips and Technologies into this market will have a catalytic effect, enhancing competition and therefore innovation among all of the chip set players. We expect this heightened competitiveness to accelerate the trend toward intelligent peripherals and subsystems of all kinds, opening the door a little wider for tomorrow's more sophisticated machines and more powerful applications.

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Kevin Landis

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Research *Bulletin*

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INTEL INTRODUCES FIRST COMMERCIAL 64-BIT MICROPROCESSOR

EXECUTIVE SUMMARY

On February 27, Intel Corporation introduced the first 64-bit microprocessor that integrates onto a single chip computing capabilities typically associated only with supercomputing systems and three-dimensional graphics workstations. The i860 microprocessor contains more than one million transistors and performs up to 80 million calculations per second.

TECHNICAL DETAILS

Features of the new chip include the following:

- 64-bit integer RISC core designed to achieve a performance rate of 86,000 Dhrystones per second at 40 MHz
- Vector floating-point (FP) unit
  - Individual floating-point multiplier and floating-point adder that allow simultaneous FP multiples and adds, resulting in a peak performance rate of 80 mflops at 40 MHz
- 3-D graphics unit that supports high-speed rendering of three-dimensional objects
- Designed to use industry standard DRAMs instead of more costly SRAMs
- On-board 4K instruction cache and 8K data cache
- Manufactured under Intel's patented CHMOS IV, 1-micron double-metal process
  - Die size: 10 x 15mm
  - Package: 168-pin ceramic PGA

- Offered in two speed grades—33 MHz and 40 MHz
  - Samples of the 33-MHz product are available now at $850 each. Production quantities will be available in Q4 of 1989 at $750 in quantities of 1,000.
  - Samples of the 40-MHz product will be available in Q3 of 1989; no pricing was disclosed.

Intel also announced a joint engineering effort under way with AT&T, Convergent Technologies, Olivetti, and Prime to create a multiprocessing version of the UNIX System V release 4.0 operating system for the i860 processor. A beta test version of the software will be available from Intel in Q4 of 1989.

DATAQUEST ANALYSIS

Since sampling of the i860 began last October, customer response has been sufficiently favorable to convince Intel that this product could more than adequately address the high-performance UNIX markets. These markets heretofore have been the bastion of Motorola's 68000 family and, more recently, RISC architectures such as Sun's SPARC, MIP's R3000, and Motorola's 88000. The modularity of the i860's design suggests that the newly introduced product is only the first in what may become a family of application-focused RISC processors from Intel.

Dataquest believes that the i860 was originally designed primarily as a coprocessor for the soon-to-be-announced 80486. This leads to some interesting speculation as to the modularity of the 80486 design, which opens the door for multiple versions of the 80486 as well.

In targeting the i860 toward the high-performance UNIX arena, Intel is abandoning the safety net afforded it by MS-DOS compatibility requirements. To compete in this new arena, the company must display the same aggressive focus and agility that enabled the Intel of old to become the preeminent microprocessor supplier to the PC industry. The establishment of close ties to strategic systems manufacturers in this turbulent market will prove critical.

The announcement of Intel's joint engineering effort with AT&T, Convergent Technologies, Olivetti, and Prime demonstrates Intel's understanding of the importance of such relationships to the success of a new processor. Clearly this represents a step in the right direction, but it remains to be seen whether Intel can generate the momentum required to compensate quickly for its late entry into this market.

The engineering workstation and graphics supercomputer markets are characterized by a growing appetite for processing power. The advent of RISC processors has effectively destroyed preexisting brand loyalties and thrown the market wide open. Although these markets appear open, Intel is entering at a point when competitors have already substantially positioned themselves after 18 months of jockeying for strategic alliances. It will be interesting to watch the world's largest microcomponent vendor play catch-up.

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THE PC CHIP SET MARKET: WADE IN CAREFULLY—THE POOL IS FULL!

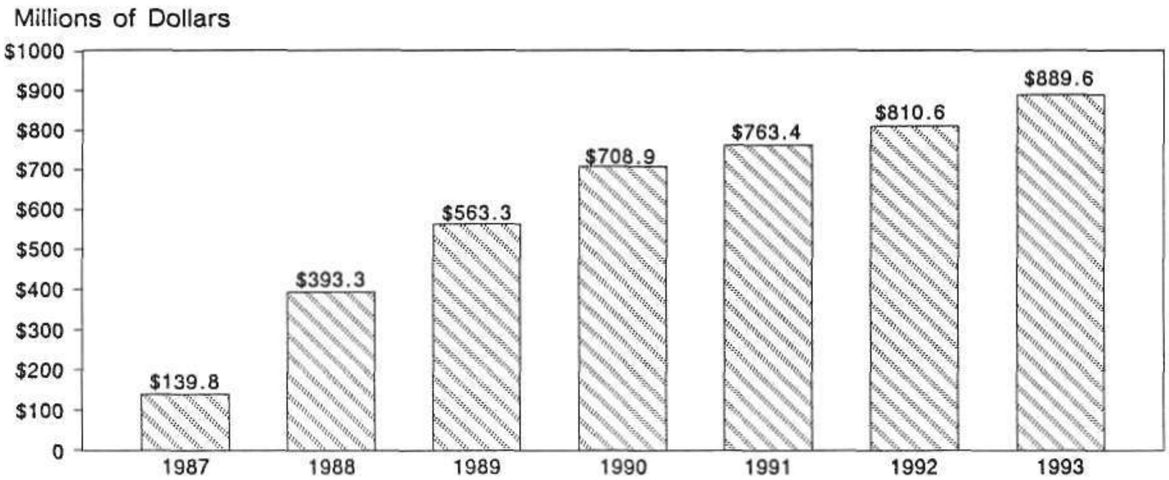
INTRODUCTION

Worldwide, there were only six PC logic chip set vendors in 1987. In 1988, the number climbed to 13, and by the end of this year Dataquest expects to see 19 vendors worldwide. The new entrants are both large, well-capitalized semiconductor manufacturers and small, start-up design houses. These new suppliers have been attracted by the tremendous growth rate of the market and the initially small number of participants. This is characteristic of any emerging market. The main differences between this market and other emerging markets are the large amount of standardization already present and the ease of sizing the market by examination of the total number of PCs shipped.

Dataquest believes that the rapid increase in new entrants and capacity will bring this industry to the saturation level by the end of this year, based on the Dataquest PC shipment forecast. We expect this saturation to lead to aggressive price competition, driving vendors to look for penetration of these products into new applications and markets. Figure 1 presents Dataquest's estimated actual and forecast revenue for the worldwide PC logic chip set market.

Figure 1

Worldwide PC Chip Set Market Forecast (Millions of Dollars)



0003634-1

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HIGH GROWTH RATE ATTRACTS MANY NEW ENTRANTS

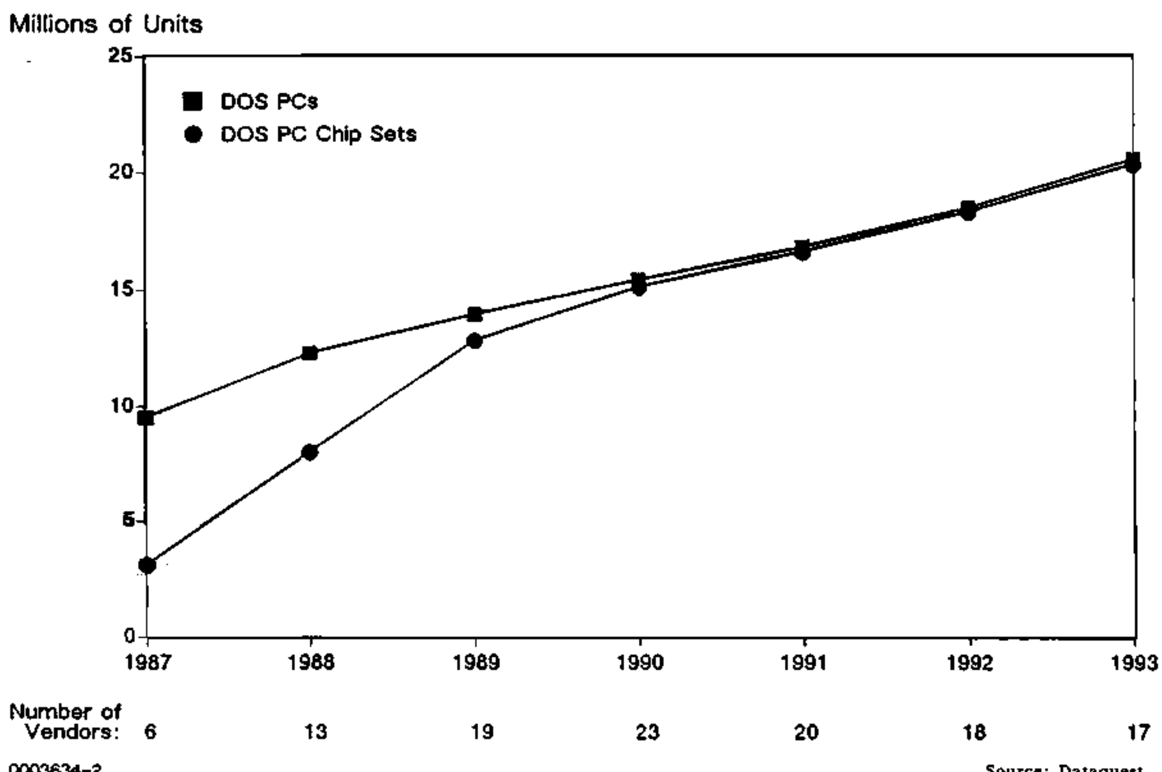
Dataquest estimates the compound annual growth rate (CAGR) for chip set unit shipments from 1987 to 1993 to be about 38 percent, an attractive rate of growth to investors, which should entice them to seek ways to participate in this industry. However, because of the nature of the relationship between PC consumption and chip set consumption, it is important for potential new entrants to look at the development of this market in terms of the product life cycle.

Figure 2 graphs shipments of chip sets against the shipments of DOS PCs, showing the rapid rise of chip set shipments as they approach the level of PC shipments. Between 1987 and 1988, chip set shipments grew by 157 percent. The estimated CAGR for 1987 to 1990 is still almost 70 percent. Dataquest estimates that during this same period, the number of chip set vendors will increase from 6 to 23.

Dataquest believes that, in 1990, the penetration of chip sets into PCs will likely approach saturation. By the end of 1989, the penetration will be about 92 percent. At this point, the growth rate of chip set shipments will be tied directly to the growth rate of PC shipments. In fact, the CAGR for chip set shipments from 1989 to 1993 is estimated at only 12.2 percent. This level of growth should attract fewer new entrants and cause some participants to exit the industry.

Figure 2

Worldwide PC Logic Chip Set Market Forecast as Compared with the DOS PC Forecast (Millions of Units)



Source: Dataquest April 1989

A Case of Overcapacity

According to a Dataquest survey, worldwide logic chip set vendors expect to ship more than 15 million units in 1989. Table 1 lists the results of this survey along with Dataquest's estimated actual and forecast numbers for chip set and PC unit consumption for 1987 through 1989. The vendors expect to ship 17.5 percent more than the forecast for chip sets in 1989 and 8.1 percent more than the forecast PC consumption.

Table 1

Worldwide PC Chip Set Vendor Survey Results (Thousands of Units)

	1987	1988	1989
Dataquest DOS PC Consumption Estimate	9,552	12,293	13,953
Dataquest DOS Chip Set Consumption Estimate	3,116	8,014	12,837
Vendor-Estimated Chip Set Shipments	3,116	8,014	15,095

Source: Dataquest
April 1989

The difference between the vendors' expectations and the Dataquest forecast might be explained by aggressive goal setting on the part of the vendors. One could also argue that some units will be shipped into inventory. It is clear, however, that more than enough capacity exists to satisfy the demand for chip sets, and it is expected that new entrants to the industry will aggravate this situation.

The implications of this analysis should be obvious. The competition for market share in this industry is likely to lead to aggressive, if not predatory, pricing policies on the part of participants. Given the degree of standardization of these products, they will take on more of the attributes of a commodity, where pricing and service are the keys to success.

FORECAST METHODOLOGY AND ASSUMPTIONS

The PC chip set forecast is derived from the Dataquest Personal Computer Industry Service PC forecast and from a survey of worldwide chip set vendors. Each year, Dataquest forecasts worldwide shipments of personal computers. Table 2 gives the Dataquest estimated worldwide shipments for DOS PCs. Dataquest's new chip set forecast for 1989 through 1993 is derived as a function of saturation of the DOS market. The estimates for 1987 and 1988 are based on the chip set vendor survey and Dataquest analysis. The following significant assumptions were made in these forecasts:

- The worldwide DOS PC market will continue to grow through the period at a CAGR of about 14 percent.
- As a general trend, discrete chips will be displaced by very large scale integration. In personal computers specifically, discrete logic chips will be replaced by logic chip sets. Because of the advantages of chip sets for the systems manufacturers—lower cost, better performance, faster time to market—this displacement has happened very rapidly.

- Average selling prices (ASPs) will fall in 1989 because of price competition. They will rise in 1990 as the introduction of EISA chip sets and increased penetration of the MCA chip sets shifts the product mix toward the high end. ASPs will then come down slowly through the rest of the period as price decreases are offset by the continued move in product mix toward the high end.

Table 2

Worldwide PC Logic Chip Set Market Forecast
(Thousands of Units)

	1987	1988	1989	1990	1991	1992	1993	1987-1993 CAGR
DOS PC Shipments	9,552	12,293	13,953	15,444	16,807	18,491	20,570	13.64%
Chip Set Shipments	3,116	8,014	12,837	15,136	16,639	18,306	20,364	36.73%
Saturation	33%	65%	92%	98%	99%	99%	99%	
Chip Set ASP	$44.88	$49.08	$43.88	$46.84	$45.88	$44.28	$43.69	(0.45%)
Chip Set Revenue ($M)	$139.8	$393.3	$563.3	$708.9	$763.4	$810.6	$889.6	36.12%
Chip Set Revenue Growth	N/A	181.2%	43.2%	25.9%	7.7%	6.2%	9.7%	

N/A = Not Available

Source: Dataquest
April 1989

DATAQUEST ANALYSIS

Critical Success Factors for Participants

In order to participate successfully in this industry, vendors will require certain capabilities and resources, including the following:

- Systems Expertise—Systems designers are looking for vendors that can work with them from the beginning of the board design to integrate and sometimes customize a chip set into the system. Chip set vendors with board design and systems expertise will be able to provide this capability.

- Design Tools—Fast chip design turnaround will be required because of short product life cycles. Access to design tools will allow vendors to offer products as a core that can be modified to allow customers some degree of differentiation.

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Research Newsletter

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MICROCOMPONENT NEWS: FIRST QUARTER 1989

"Microcomponent News" is designed to inform the reader of key happenings in the microcomponent marketplace by providing short, informative abstracts for quick, easy screening. Each issue will provide a synopsis of news events gathered from a variety of sources, including company press releases and trade magazines. The abstracts are organized by key topics and are listed in alphabetical order by company. This second issue summarizes the major events that occurred during the first quarter of 1989.

The following is a key to the publications we reviewed during our research for this document:

Business Wire	BW	Company News Release	CNR
DQ Monday	DQM	Electronics Buyers News	EBN
I.C. ASIA	ICA	I.C. USA	ICU
Semiconductor Weekly	SW		

DQ Monday, I.C. ASIA, and I.C. USA are produced by Dataquest's Components Division.

MICROPROCESSORS

Advanced Micro Devices (AMD)

AMD expects to sample 12–, 16–, and 25–MHz versions of a CMOS version of the 8086 16–bit MPU in the second half of 1989. (ICA Jan. 1989, pg. 21)

Cypress Semiconductor

Cypress claims it has upgraded its SPARC 32-bit RISC MPU to 33-MHz at a computation rate of 24 mips. This represents a 20 percent performance increase over the existing 20-mips version. (DQM Feb. 27, 1989)

Fujitsu

Fujitsu is developing the G MICRO/300 TRON 32-bit MPU that will integrate 900,000 transistors on-chip. The MPU is rated at 20 mips processing speed. Fujitsu also has completed a 10-mips SPARC processor built with 20,000 gates. A 15-mips version will follow in about one year. (SW Jan. 9, 1989)

Hitachi

Hitachi has released news on the development of a BiCMOS 32-bit MPU operating at 70 mips. This ultrahigh-speed device has 530,000 transistors on a 13-square-millimeter die. (ICA March 1989)

Intel

Intel has announced a price reduction on the 80386SX MPU from a level of $139 (1,000 pieces) to $89, effective in the second quarter of 1989. This is the 16-MHz version produced in 1.5-micron CMOS technology. (DQM Feb. 6, 1989)

Intel has introduced the i80860 64-bit microprocessor incorporating more than 1 million transistors on-chip. The i860 is a RISC-based processor integrating the following units on-chip: a 64-bit RISC integer unit, a vector floating-point unit, a graphics unit, an MMU, and instruction and data caches. It is built in the 1-micron, CHMOS-IV process and will be sampled at 33 MHz now, and at 40 MHz in the third quarter of 1989. In integer calculations, the i860 does 86,000 Dhrystones/second at 40 MHz. When the floating-point unit and other processing features are factored in, the i860 executes at 80 mflops at the same 40 MHz. Intel has specified that the i860 is optimized for very compute-intensive applications such as multiprocessing systems, 3-D workstations, and graphics subsystems. (CNR Feb. 27, 1989)

Intel is now introducing the i80486 microprocessor family. This group of products contains the i486 CPU, a LAN controller, a PLD, PC-compatible chip sets, and development tools. The i80486 MPU is a 1.2-million-transistor device built in 1-micron CHMOS. It is a binary-compatible upgrade from the 80386 but is fully integrated with a floating-point coprocessor, cache controller, and paged memory management unit.

The i80486 is being introduced at 25 MHz, with sampling in the third quarter and production availability in the fourth quarter of 1989. Performance at 25 MHz is specified as 15 to 20 VAX mips and 37,000 Dhrystones/second. It is packaged in a 168-pin PGA. Pricing is $950 for 1,000 pieces. (CNR April 10, 1989)

Intel also has released the 33-MHz version of the i80386 MPU. The 33-MHz i386 operates at 8 mips or better and is manufactured in the 1-micron CMOS-IV process. The enhanced speed of the i80386 permits it to fulfill more advanced applications in technical workstations and file server designs. (CNR April 1989).

Intergraph

Intergraph Corporation's Advanced Processor Division has announced the release of the new C300 Clipper RISC microprocessor. The 40-MHz version has been in production since the beginning of 1989, and the 50-MHz C300 module is available now. Additionally, the company announced a 37 percent price reduction on the existing C100 Clipper MPU module. The C300 Clipper is fully software- and pin-compatible with the first-generation C100 Clipper. (CNR Jan. 6, 1989)

Japan Microtech Research

Japan Microtech Research, a subsidiary of the U.S.-based Microtech Research, has assembled a software development tool kit specifically for the G-Micro 200 TRON 32-bit MPU. The kit consists of a C compiler, a cross-assembler, and a debugger, all of which run concurrently on a Digital Equipment VAX system. The development kit sells for $35,276 and eventually will be ported to workstations made by Sun and others. (SW Jan. 16, 1989)

Matsushita Electric

Matsushita has developed a 64-bit RISC microprocessor, which it introduced at ISSCC. The prototype is a 440,000-transistor device built in 1.2-micron CMOS technology. It was designed for use in parallel processing systems. The MPU also features a 1-Kbyte integrated cache memory. (SW Jan. 11, 1989)

Microchip Technology

Microchip Technology Inc. is being sold to an investment group by its parent company, General Instrument. The investment group is headed by Sequoia Capitol. Microchip will remain in Chandler, Arizona, and will retain its existing staff and business focus. (EBN March 20, 1989, pg. 3)

Motorola

Motorola Semiconductor has released the MC68040 32-bit MPU, the next-generation upgrade to the 68030. The 68040 is a 1.2-million-transistor device fully integrated with an integer unit, 80-bit floating-point unit, paged memory management unit, and instruction/data caches. It is 100 percent software-compatible with the existing 68000 family but includes enhancements to speed execution time. It is aimed at systems operating in the 10-15-20 VAX mips range. (CNR March 23, 1989)

Motorola has announced the availability of the 50-MHz 68030, which executes at 12-mips processing speed. The 50-MHz version of the 030 is built in 1-micron HCMOS and will be sampled in May at a price of $650. Volume production will commence in the third quarter of 1989. (BW April 5, 1989)

Motorola and Mips Computer Systems are each developing organizations in Japan to promote RISC microprocessor research. These are in effect similar groups to U.S.-based operations—88 Open and Synthesis, respectively. The Japan-based groups will support Motorola's and Mips' respective RISC MPU architectures. (SW Jan. 19, 1989, Nikkei Sangyo, pg.15)

NEC

A ruling has been issued on the result of litigation over NEC's V-series MPUs. The California District Court ruled that no violation of Intel's 8086/8088 microcode occurred. It found that Intel had not made adequate efforts to protect its copyright and therefore forfeited its rights. (SW Feb. 9, 1989)

NEC has signed a five-year manufacturing and marketing contract with Mips Computer Systems for the R3000 series RISC MPUs. The contract covers the development of CMOS, BiCMOS, and ECL MPUs; software; documentation; and development tools. These will be produced in Japan and in Roseville, California. (SW Feb. 9, 1989)

NEC has announced the manufacture of a 15-mips version of the 32-bit V70 MPU. The high-speed processor is built in 0.8-micron aluminum, double-layer CMOS with silicide gate technology. It will be shipped at 33 MHz in the third quarter of 1989. Future developments include 40-, 50-, and 60-MHz versions. (ICA March 1989)

Olivetti

Olivetti SpA. of Italy has selected the i860 64-bit processor from Intel to power a new series of minicomputers. Previous choices were Motorola and the SPARC architectures. (DQM March 6, 1989)

MICROCONTROLLERS

Hitachi

Hitachi has filed suit in the Tokyo District Court against Motorola, citing patent infringements from Motorola's 68HC11 8-bit microcontroller. Hitachi is requesting Motorola be halted from manufacturing, selling, and exporting the devices to Japan. (SW Feb. 21, 1989)

Motorola

Motorola has brought suit against Hitachi over patent infringement and unfair competition. Motorola states that Hitachi violated patents with Hitachi's new H8 series microcontrollers. (DQM Jan. 23, 1989)

Siemens

Siemens of West Germany will begin to ship a new 16-bit microcontroller at year end. The 80C166 is a proprietary MCU architecture poised initially for consumer and automotive applications. (EBN March 13, 1989)

MICROPERIPHERALS

Chips And Technologies

Chips and Technologies has developed a mass storage controller called the Micro Channel Fixed Disk Adapter Chipset. The two-chip set consists of the 82C780 Micro Channel Hard Disk Controller and the 82C784 Data Separator. This PC-oriented product is aimed at integrating all of the floppy and hard disk control functions as a means of reducing the existing parts count and maintaining architectural compatibility with AT-, PS/2-, and EISA-compatible systems. (DQM Feb. 27, 1989)

ERSO

The Electronic Research and Service Organization of Taiwan has developed a five-chip set for suppliers of PS/2 system clones. This chip set is aimed at the requirements of IBM PS/2 model 50/60-compatible systems, and already has 18 companies interested in it. (DQM Jan. 9, 1989)

Intel

Intel has developed and introduced a Microcom Networking Protocol-based modem chip set. The 89C024XE provides communication at up to 2,400 bits per second, data encryption, and error correction. The chip set contains a 16-bit microcontroller for signal processing and modem control, and an analog front end for two- and four-wire telephone interfaces. (ICU Feb. 1989, pg. 17)

Texas Instruments

TI is now in production with an upgraded version of the TMS34010 Graphics System Processor. The new 60-MHz version is the TMS34010FNL-60 device. It operates on a 132nS instruction cycle providing 7.5-mips execution speed with no wait states. Pricing at 10,000 pieces is set at $76. (CNR Feb. 27, 1989)

Weitek

Weitek Corp. introduced the Abacus 3168 floating-point coprocessor that is specifically designed for the Motorola 68020 and 68030 MPUs. The 3168 will be offered in 20-, 25-, and 33-MHz speeds, with general sampling of the device scheduled for July 1989. The 3168 evolved from the WTL 1164/1165 chip set that was originally implemented for 68020-based workstations. Software support is being offered through Green Hills Software Inc. via C, FORTRAN, and Pascal compilers. The 3468 currently is supplied on a daughterboard with additional logic for beginning designs. Production of the single-chip 3168 will begin in September 1989. (CNR Jan. 23, 1989)

Weitek also has released a 33-MHz version of the 3167 floating-point coprocessor for 80386-based systems. In addition, Weitek has reduced the price of the 20- and 25-MHz versions of the 3167. (DQM March 13, 1989)

Brand A. Parks

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Research Newsletter

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80486/68040: A RISC-LESS APPROACH

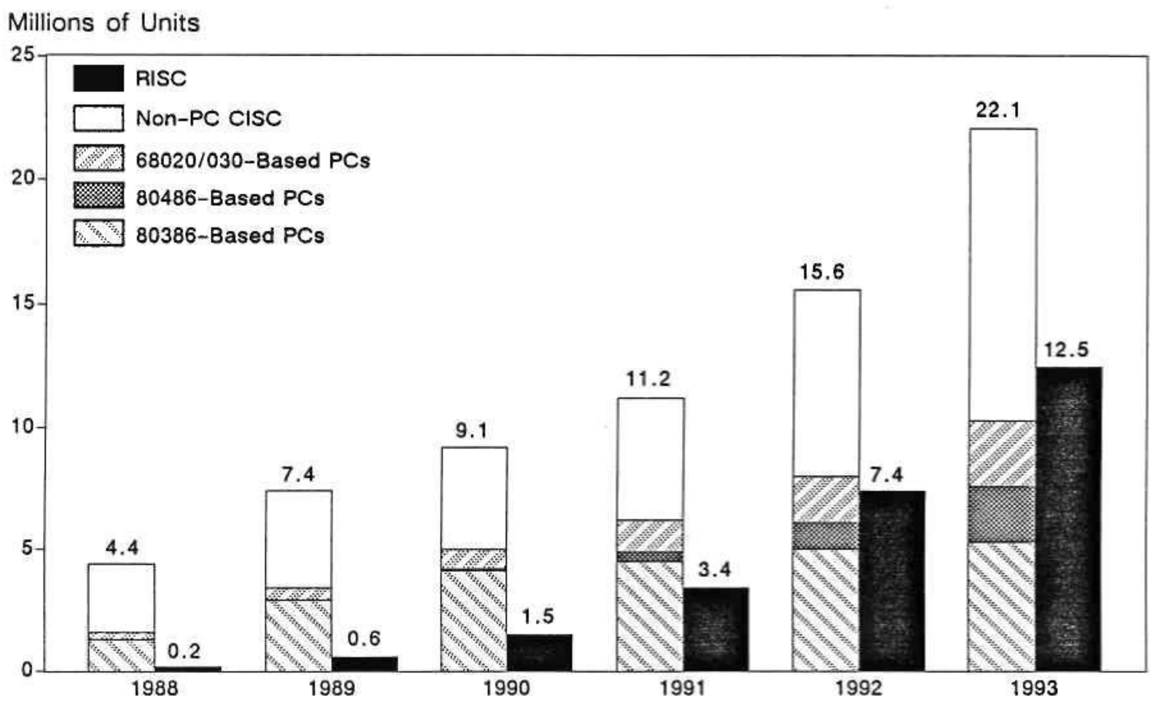
SUMMARY

On April 10, Intel announced the widely anticipated 80486 microprocessor. This announcement came less than two weeks after the unveiling of Motorola's 68040. The striking market and technology parallels between these two processors offers an interesting insight into the strategic choices facing Intel, Motorola, and their customers.

Despite the constant barrage of media hype about mips, mflops, embedded control, and RISC versus CISC, the 32-bit microprocessor market still belongs to Intel and Motorola. Figure 1 highlights Dataquest's PC forecast by microprocessor family as a function of total 32-bit microprocessor consumption. Based on the PC forecast alone, we are predicting that Intel's 80386/486 and Motorola's 68020/030 product lines will continue to dominate the general-purpose 32-bit microprocessor market for the foreseeable future.

Figure 1

Worldwide 32-Bit Microprocessor Unit Shipment Forecast



0003733-1

Source: Dataquest
April 1989

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TIES TO THE PAST

Intel and Motorola are undeniably the microprocessor industry leaders, each enjoying the luxury of a large, lucrative, and so far, loyal customer base. However, customer loyalty in the microprocessor business is born strictly of necessity and driven by the relentless competitive pressures facing the computer industry. With each succeeding product iteration, system designers must choose between the upgrade and the redesign paths, balancing system performance requirements against software compatibility considerations. It is toward these critical choices that each of these microprocessors is aimed.

Switching Costs: An Overriding Consideration

Nowhere are switching costs more undeniably overriding than in the selection of the microprocessor for succeeding generations of computer products. In jumping to a new processor, a computer vendor faces the prospect of obsoleting an entire software applications base. This imposes substantial switching costs not only on the computer vendor, but on the end user. More importantly, because "replatforming" is essentially a fresh start, the field is thrown open to all competitors, jeopardizing the customer bases of both the microprocessor vendor and the system designer. Clearly, software considerations provide all parties with a compelling reason for maintaining and extending their existing platforms.

Keeping the Platform Alive

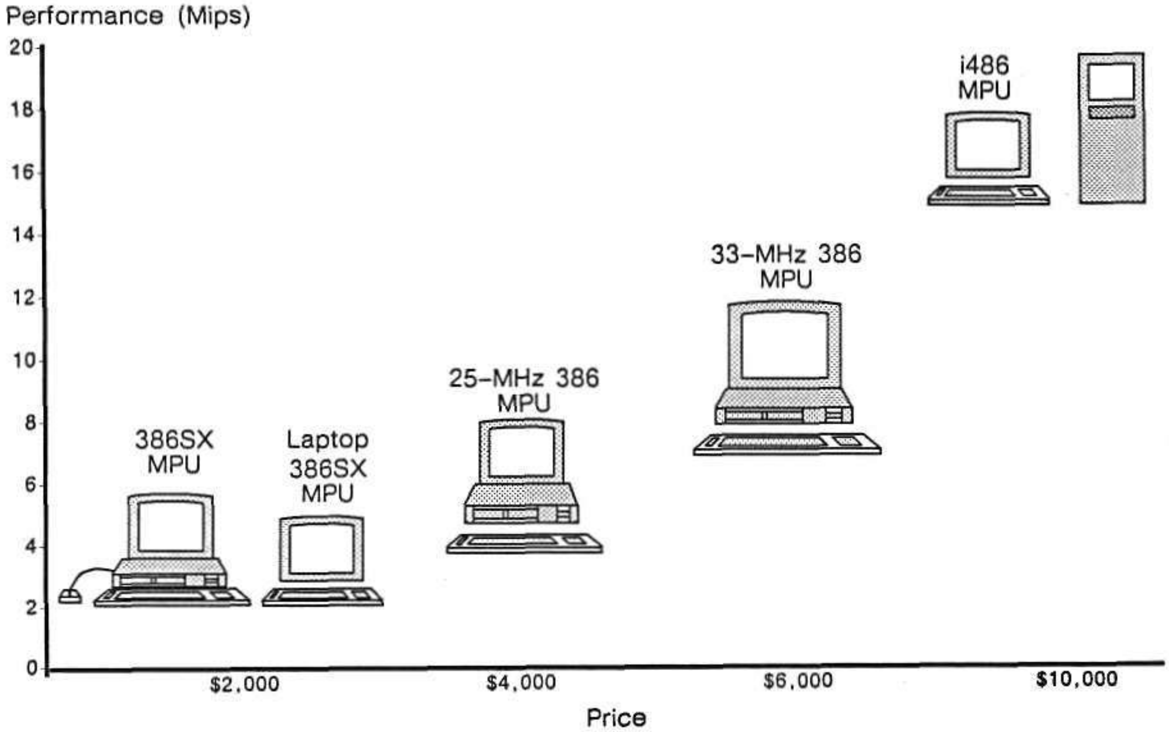
Dataquest believes that as long as these microprocessor family extensions offer system designers a competitive level of performance, software considerations will provide sufficient reason for their existing customer base to stay within the fold.

How long can Intel and Motorola keep offering competitive performance levels on updates to these aging platforms? Historians might point to the fact that each of these is essentially a late '70s design and argue for the inevitability of stagnation under such a restrictive and cumbersome set of constraints. So far, however, both firms have displayed an annoying tendency to make their innovative new ideas work within the constraints they have given themselves. To date there has been little indication of the expected trade-off between innovation and backward compatibility.

But these companies did not reach the commanding positions they now enjoy by being naive. Far from it—the longevity of the 68000 and the 8086 architectures is testament to each firm's visionary design philosophies. Intel's vision of a sole-sourced 80386/486 system-level price/performance spectrum is shown in Figure 2. Motorola's 68040 is intended to similarly extend the 68000 product line, allowing its customers to offer compatible systems at multiple price/performance points.

Figure 2

32-Bit Performance for Everyone



0003733-2

Source: Intel Corporation

FEATURE COMPARISON

Because of the limited information available on the 68040, it is difficult to accurately compare these two products. However, based on features described in Motorola's March 28 press release, the chips appear strikingly similar.

RISC/CISC: How Valid a Distinction?

As expected, both companies seem to have taken a page from the RISC book, optimizing performance by minimizing the number of clock cycles required for the execution of key instructions. Like their RISC counterparts, these devices have an optimized subset of frequently used commands. Unlike their RISC counterparts, the 68040 and the 80486 have retained the balance of their instruction sets in order to maintain compatibility with prior generations. Figure 3 shows the reduction in clock cycles required for certain key instructions in the 80486. Motorola's 68040 is expected to reflect a similar reduction in cycles per instruction, bringing both CISC processors closer to RISC processor performance.

Figure 3

RISC Design Techniques Reduce Clocks per Instruction

Instruction Type	Clock Counts 386 CPU	i486 CPU	SPARC	88000
Load	4	1	2	1–3
Store	2	1	3	1
Reg/Reg	2	1	1	1
Jump (Taken/Not Taken)	9/3	3/1	1/2	1
Call	9	3	3	1

0003733-3

Source: Intel Corporation

Integer Unit

The 80486 boasts six new instructions aimed at facilitating cache management and future multiprocessor applications. One of these is a byte swap instruction that will allow the 80486 to accept both big endian (68000 style) and little endian (80386 style) data, obviously opening access to non-X86 data bases. There is no indication at this time whether the 68040 will also accept both types of data; however, Motorola's 88000 supports both.

More important, perhaps, is the change from a 2X clock-in to a 1X clock-in on the 80486. This will become more significant as clock speeds approach 50 MHz. The 68040 is believed to still require a 2X clock-in. Both products will initially be offered at 25 MHz, although the 80486 may be available at 33 MHz before the 68040 comes to market.

Floating-Point Unit

Both the 80486 and the 68040 have migrated the floating-point unit (FPU) on-board. Both new FPUs are compatible with their predecessors, the 80387 and the 68882, as well as with IEEE standard 754.

Memory Management Unit

Again, both the 68040 and the 80486 have on-chip memory management units (MMU), as do the earlier 68030 and 80386. Both new MMUs will support paged mode operation and will undoubtedly be compatible with their predecessors.

Cache

The 80486 and the 68040 both feature 8K bytes of on-chip cache memory with full bus snooping capabilities. In the case of the 80486, the cache is a unified code/data cache that can be configured by the user. The 68040 will have separate data and instruction caches, each with 4K bytes.

Dataquest views this on-chip migration of the FPU and caches as a natural adjustment, given the need for increased system speed and the availability of die area afforded by finer-line geometries.

AVAILABILITY

Intel already has first silicon on the 80486, with production quantities scheduled to ship in approximately six months. Motorola, on the other hand, is still five to six months away from first silicon. This would imply that the 68040 will not begin shipping in volume for as much as a year from now. In order to address this window of vulnerability, and in an effort to placate its customer base, Motorola last week announced a 50-MHz version of the 68030, capable of delivering up to 12 mips. This product will begin sampling in May, with volume production expected in the third quarter of this year.

BRIDGE TO THE FUTURE

It is tempting to conclude that because of software-imposed brand loyalty, processors do not compete with one another. But that would be rather simplistic, since processors compete daily not only for new system designs, but secondarily as computer vendors compete with one another for consumer dollars.

Recognizing perhaps the ultimate mortality of these product families, Intel and Motorola have taken up competitive positions away from the security of their old platforms. If the 80486 and the 68040 represent these companies' present, with a nod to a distinguished lineage, then Intel's 80860 and Motorola's 88000 represent their future. These processors allow each to pursue new high-performance applications that are not limited by the old compatibility constraints.

However, the fundamental similarities between the 80860 and the 80486 (such as compatible register sets) suggest that Intel designed the 80860 with an eye toward providing a bridge between the huge 80X86 applications base and new end-user markets.

Dataquest believes that we will soon see an 80486-based system, possibly with an 80860 applications accelerator option. It would likely be made by a "PC" company, competing head-to-head with Sun, Digital, HP/Apollo, et al, driving yet another nail in the coffin of the increasingly arbitrary and outdated PC/workstation distinction.

Because first silicon on the 68040 is still some months away, it is not yet known whether Motorola will implement the necessary hardware compatibilities to accomplish an easy bridge to the 88000, or if it is even necessary.

A WORD ABOUT THE FORECAST

The 32-bit microprocessor unit shipment forecast presented in Figure 1 represents a significant strengthening over Dataquest's previous forecast, in large part because of a strengthening of the 32-bit single-user personal computer market. In order to relate PCs sold in a given year to microprocessors shipped for the same year, the PC numbers were increased approximately 17 percent allowing for a 60-day WIP/dealer inventory. Remember also that Dataquest's PC forecast does not consider the impact of multiuser systems such as NCR's tower products or of add-in accelerator cards.

Dataquest considers the following products to be RISC processors: SPARC, MIPS' RXXXX, Motorola's 88000, Intel's 80860/80960, Clipper, Transputer, Acorn, and AMD's 29000. Included in the CISC segment are Intel's 80386/80486, Motorola's 68020/030/040, National's 32X32, NEC's V60/70, and the TRON MPUs. The forecast presented in Figure 1 does not address Intel's 80386SX or Motorola's 68000/10.

DATAQUEST CONCLUSIONS

Dataquest sees the following issues as key to future market development:

- Greater emphasis on multitasking operating systems
- Increased connectivity among single-user systems via file servers
- Adoption of multiuser systems for departmental computing
- Development of multiprocessor systems for high-end computing applications

Dataquest views these issues below as transitory, and therefore of limited importance:

- The distinction between RISC and CISC
- The distinction between personal computers and single-user workstations

By adopting their two-pronged strategies, Intel and Motorola are effectively addressing these issues without passing up the opportunity to exploit the tremendous advantages afforded by their past successes. It is our view that the much anticipated migration toward the RISC camp will be slower and less widespread than anticipated. This assessment is based largely upon the consideration of established customer bases, switching costs, and the merging of RISC innovations onto CISC architectures.

It can be argued that design win opportunities within the embedded segment far exceed those more visible reprogramming applications, therefore offering abundant opportunities for the new RISC architectures. But, it is also important to recognize the massive installed base of embedded designs already committed to Intel's and Motorola's architectures and the latent effect of architectural familiarity on new designs.

If Intel and Motorola are successful in protecting the bulk of their customer bases from the onslaught of these new RISC architectures, competition from other sources may develop. The prospect of two very large user groups being served by sole-source suppliers may prove too enticing to pass up. Reports of 80386 look-alikes already exist.

Dataquest believes that in the long run, the computing community can support only a few platforms (perhaps three or four). This leaves us with a surplus of solutions, suggesting a shakeout to come. Be that as it may, one thing is for certain—Intel and Motorola have the home-field advantage.

Alice K. Leeper
Kevin M. Landis

Dataquest

Conference Schedule

1989

Semiconductor User/ Semiconductor Application Markets	February 27-28	Le Meridien Hotel San Francisco, California
Japanese Components	April 20-21	Tokyo Bay Hilton International Tokyo, Japan
Computer Storage	April 26-28	The Doubletree Hotel Santa Clara, California
Document Processing	May 16-18	Monterey Sheraton Hotel Monterey, California
Copiers	May 16-17	
Printers	May 16-17	
Electronic Publishing	May 18	
Imaging Supplies	May 18	
Color	May 18	
SEMICON/West Seminar	May 24	The Dunfey Hotel San Mateo, California
Telecommunications	June 5-7	Silverado Country Club Napa, California
European Components	June 7-9	Park Hilton Munich, West Germany
Asian Semiconductor and Electronics Technology Seminar	June 28	Radisson Hotel San Jose, California
Financial Services	August 22-23	The Doubletree Hotel Santa Clara, California
Technical Computing and Applications	September 11-13	The Doubletree Hotel Santa Clara, California
European Copying and Duplicating	September 18-19	Majestic Hotel Cannes, France
Western European Printer	September 20-22	Majestic Hotel Cannes, France
Taiwan Conference	September 25-26	Grand Hotel Taipei, Taiwan
Distributed Processing	September 26-28	The Doubletree Hotel Santa Clara, California
SIA/Dataquest Joint Conference	September 27	Santa Clara Marriott Santa Clara, California
Information Systems	October 2-6	Tokyo American Club Tokyo, Japan
Semiconductor	October 16-18	Monterey Sheraton Hotel Monterey, California
Asian Semiconductor and Electronics Technology	November 2-3	Kunlun Hotel Beijing, China
European Telecommunications	November 8-10	Grand Hotel Paris, France
European Personal Computer	December 6-8	Athens, Greece

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Research Newsletter

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8514/A, TIGA, OR VESA: WHAT'S THE NEXT PC GRAPHICS STANDARD?

SUMMARY

It is a tradition in the IBM environment that a new-and-improved graphics hardware standard comes into vogue every two years. Though the video graphics array (VGA) is the current fashion, the next style is being readied, and the stakes are high for the winner. The main contenders are IBM and third-party IBM-compatible vendors, third-party Texas Instruments-compatible vendors, and, to a lesser extent, vendors of enhanced VGA products.

Texas Instruments (TI) contends that boards based on its 34010 chip are the best choice because it offers the best performance at a low price and has good software support. Although it does offer good price, performance, and compatibility, it is unclear why the market needs something other than the de facto IBM standard. Dataquest believes that, even though TI may serve a high-performance niche in specialized PC graphics markets, its push into the mass market may further confuse the user.

There is a coalition called VESA (for Video Electronics Standards Association) that wants to market standardized medium-resolution (800 x 600) products. Basically, this is a VGA-type market, with enhancements, and should have moderate success, distinct from the TI or IBM standards.

The IBM standard is based on its 8514/A graphics board, which was introduced in 1987, but is only now beginning to show impressive results. It is clearly the de facto standard for high resolution on IBM's PS/2 machines. Chip vendors are already offering 8514/A-compatible products. TI is competing with third-party 8514/A vendors for this market. Dataquest believes that the 8514/A-type products are most suited for the next-generation mainstream graphics market.

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STANDARDS IN THE IBM ENVIRONMENT

A graphics hardware standard allows a world of software to run on a family of machines from various vendors. The need for consistent display standards is acute in the IBM environment, where improvements in special resolution and number of colors is a constant but problematic process (unlike the Macintosh environment, where resolution density is fixed and the QuickDraw standard has been unwavering).

Under IBM, there have been two standards: the enhanced graphics adapter (EGA) standard was introduced in 1984 and was superseded in 1987 by the introduction of the VGA. The EGA was the best-selling product until 1988; now the VGA is the dominant standard. But there is considerable lag between when a standard is first introduced and its widespread availability and use. This lag is a result of the following requirements:

- Widespread software support
- Availability of third-party graphics chips, boards, and monitors
- Readiness of the distribution channel
- Acceptance by the user community

We expect the VGA to continue to be the best-selling product for the foreseeable future, although the next standard after VGA will build up momentum over the next 18 months.

There is a historical trend worth noting that follows the introduction of a new graphics standard by IBM. The steps are as follows:

- Phase I—IBM introduces a new graphics standard.
- Phase IIA—Third-party vendors introduce a semicompatible product.
- Phase IIB—Third-party vendors introduce a fully compatible product.
- Phase IIC—Third-party vendors introduce a fully compatible, but enhanced, version.
- Phase III—The original standard becomes a full commodity product.
- Phase IV—A new graphics standard is introduced.

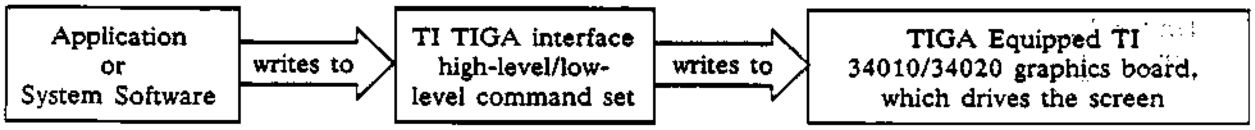
This cycle can take about three years. In terms of current standards, the industry is at about Phase III with the VGA and Phase IIB with the 8514/A. However, there is still considerable argument with regard to the acceptance of the 8514/A as the next standard after VGA, from certain camps that have alternative products to sell.

Current Situation of Standards

According to the trade press and third-party vendors, there are arguments among various camps regarding the next standard after VGA. Discussions of the camps follow.

The TI 34010/34020 TIGA

The Texas Instruments Graphics Architecture, or TIGA, is a new software interface from TI that will run on its 34010/34020 graphics processors. It will allow software written to the TIGA standard to run on any TI 34010/20-based graphics board that has been made TIGA compatible. This works as follows:



TI is promoting the above scheme as the next-generation mainstream graphics standard, as opposed to IBM's 8514/A standard.

IBM's 8514/A

The 8514/A is IBM's 1,024 x 768 resolution add-on board, and is based on proprietary VLSI parts. Software writes to the 8514/A as follows:

Third-Party Consortium's VESA

VESA is a screen-addressing scheme from a consortium of third-party graphics vendors. The scheme is an extension of IBM's VGA standard for offering resolution higher than that offered on VGA, at 16 or 256 colors. It is intended as an interim step between the basic VGA (640 x 480 resolution, 16 colors) and the next 1,024 x 768 resolution standard. The consortium consists of graphics board, chip, and monitor vendors.

Each of these standards can support interlaced or noninterlaced screens, which is irrelevant to the applications software or graphics standard.

THE STANDARDS BATTLE: 8514A, TIGA, AND VESA

Which one of the above standards or proposals is going to be the mainstream standard of the next few years?

To begin with, the VESA proposal is only an interim scheme that is to be used mainly with the current generation of 800 x 600 resolution-type multisynch monitors, and, in our view, it is not a long-term solution for 1,024 x 768 screens. The VESA proposal is acceptable for allowing enhanced VGA boards (which are mainly nonintelligent in nature) to come under one standards umbrella. The real battle is for an intelligent or processor-based 1,024 x 768 graphics standard, the two contenders for which are TI and IBM.

TI versus IBM

In Dataquest's view, there are four important fronts in the battle over the next graphics standard:

- Performance
- Compatibility
- User frustration
- Price

Performance

Historically, performance has been the most misused and abused area of comparison in all categories of graphics hardware before PC graphics—and this is again true in the current PC graphics battleground. Graphics performance numbers tend to be used like many statistics; that is, they are creatively selected and tailored to support any cause. So PC graphics performance numbers must be taken with a grain of salt. In general, however, several points can be safely observed:

- TI 34010 (and the resulting board) is a midrange to high-performance part. But being software-programmable as a general-purpose processor, it does not have the very high performance of a special-purpose processor hardwired to perform a specific function. The 34020 will be significantly faster—as will be the second iterations of competing parts.

- The IBM 8514/A chip set is a midrange part, specifically optimized for high performance in the IBM PC environment. It offers at least comparable, and often better, performance in the three important areas of BITBLT, line drawing, and character support.

The fundamental difference between the two competing parts is that, although the IBM part is hardwired to perform a limited set of functions quickly, it pays for this by not being as flexible as a general-purpose processor.

On the other hand, the TI part is a general-purpose, software-programmable microprocessor, which is why it is also usable in print controllers and fax machines. But it pays for this flexibility in raw drawing speed. (The old "no free lunch" principle—even the ill-fated, hardwired Intel 80786 was faster in some areas.)

The raging debate and hype (particularly from the TI camp) is that one part guarantees better performance than the other. We believe that the two parts are more similar in performance than dissimilar. Each is faster in some areas (TI does not own performance, although that is the message in the media), and each is expected to enhance its performance in the future. Furthermore, it would be naive to assume that third-party 8514/A parts will not be able to offer comparable performance in many cases and better performance in others.

Performance improvement is an ongoing process, provided one starts with a reasonable architecture, which is true for TI and IBM.

Compatibility

The fundamental mandate is to be compatible with all software written for the MS-DOS and OS/2 market at 1,024 x 768 resolution. This can be achieved in a number of ways:

- Be TI/TIGA compatible, and hope that most future software will support TIGA either directly or under Windows and Presentation Manager (PM). This is a reasonable assumption.

- Be IBM 8514/A compatible, either directly or through Windows/PM. This is a good bet because we expect the 8514/A to become a de facto standard.

The User Frustration Factor

Although TI is doing a very good job of eliciting software support for TIGA, there can be little doubt about the support IBM will continue to command. It would appear that the question is which product is expected to have the most support. But even if the answer is IBM's 8514/A, there is a larger question with regard to what we call the UFF, or the user frustration factor.

Dataquest believes that the aggravating incompatibilities in the PC environment make the PC less friendly to the average user than the Macintosh environment. Do users really need yet another standard? If vendors continue to muddy the waters with competing standards—in order to sell hardware at the expense of user friendliness—will the IBM platform ever be as friendly as the Mac?

Price

The TI 34010 costs approximately $20 to $40. The 8514/A parts from clone vendors are expected to be priced in the same range, although it will be higher at first. (This price is a small premium over VGA prices). Although the prices are similar for the graphics engine, what is different is the glue logic required for the finished board and its associated cost—which is expected to be lower for the more highly integrated 8514/A solutions. Another important issue is the expected economies of scale. If the 8514/A catches on as is forecast, there should be significant cost reductions. The competitive environment will also heavily impact prices: more than five vendors are expected to sell 8514/A parts, versus the sole-sourced TI part. Of course, such a highly competitive environment affects more than just pricing.

MARKET DYNAMICS

In this section, we present some of our forecasts, based on qualitative as well as quantitative factors. In the case of the 8514/A, such factors are the following:

- Installed base, growth rate, and backlog for the IBM 8514/A

- Current and expected software support

- Expected availability, pricing, and performance of third-party 8514/A chips
- Expected availability and pricing of compatible monitors, both interlaced and noninterlaced
- Growth in the PC and PS/2 market, as well as in the CAD, desktop publishing, and business graphics segments
- IBM's commitment to the standard, and its implementation on future PS/2 motherboards.

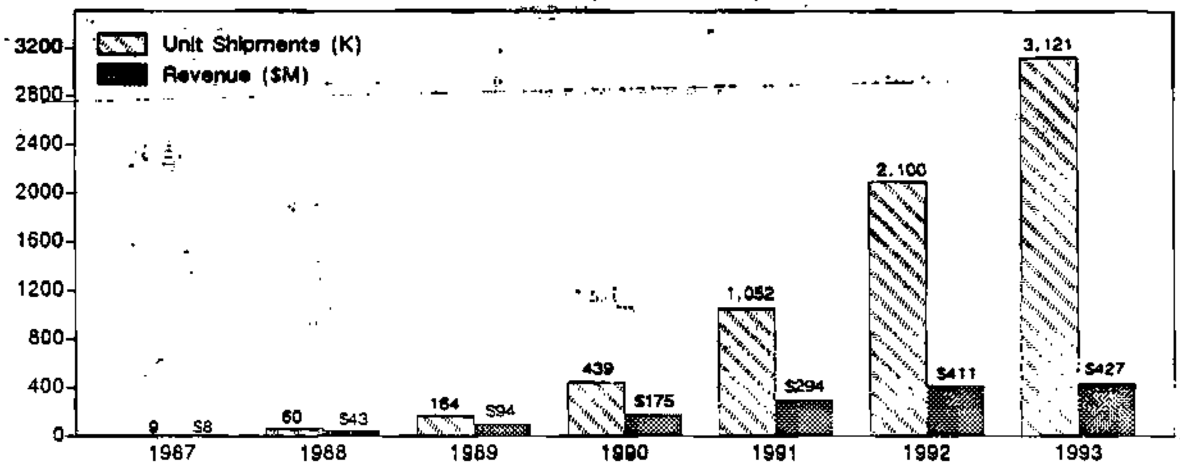
Figure 1 shows our forecast for 8514/A compatibles. Although we originally designed the 8514/A-compatibles forecast to include products that are at least AIFS, or software compatible, we expect that from 1990 onward, most 8514/A compatibles also will be hardware register-level compatible. We also expect that the non-8514/A-compatible market will be dominated by TI 34010/34020-based products.

Figure 2 shows Dataquest's forecast for high-end PC graphics products from all application segments, using all types of graphics engines. Our definition of high-end PC graphics includes mostly those products that have some intelligence, using any type of processor, and does not include "frame buffers" such as EGA/VGA and enhanced VGA.

Figure 3 is a forecast for all VGA compatibles.

Figure 1

High-End PC Graphics
8514/A Compatibles
Worldwide Forecast

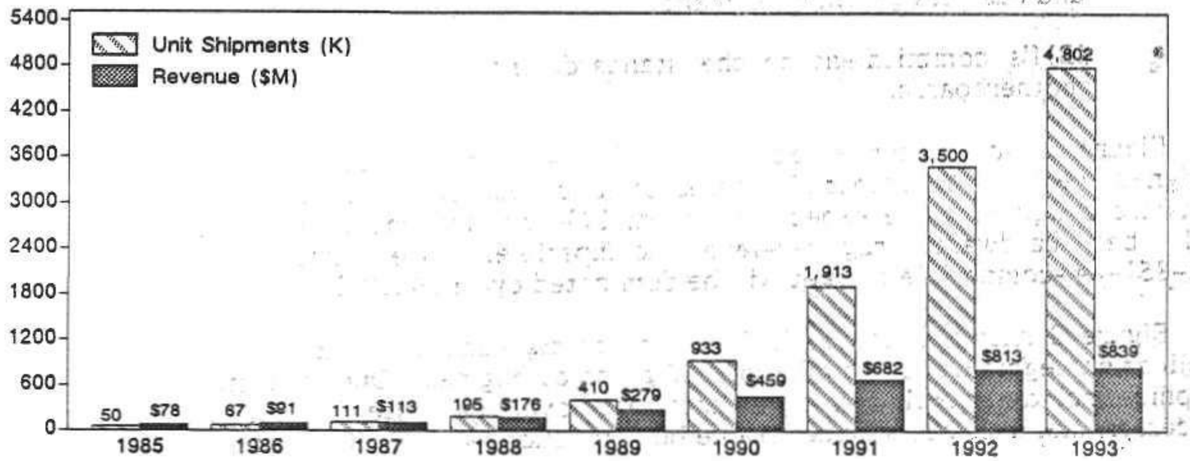


0004525-2

Source: Dataquest
June 1989

Figure 2

Total High-End PC Graphics Worldwide Forecast

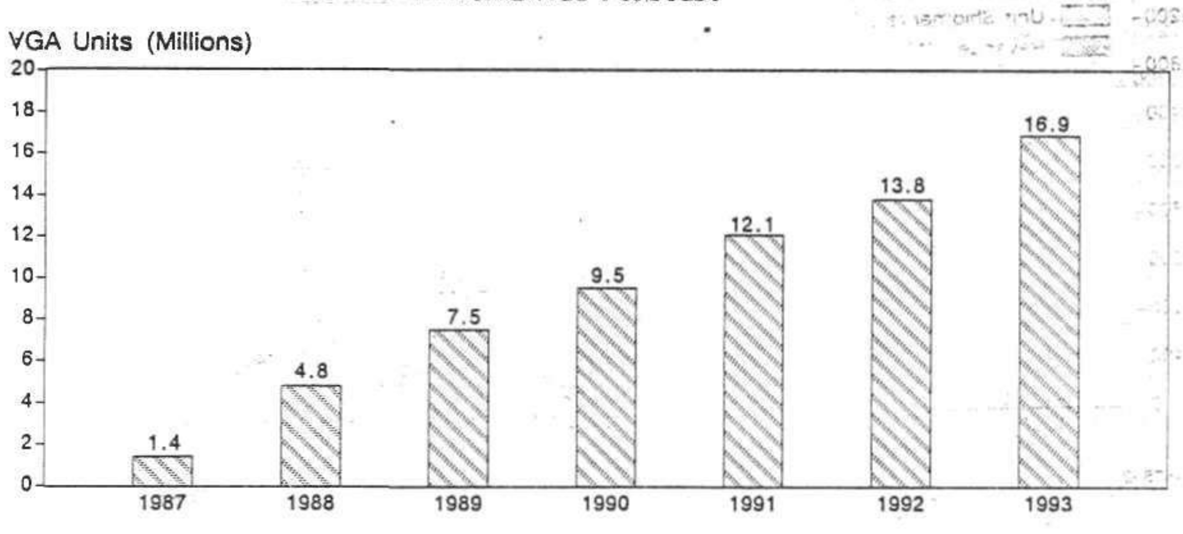


0004525-3

Source: Dataquest June 1989

Figure 3

PC Graphics VGA Market Worldwide Forecast



0004425-1

Source: Dataquest June 1989

Texas Instruments

TI continues to promote its TI 34010 very aggressively and recently announced its standard graphics interface, called TIGA. Future graphics boards based on the TI part will be TIGA compatible, and software support is expected to be good. A number of vendors, including Compaq, Dell, Hewlett-Packard, and Wyse, have announced products based on the TI part. (Compaq is having its board done by Renaissance GRX of Bellevue, Washington.)

Tseng

Tseng initially had aggressive plans to target the 8514/A with its own VLSI, as it did in the VGA market. However, how soon the company gets in the running is currently not known.

Chips and Technologies

Chips announced its 8514/A compatible single-chip solution, the 82C480, on June 27, 1989. The company is providing an interface driver, the Adapter Interface (AI), and will also release a register specification document, giving software developers the option of bypassing the AI. The 82C480 offers ISA and MCA bus support (no EISA), interlaced display support to 1,600 x 1,200 resolution, and noninterlaced display support up to 2,360 x 1,770 resolution.

Western Digital Imaging

Western Digital Imaging (WDI) was the first vendor to announce an 8514/A-compatible chip set. On June 7 WDI announced a two-chip set, called the Personal Workstation Graphics Array 1 (PWGA1). The PWGA1 offers ISA, MCA, and EISA bus support and supports both interlaced and noninterlaced monitors at up to 1,280 x 1,024 resolution. The company will provide register-level interface specifications for software vendors.

Headland Technology

Headland Technology (formerly Video 7) reportedly is developing its own 8514/A-compatible chip set. The company is not expected to finish development in 1989, but it is planning to have 8514/A compatibles for 1990. In the past, it has offered boards based on another vendor's chip sets, and it may do so again.

Integrated Information Technology (IIT)

IIT is a new Santa Clara, California-based semiconductor company, the first products of which were math coprocessors. It plans to sell a register-level compatible 8514/A and VGA on a single chip product this year, with plans to sample in August 1989. The full-custom single chip will be offered as a 144-pin package. It uses a common memory space for both 8514/A and VGA screens. The part is initially to be sold for less than $100, and the company plans to come down the price curve aggressively. IIT intends to be in the chip business only; board sales are not anticipated.

IBM

IBM, the inventor of the 8514/A, has been shipping the product since third-quarter 1987, although shipments initially were very slow in ramping up. Since then, a significant body of software has been created that supports the device. IBM has shipped more than 100,000 of its 8514/A products and is expected to ship up to 150,000 in 1989 alone. Its backlog is considerable, and there is a wait of several weeks for products. So far, this activity has been without much of a marketing effort. IBM is now aggressively promoting the product for its PS/2 machines; it has no intention of offering it for the PC AT market. Furthermore, IBM is expected to implement it as a chip set on the motherboard of its higher-end PS/2s, starting early next year.

DATAQUEST ANALYSIS

In the battle between TI and 8514/A vendors, the question is not really about which is the better part. In Dataquest's opinion, TI has the more versatile part in general, while the IBM standard is specific to the PC and PS/2 environment. And all claims to the contrary, we believe that the IBM part does quite well—even better in many cases—against the TI part. Because the two choices are at least comparable in performance, we do not believe that performance should be the centerpiece of the argument when discussing the mainstream power-user market. (The TI 34010/34020, we believe, is well suited for certain line-drawing performance demanding markets such as CAD.)

For the mainstream market, the question is, if IBM compatibility is important, what is the more suitable part for IBM compatibility? The answer is the 8514/A.

But why is IBM compatibility important? Certainly, users will gain the peace of mind that any future software that supports high resolution will run on IBM and compatible hardware. That being the case, why do we need another standard? Dataquest contends that we do not. Establishing yet another standard is tedious and confuses a market that has had enough confusion (particularly with regard to bus structures—MCA versus EISA). With graphics standards aggravating an already tenuous situation, if the industry does not tread carefully, customers could migrate to Apple, Sun, and even IBM itself, at the expense of the IBM-compatible community.

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Ken Pearlman
Sohail Malik

Dataquest
a company of
The Dun & Bradstreet Corporation

Research *Newsletter*

EISA *AND* MCA: THE BEGINNING OF THE END OF THE BUS WARS

SUMMARY

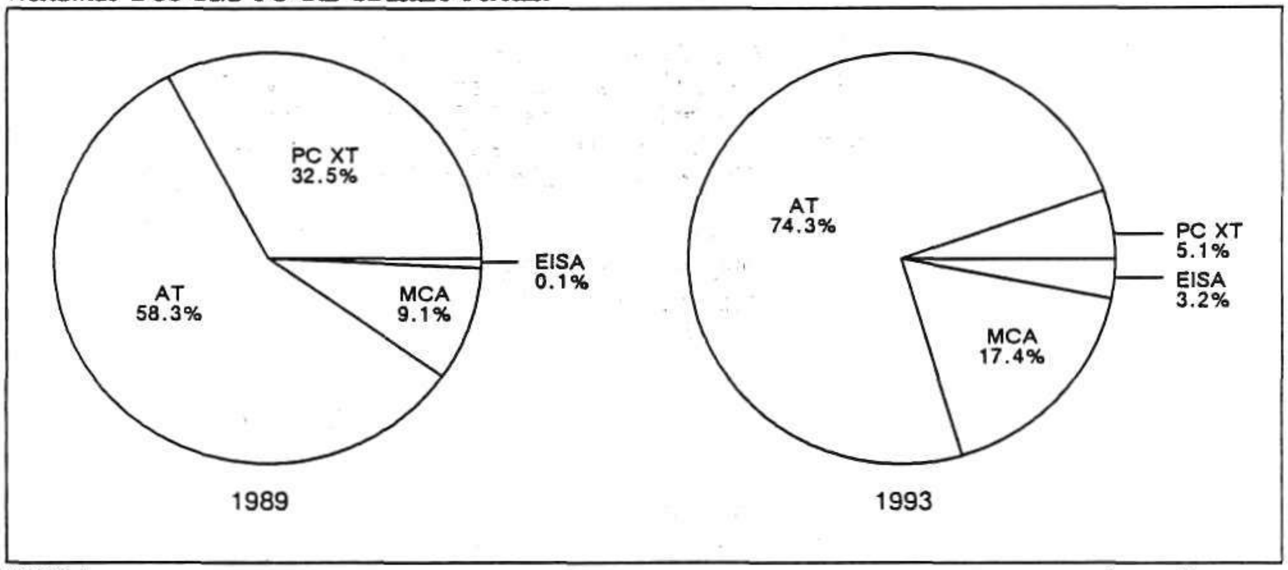
On July 14, just four days after Intel Corporation announced the industry's first Extended Industry Standard Architecture (EISA) chip set, Compaq Computer Corporation announced the signing of a patent cross-license agreement with IBM. The agreement covers a broad range of technologies, including Micro Channel Architecture (MCA) patents. In its press release, Compaq reiterated its commitment to EISA, stating once again that it is not currently developing, and has no plans to develop, MCA-based products. Dataquest believes that this statement accurately reflects Compaq's current position; however, now that Compaq has access to this technology, we must ask: Is it prudent for Compaq *not* to introduce an MCA product?

BACKGROUND

Compaq is generally considered to be the leader of the EISA consortium, which was started by a group of PC manufacturers who did not want to pay royalties to IBM for using the Micro Channel Architecture. The consortium charged that IBM developed MCA as a strategy to increase its market share and to limit the number of PC manufacturers by increasing barriers to entry for low-cost manufacturers. IBM has denied this charge, stating that the MCA bus was developed because of its technical superiority and ability to meet future computing demands.

Figure 1 shows Dataquest's DOS-OS/2 personal computer forecast by bus type. IBM has been shipping MCA bus PCs since April 1987. Dataquest estimates that 1.8 million MCA-based

FIGURE 1
Worldwide DOS-OS/2 PC Bus Structure Forecast



0004624-1

Source: Dataquest
August 1989

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systems were installed worldwide by the end of 1988, growing to 3.2 million installed systems by the end of 1989. Whereas, the first EISA bus PC announcement is not expected until late this year.

Within the industry and the trade press, a great deal of debate exists as to the relative merits of both standards as well as speculation over which standard will be embraced by the user community. In Dataquest's opinion, MCA will become the accepted standard, although EISA may play an interim role in extending the product life of the AT architecture; however, we believe that EISA will not survive in the long term. We base our argument on MCA's two-and-a-half year headstart, during which PC clone makers and third-party add-in board manufacturers have developed a substantial base of MCA products, which automatically lends credibility to the standard. The reluctance of manufacturers to invest resources in a nonexistent market, IBM's influence, and fragmentation within the EISA ranks will further hinder acceptance of the EISA standard.

THE AGREEMENT

Compaq has been negotiating the recently consumated cross-licensing agreement with IBM since 1987, when IBM first introduced MCA. The issue arose when IBM began to push for royalties from manufacturers of PC XT and PC AT products. Because Compaq had anticipated paying some form of licensing fee, it had set up a reserve fund while negotiating an acceptable fee.

According to this agreement, both companies are granted a worldwide, nonexclusive license that covers patents filed prior to July 1, 1993. The agreement covers patents relating to personal computers, peripherals, and other advanced technologies, including MCA. Because of the relative size of each company's patent portfolio, Compaq will pay a fixed net cash payment to IBM, which will be paid in five annual installments. According to a July 17, 1989, article in *The Wall Street Journal*, the fee would amount to approximately 0.5 percent of Compaq's anticipated total revenue for the five-year period, which is considered very low for an IBM licensing fee.

The most obvious benefit to IBM from this agreement is the revenue generated from the licensing fee. However, the more subtle benefit is the effect that this agreement may have on the remaining members of the EISA consortium. Only four of the original "Gang of Nine" have yet to execute an MCA cross-licensing agreement. More important, IBM now has removed the major barrier to Compaq's embracing MCA. In fact, the fixed payment may actually maximize the incentive for Compaq to sell as many MCA machines as possible, because apparently there is no additional per-machine royalty payment included in the terms of this agreement.

For Compaq, the announcement of this agreement resolves the uncertainty of the potential cost of these fees to the company, which is a positive sign for investors. Compaq has been setting aside reserves for these costs since 1987, but analysts were concerned, nevertheless, that the reserves would be inadequate.

Access to a broad range of IBM technology must be considered an asset. Most important, whether or not Compaq sought MCA, the company now has access to the technology. This represents a fallback alternative to its current EISA strategy.

INDUSTRY RESPONSE: A QUIET AVALANCHE?

Prior to July 10, the MCA/EISA issue was variously referred to as EISA versus MCA, The Bus Wars, or Compaq Battles IBM. On July 10, Intel announced the availability of the first EISA chip set and distributed a product background paper entitled "MCA *and* EISA: A New Road To Travel." This title reflects a subtle change in Intel's posture. Intel is no longer interested in fighting a bus war, it is only interested in selling silicon. Intel recognizes that the real market segment is the 32-bit personal computing market, not the MCA or EISA market. The logic of this strategy applies to systems as well as silicon. Why pursue a strategy that will bar access to the whole market? Or, more simply, if the customer wants a blue suit, sell him a blue suit.

Five of the original Gang of Nine EISA members already have licensed MCA from IBM. Pressure to follow these members will increase dramatically as the logic of the Intel strategy is recognized. Additionally, widespread acceptance of MCA over EISA may further weaken the bargaining position of firms seeking an MCA license. The Compaq/IBM agreement makes it clear that the terms now available are not as disagreeable as the clone makers first feared. This attitude may be attributable, in large part, to the arrival of the EISA chip set. Viewed in this context, the EISA strategy can be considered a success, in that it has delivered MCA at a palatable price.

DATAQUEST CONCLUSIONS

Now that Compaq has successfully negotiated a license agreement, Dataquest expects the remainder of the EISA consortium to begin settling accounts with IBM. Regardless of Compaq's stated intent, we believe that this agreement will cause third-party systems and peripherals manufacturers to have even less enthusiasm (if that is possible) toward developing EISA products. We also expect Compaq to rethink its MCA position and to eventually address the entire 32-bit personal computing market by offering products supporting both bus standards. This transition will present some awkwardness for Compaq, but we can envision a scenario in which the company determines that success requires satisfying key customer needs, which include the ability to choose between EISA *and* MCA. Does this mean that EISA is a failure? Hardly—It now appears that the Gang of Nine members will have access to MCA on terms that they can live with.

Ken Pearlman
Kevin Landis

Dataquest
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Research Newsletter

MICROCOMPONENT NEWS: SECOND QUARTER 1989

The *Microcomponent News* is designed to inform the reader of key happenings in the microcomponent marketplace by providing short, informative abstracts for quick, easy screening. Each issue will provide a synopsis of news events gathered from a variety of sources, including company press releases and trade magazines. The abstracts are organized by key topics and listed in alphabetical order by company. This issue summarizes the major events that occurred during the second quarter of 1989.

The following is a key to the publications reviewed during research and included in this issue:

Business Wire	BW
DQ Monday	DQM
Electronic News	EN
I.C. USA	ICU
Company News Release	CNR
Electronics Buyers News	EBN
I.C. Asia	ICA
Semiconductor Weekly	SW

DQ Monday, *I.C. Asia*, and *I.C. USA* are Dataquest products produced by its Components Division.

MICROPROCESSORS

Bipolar Integrated Technology (BIT)

BIT announced the introduction of its ECL technology SPARC microprocessor. The device is called BIT SPARC and is a six-chip set. BIT SPARC executes at a rate of more than 65 mips and calculates arithmetic functions at a rate up to 40 mflops. (BW June 7, 1989)

Fujitsu

Fujitsu, Hitachi, and Mitsubishi have developed a new version of the G Micro TRON 32-bit microprocessor that operates at 4.5 mips. This MPU was designed in 1.0-micron CMOS technology and was sampled in August. The G Micro/100 is the latest of three G Micro MPUs developed by these companies. Other products include a G Micro/200 and G Mirco/300 with performance ratings of 7 and 20 mips, respectively. (SW April 25, 1989)

Fujitsu plans to expand its RISC MPU business by supplying Sun Microsystems with the majority of SPARC MPUs for Sun's SPARC-based workstations. Also, Fujitsu will complete development of a new RISC MPU in conjunction with Sun. The new RISC device will operate in the 30- to 40-mips processing range. (SW April 20, 1989)

Intel

Intel's i860 64-bit RISC MPU has been selected by DARPA for use in an experimental supercomputer project that will use up to 2,000 of the MPUs. The system will execute arithmetic calculations at more than 128 billion 64-bit flops. The project is called Touchstone and is intended to develop a system that performs at least 100 times faster than today's supercomputers. (EBN April 10, 1989)

LSI Logic

LSI Logic began manufacturing 32-bit SPARC MPUs in a joint venture called Japan Semiconductor. This venture was formed between LSI Logic and Kawasaki Steel. LSI Logic's R2000/3000 MPUs were expected to be manufactured there beginning at midyear. (SW May 9, 1989)

SIS Newsletters 1989 Microcomponents

0005043

Motorola

Motorola announced volume production of 20- and 25-MHz versions of the 88000 RISC 32-bit microprocessor. The 25-MHz version operates at 21 mips. Further announcements of higher-speed versions will be made this year. (CNR June 7, 1989)

A strategic partnership has been announced between Motorola and Thomson-CSF regarding the use of the 88000 RISC MPU in military and defense products. Also, Motorola granted Thomson-CSF alternate sourcing rights for militarized versions of the 88000 family. The Thomson-TMS subsidiary of Thomson-CSF will manufacture the 88100 and 88200 devices along with future versions of the family. (CNR May 22, 1989)

NEC

NEC will begin production of the MIPS R3000 RISC MPU at its Sagamihara, Japan, facility in October. The initial production rate will be 10,000 devices per month with expansion to the R4000 product in late fiscal 1990. (SW April 22, 1989)

NEC has completed development of the V53 16-bit microprocessor, which is based on the V33 MPU. The V53 is an enhancement of the earlier V40/50 devices and represents four times the speed at 2.8 mips. The V53 was designed using a 1.2-micron CMOS technology and operates at 10.0, 12.5, and 16.0 MHz. As a high-integration MPU, nine equivalent LSI devices have been brought onto a single chip. Sampling occurred in August and production will begin late in the year toward a goal of 100,000 units total in 1990. (SW June 28, 1989)

Oki Electric

Oki is developing tools to assist in the evaluation effort for G Micro/series TRON processors. Oki is joining Fujitsu, Hitachi, and Mitsubishi in this effort. (SW May 1989)

Tateisi Electronics

Tateisi has developed a line of microprocessors and general-purpose controllers based on fuzzy logic technology. The MPU products consist of custom digital logic devices and analog fuzzy components for image processing. Tateisi anticipates roughly $7 million to $15 million for the new products and a $763 million business in five years. (SW May 1989)

VM Technology

The VM860SOG application-specific microprocessor has been developed by VM Technology as an alternative for laptop computers and personal note systems. This device is a sea-of-gates array integrated with the 16-bit VM860/861S microprocessor. The beginning unit price will be approximately $37, with mass production of 100,000 units per month. (SW May 12, 1989)

Zilog

Zilog has upgraded its 6-MHz Z80 MPU with an integrated clock generator/controller function and four power-down modes. Named the Z84C01, the device will be offered at $2.29 or $2.95 (depending on the package) and in 100-piece quantities. (EN May 15, 1989)

MICROCONTROLLERS

Hitachi

Hitachi announced the H8/330, the first product in the new high-speed H8 8-bit microcontroller family. The company also announced the H8/500 MCU family, which is a 16-bit configuration of the H8 product line. Hitachi claims that the H8/330 MCU has the fastest execution time at 200 nanoseconds per instruction. The H8/330 also contains an 8-bit by 16-register general register structure, 16 Kbytes of EPROM, 512 Kbytes of RAM, and various specialized timers. Samples are $18 to $92, depending on the package type. (SW May 1989)

Hitachi also introduced the HD647180X high-integration 8-bit microcontroller based on the Z80 CPU. Hitachi says it is the industry's highest integration standard MCU with Z80 code compatibility. The HD647180X executes in 0.375 microsecond and contains 15 peripheral functions. In 1,000-piece quantities, the 8-MHz version sells for $19.10 in an 84-pin PLCC package. Production volume began in the second quarter of this year. (CNR April 24, 1989)

Fujitsu

Fujitsu began marketing a development support system and operating system for its MB89700 8-bit MCU series. The operating system is called REALOS/97, and the support package includes a compiler, macro assembler, software, and host simulators. Prices are $2,985, $1,940, $1,194, and $4,328 for each of the support tools, respectively. (SW May 4, 1989)

Mitsubishi

Mitsubishi increased 8-bit microcontroller production to a current level of 15 million units per month to compensate for overall demand. In order to accomplish this, Mitsubishi installed new production lines at its Kochi and Kumamoto plants in Japan. The overall increase in demand may stem from increased use in home appliances. (SW May 8, 1989)

NEC

NEC will increase microcontroller production from a fiscal 1988 level of 22 million units per month to a new level of 30 million units monthly. The company also will focus on customized devices and RISC components. (SW June 1989)

Siemens

Siemens announced a new 20-MHz 8-bit microcontroller, the SAB 8032B. The SAB 8032B is completely compatible with the existing 8051 family architecture and requires no design change for an 8031 upgrade. Pricing currently is set at $4.96 in a 40-pin PDIP package or $5.51 in a 44-pin PLCC package in 5,000-piece quantities, with volume production scheduled for the middle of 1989. (CNR May 1, 1989)

MICROPERIPHERALS

Integrated Information Technologies

IIT announced the IIT-2C87A and IIT-3C78 numeric coprocessor components. These devices are plug and object code compatible with Intel's 80287, 80287A, and 80387 arithmetic coprocessors for the 80286 and 80386 MPUs. IIT claims to have doubled the speed and performance in the 80287-compatible coprocessor and increased performance 50 percent in the IIT3C87 80387-compatible coprocessor. Pricing for both coprocessor devices is said to be comparable with the Intel equivalent components, with production availability set for the third quarter of 1989. (CNR April 24, 1989)

IIT also announced a single-chip, high-end graphics device that incorporates the VGA standard and the 8514/A standard. The Integrated Graphics Array (IGA) contains complete 8514/A compatibility and all VGA, EGA, CGA, MDA, and Hercules backward compatibility. The IGA is a full-custom device built in 1.2-micron CMOS and packaged in a 144-pin quad flat pack. It will be available on an engineering board in August. (CNR June 27, 1989)

Intel

Intel announced a new 32-bit LAN coprocessor as part of its i486 peripheral family. The 82596CA performs all CSMA/CD functions parallel to the i486 MPU. This device connects directly to the i486, reducing bus interface complications and therefore system design complexity. Intel stated that the 82596CA is intended for workstations, minicomputers, and file servers. Pricing of the LAN coprocessor is $88 in 1,000-piece quantities and production volume is set for the fourth quarter of 1989. (CNR April 10, 1989)

NEC

NEC completed development of a high-speed graphics display controller designed to process display data at a 20 percent increase over existing controllers. It is being built in 1.2-micron CMOS and was sampled in July. Volume production pricing will be approximately $37.31. (SW May 11, 1989)

Weitek

Weitek Corporation announced the Abacus 3170 and 3171 floating-point coprocessors for SPARC MPU designs. The 3170 is intended for Fujitsu SPARC MPU designs and the 3171 is targeted at the Cypress SPARC processor series. The 3170 and 3171 are being offered in speed grades ranging from 20 to 40 MHz. Each device is an integrated floating-point data path and controller in a 143-pin PGA package. The 3170 is $356 for

20 MHz and $427 for 25 MHz, both in 1,000-piece quantities. The 3171 is $427 for 25 MHz and $925 for 40 MHz, both in 1,000-piece volumes. (CNR April 17, 1989)

Weitek also announced the Abacus 4167 floating-point coprocessor for Intel's new 80486 processor. The 4167 is claimed to offer a five- to sixfold increase over the i486's on-chip math unit. The 4167 contains 16 64-bit registers to speed calculations and is memory mapped to speed data handling. It is built in 1.0-micron CMOS and will sell for $565 in 1,000-piece volumes. Limited production should occur in December. (CNR May 8, 1989)

Brand A. Parks

- High–Volume/Low–Cost Manufacturing—Because of the increasing commodity status of these products, access to high–volume/low–cost foundries will be essential.

- Customer Service/Support—Because of the lack of any major differentiation in these products, service and customer support is as important as pricing. A user might not switch vendors for either better pricing or better service, but if offered both, will find it difficult to resist.

Opportunities

As the chip set market approaches saturation and vendors find themselves with excess capacity, they will be forced to look for new applications for logic chip sets outside of the personal computer. Two areas that will benefit from this are the embedded DOS market and the personal workstation market.

Embedded DOS Market

At least one chip set vendor is pursuing embedded DOS applications as its primary strategy, and most others have thought about it as a secondary strategy but have not yet dedicated resources toward this market. The embedded DOS market can be defined as having applications that contain some form of keyboard (input device) and some sort of display (output device) that could benefit from the protocol of the DOS PC logic interface. These applications tend to be for low–end PC logic products. Examples are vending machines, traffic controllers, process controllers, communications, and medical and analytical instrumentation.

Personal Workstation Market

As the high–end personal computer products approach the functionality of low–end workstation products, a segment is developing that some have called the personal workstation market. With the introduction of the Intel 80486 and i860 microprocessors, opportunities exist to develop high–end chip sets that will combine the use of complex–instruction–set computer (CISC) and reduced–instruction–set computer (RISC) microprocessors to offer a system that will run both DOS and UNIX applications. One chip set vendor already has announced plans to develop a RISC chip set.

This market is not well defined. Questions exist as to the size and viability of this segment, and standardization issues need to be resolved.

DATAQUEST CONCLUSIONS

The rapid initial growth rate of the DOS PC logic chip set market has invited many new entrants to this industry and has brought the market from infancy to saturation in a very short period of time. Although a change in product mix toward the high–end products will somewhat offset price declines over the next several years, pricing pressure will be considerable. This will cause some vendors to exit this market altogether and others to dedicate resources to seeking out new applications for these products. Vendors with access to low–cost foundries, appropriate design tools and expertise, and high–quality global sales organizations will stand the best chance of success.

Ken Pearlman

Dataquest

Conference Schedule

1989

Semiconductor User/ Semiconductor Application Markets	February 27-28	Le Meridien Hotel San Francisco, California
Japanese Components	April 20-21	Tokyo Bay Hilton International Tokyo, Japan
Computer Storage	April 26-28	The Doubletree Hotel Santa Clara, California
Document Processing	May 16-18	Monterey Sheraton Hotel Monterey, California
Copiers	May 16-17	
Printers	May 16-17	
Electronic Publishing	May 18	
Imaging Supplies	May 18	
Color	May 18	
SEMICON/West Seminar	May 24	The Dunfey Hotel San Mateo, California
Telecommunications	June 5-7	Silverado Country Club Napa, California
European Components	June 7-9	Park Hilton Munich, West Germany
Asian Semiconductor and Electronics Technology Seminar	June 28	Radisson Hotel San Jose, California
Financial Services	August 22-23	The Doubletree Hotel Santa Clara, California
Technical Computing and Applications	September 11-13	The Doubletree Hotel Santa Clara, California
European Copying and Duplicating	September 18-19	Majestic Hotel Cannes, France
Western European Printer	September 20-22	Majestic Hotel Cannes, France
Taiwan Conference	September 25-26	Grand Hotel Taipei, Taiwan
Distributed Processing	September 26-28	The Doubletree Hotel Santa Clara, California
SIA/Dataquest Joint Conference	September 27	Santa Clara Marriott Santa Clara, California
Information Systems	October 2-6	Tokyo American Club Tokyo, Japan
Semiconductor	October 16-18	Monterey Sheraton Hotel Monterey, California
Asian Semiconductor and Electronics Technology	November 2-3	Kunlun Hotel Beijing, China
European Telecommunications	November 8-10	Grand Hotel Paris, France
European Personal Computer	December 6-8	Athens, Greece

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Research Newsletter

THE PC GRAPHICS CHIP SET DILEMMA: VOLUME UP, REVENUE DOWN

INTRODUCTION

It seems as if the PC graphics chip set market is doomed to the same fate as the PC logic chip set market: rapid saturation of chip sets into graphics applications, accompanied by a large number of new market entrants—leading to overcapacity, aggressive pricing, and declining margins. Dataquest believes that this dilemma is bound to be repeated in each of the PC peripheral chip set markets (logic, graphics, communications, mass storage, modem, and fax) as established chip set and semiconductor companies follow one another into these most obvious product-line extensions. At the same time, apparently low barriers to entry invite many new market participants. The consumer is a major winner in this situation, receiving more system performance for less cost. The semiconductor and chip set companies are major losers, as they quibble over a relatively well-defined and limited market, seemingly unable to extricate themselves from this cycle.

PC GRAPHICS MARKET OVERVIEW

Dataquest's forecast for the low-end PC graphics merchant chip set market, as derived from total PC shipments and total graphics device shipments, is shown in Table 1. Figure 1 charts historical and forecast low-end merchant chip set revenue.

Total worldwide merchant PC graphics chip set revenue was $108 million in 1988, representing an increase of 96.4 percent over 1987 revenue of $55 million. Dataquest is forecasting 1989 revenue at $182 million, an annual growth rate of 68.5 percent.

Saturation

The saturation of chip set solutions into graphics devices signals the end of the rapid-growth phase for the market. Dataquest expects unit compound annual growth rate (CAGR) for merchant chip sets from 1987 through 1993 to be 39.8 percent, and the CAGR for the period 1989 through 1993 is expected to be 18.0 percent. As a result of severe pricing pressure, however, average selling price (ASPs) are forecast to decline by a CAGR of negative 26.8 percent in this period. Consequently, we expect revenue to decline beginning in 1990 and the revenue CAGR for 1989 through 1993 to be a negative 13.6 percent.

Competition

In 1987, there were five merchant graphics chip set vendors; in 1988, there were nine vendors offering merchant products. Currently, 12 vendors are in the market. As the business shifts from add-in boards to motherboard implementations, some vendors now offering boards with proprietary chip sets will begin to offer those chip sets on the merchant market. Dataquest estimates that there will be between 16 and 20 merchant graphics chip set vendors by the end of 1990.

The increase in the number of competitors combined with expected slower growth in unit shipments has led to aggressive pricing strategies. Such strategies will result in lower revenue overall for the industry and continued margin pressure for individual vendors.

The three largest merchant vendors of low-end PC graphics chip sets are Western Digital, Chips and Technologies, and Cirrus Logic. These companies accounted for 90 percent of the merchant revenue in 1987 and 75 percent in 1988.

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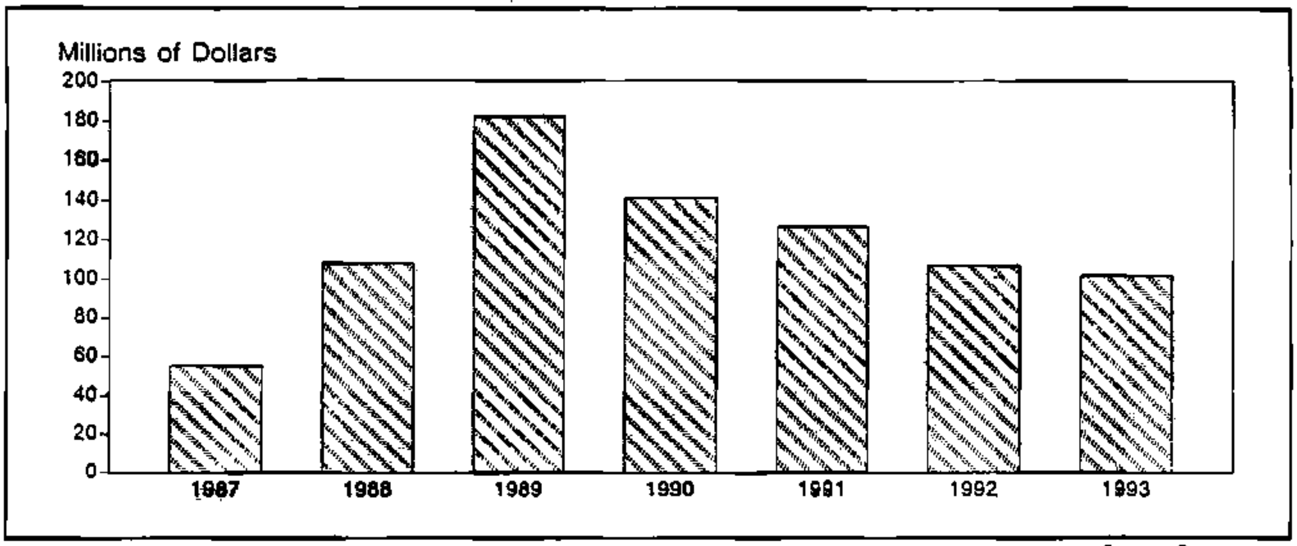
TABLE 1
Low-End PC Graphics Merchant Graphic Chip Set Market Estimated Worldwide History and Forecast (Millions of Units)

	1987	1988	1989	1990	1991	1992	1993	CAGR 1987-1993	CAGR 1989-1993
Total DOS PC Shipments	9.6	12.3	13.8	15.4	17.1	18.7	20.6	13.6%	10.5%
Growth Rate		28.1%	12.2%	11.6%	11.0%	9.4%	10.2%		
Total Low-End Graphics Devices	9.2	11.1	13.7	14.3	15.8	16.4	18.3	12.1%	7.5%
Growth Rate		20.5%	23.2%	4.6%	10.8%	3.8%	11.1%		
Low-End Graphics Chip Sets	4.3	7.5	11.8	13.0	15.0	16.1	18.2	27.2%	11.5%
Saturation	46.7%	67.9%	86.0%	91.0%	95.0%	98.0%	99.6%		
Merchant Graphics Chip Sets	2.1	4.5	8.1	10.2	12.5	13.7	15.7	39.8%	18.0%
Growth Rate		114.7%	79.3%	25.1%	22.7%	9.9%	14.9%		
Merchant Graphics Chip Set ASP	$26.1	$23.9	$22.4	$13.9	$10.2	$7.8	$6.5	(20.8%)	(26.8%)
Growth Rate		(8.6%)	(6.0%)	(38.0%)	(27.0%)	(23.3%)	(17.2%)		
Merchant Graphics Chip Set Revenue ($M)	$55.0	$108.1	$182.1	$141.3	$126.6	$106.7	$101.5	10.7%	(13.6%)
Growth Rate		96.3%	68.5%	(22.4%)	(10.4%)	(15.7%)	(4.9%)		

Source: Dataquest
October 1989

FIGURE 1
Total Low-End Merchant Graphics Chip Set Revenue
Estimated Worldwide History and Forecast



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Source: Dataquest
October 1989

MARKET SEGMENTATION—STANDARDS

The evolution of graphics adapters has led us from the original Hercules Graphics Adapter (HGA) to the Video Graphics Array (VGA), which is now the standard on the IBM PS/2 line of computers. The Dataquest forecast for merchant low-end PC graphics chip sets by standard type is presented in Figure 2. We expect VGA to be the dominant standard beginning in 1989. Growing at a CAGR of almost 50 percent for the period, VGA appears to be a satisfactory solution for the majority of applications. As prices of VGA chips continue to decline, the older standards will lose share to VGA and will become obsolete.

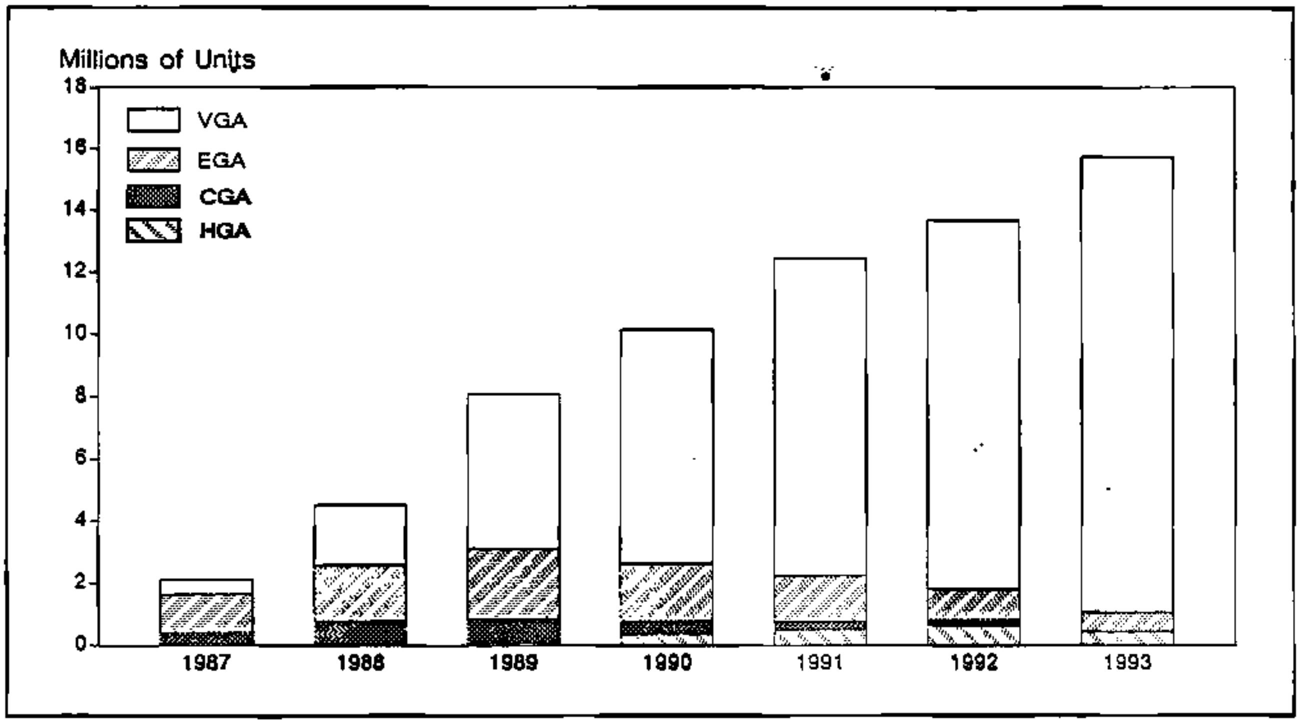
Although it is not reflected in these forecasts, we expect the next PC graphics standard or standards to begin eroding VGA growth sometime in the 1991 to 1993 time frame. The shift toward a new standard will depend on pricing of chips, monitors, and memory and will be slower than previous shifts. The next PC graphics standard currently is under debate. Although the shift to a new standard will not occur as rapidly as it has in the past, Dataquest believes that the IBM 8514/A will be the eventual successor to VGA in the mainstream PC market.

FACTORS FOR SUCCESS

At this point, the decision to use chip sets in graphics designs is very simple. It is really the only way to go, in consideration of the following advantages:

- Optimum performance and chip count
  - Reduced number of components needed
  - Optimized performance and reliability
  - Higher functionality with lower power consumption
- Time to market—Shortened by off-the-shelf parts and designs
- Cost savings
  - Improved manufacturability
  - Simplified debugging
  - Easier field repair

FIGURE 2
Merchant Graphics Chip Sets by Standard Type
Estimated Worldwide History and Forecast



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Source: Dataquest October 1989

The choice of which chip set vendor to use probably will depend on price and service. Other critical success factors for graphics chip set suppliers include:

- Systems expertise
- Access to design tools
- Access to high-volume/low-cost manufacturing
- Ability to demonstrate a product growth path

Everything else being equal, vendors can be divided simply into two camps: those with manufacturing capability and those without. If there is any barrier to success in this business, it would be the access to low-cost manufacturing, especially when pricing becomes a key competitive issue. Vendors without manufacturing capability are really design houses, not semiconductor companies. Their competitive advantage is that rather than supporting plant and equipment, they can direct resources into design tools, systems expertise, service, and research in an effort to maintain the lead in technology. Leading-edge products allow for higher margins, but volumes typically start low. And the leading edge quickly becomes the standard mainstream in this business, meaning higher volumes but lower prices. When competing on price, it may be an advantage for vendors to have access to their own manufacturing.

DATAQUEST CONCLUSIONS

The graphics chip set market is a subset of the total PC peripherals chip set market. This market was created by start-up semiconductor design houses; however, it has matured and is becoming the focus of efforts on the part of the large semiconductor manufacturers, which view this market as strategically important for maintaining their competitive positions.

The increase in competition already has led to severe price cutting, and several vendors have announced that they expect lower net profits in upcoming quarters as a result of margin pressure. Dataquest expects this trend to continue, with new vendors introducing products in 1990. In this scenario, the near-term (one to two years) expectation for the industry is for continued aggressive pricing, leading to sustained lower margins, as vendors fight to maintain or build market share. We expect some consolidation to begin in this time frame, with some vendors simply abandoning the market and others seeking to form alliances or mergers in an effort to control competition.

Ken Pearlman