Newsletter Index

1986-1987 Newsletter Index

The 1986-1987 SIS Newsletter Index is a quick reference guide to the titles and tables in our newsletters. It is structured as follows:

- Titles and tables are organized by keyword and company.
  - Page 2 is a company list, e.g., Intel, Motorola.
  - Pages 3-6 are a subject list, e.g., MPU, Dynamic RAM.
- The month and year follow each title listing in the Index. Refer to the month's menu to locate the newsletter or table. Newsletter titles and tables are filed by month published.

This Index is updated quarterly.

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1986-1987 Newsletter Index

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January Newsletters

The following is a list of the newsletters in this section:

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January Newsletters

Dataquest
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RESEARCH NEWSLETTER

SIS Code: 1986-1987 Newsletters, January
1986-3

GATE ARRAYS DEFY THE DOWN IC MARKET

EXECUTIVE SUMMARY

The gate array market surfaced from the undertow of the declining IC market with surprising results. DATAQUEST reports that in 1985, the worldwide IC market was down 18 percent from 1984, while the dollar value of worldwide gate array shipments rose an amazing 45.5 percent. The 1985 gate array design captures, a leading indicator of the 1986 market, climbed an estimated 33 percent over 1984.

This newsletter will report preliminary 1985 shipment revenues by company (see Table 1). It also provides a detailed forecast of the gate array market by individual technology. Data supporting our forecast are provided in the following areas:

- Design starts
- NRE trends
- Captive supplier going merchant
- Pricing trends
- End-use consumption

Table 1

ESTIMATED 1985 WORLDWIDE GATE ARRAY SHIPMENT REVENUES--TOTAL
(Millions of Dollars)

Rank	Company	Revenue
1	Fujitsu	$257.6
2	LSI Logic	135.0
3	Motorola	91.2
4	Fairchild	60.2
5	NEC	57.9
6	Honeywell	57.0
7	Ferranti Elect.	49.7
8	Toshiba	45.6
9	TI	36.5
10	Hitachi	36.2
Total		$826.9

Source: DATAQUEST
January 1986

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Current gate array trends that affect the longevity of suppliers are presented on these topics: strategic alliances, products, distribution, and customer service. The newsletter concludes with a look at what we believe is in store for the 1986 gate array market.

PRELIMINARY 1985 GATE ARRAY RESULTS

DATAQUEST Definitions

DATAQUEST defines these commonly used terms as follows:

- Gate arrays--These are digital or linear/digital integrated circuits containing a configuration of uncommitted elements customized by interconnecting these elements with one or more routing layers.

- NRE--These are nonrecurring engineering charges, or simply the cost of developing the array.

- Intracompany revenue--When an IC manufacturer takes a product line, which was developed and produced for internal consumption, to the merchant market, the revenue associated with this internal consumption is called intracompany revenue; the revenue from sales to outside companies are called merchant revenue.

- DATAQUEST gate array shipments--The shipment revenue equals the estimated production revenue plus the intracompany revenue plus the NRE revenue. (Note: we count only processed wafers with interconnect layers, not blank wafer sales, as that would lead to double counting.)

Total Gate Arrays

As Table 1 indicates, Fujitsu is the leader in total gate array revenue. Fujitsu is number two in MOS gate arrays and number one in bipolar gate arrays, as shown in Tables 2 and 3, respectively. However, one must consider that a large portion of Fujitsu's revenue comes from sales to its own divisions. LSI Logic came in number two in total gate arrays with an exclusive MOS product line. Motorola is climbing fast with a mixed bipolar and MOS product line in which its combined 1985 revenues grew 126 percent over 1984. The next seven suppliers are in a close race for position. The top ten suppliers share 61 percent of the total available market.

More detailed listings of supplier revenues can be found in the SIS Product and Markets binder, behind the ASIC tab.

Table 2

ESTIMATED 1985 WORLDWIDE GATE ARRAY SHIPMENT REVENUES--MOS
(Millions of Dollars)

Rank	Company	Revenue
1	LSI Logic Corp.	$135.0
2	Fujitsu	101.3
3	Toshiba	45.6
4	NEC	42.8
5	Seiko	33.8
6	Gould-AMI	30.0
7	Hitachi	29.1
8	Hughes	19.2
9	RCA	19.0
10	Motorola	15.0
Total		$470.8

Table 3

ESTIMATED 1985 WORLDWIDE GATE ARRAY SHIPMENT REVENUES--BIPOLAR
(Millions of Dollars)

Rank	Company	Revenue
1	Fujitsu	$156.3
2	Motorola	76.2
3	Fairchild	55.0
4	Honeywell	50.0
5	Ferranti Elect.	49.7
6	Signetics	28.8
7	TI	27.5
8	Siemens	23.4
9	Ferranti Interdesign	23.0
10	Applied Micro Circuits Corporation	21.0
Total		$510.9

Source: DATAQUEST
January 1986

MOS Gate Arrays

LSI Logic maintained its number one position in MOS gate arrays with a healthy 60 percent growth in sales compared to 1984. LSI Logic's capture of a large number of designs and design revenue contributed to its successful year. Fujitsu, Toshiba, and NEC are frontrunners among the Japanese companies that are gaining market share. Four of the top five MOS suppliers are Japanese companies. The top ten MOS suppliers listed in Table 2 comprised 64 percent of the total available 1985 MOS market.

Bipolar Gate Arrays

The ECL gate array market continues to flourish while the TTL market fades. There was a heated race to become the top 1985 supplier in the $292 million ECL market. Fujitsu, Motorola, Fairchild, and Honeywell all had 1985 sales of more than $50 million in ECL arrays and all plan major growth in 1986. Ferranti Electronics (European-based), and Ferranti Interdesign (Scotts Valley, California), continue to dominate the linear array and mixed linear digital array market with a combined market share of 52 percent of the 1985 $103.2 million market. The top ten suppliers listed in Table 3 comprise 82 percent of the total available market. It is interesting to note that only one of the bipolar top ten is a Japanese company.

GATE ARRAY GROWTH IN A DOWN IC MARKET

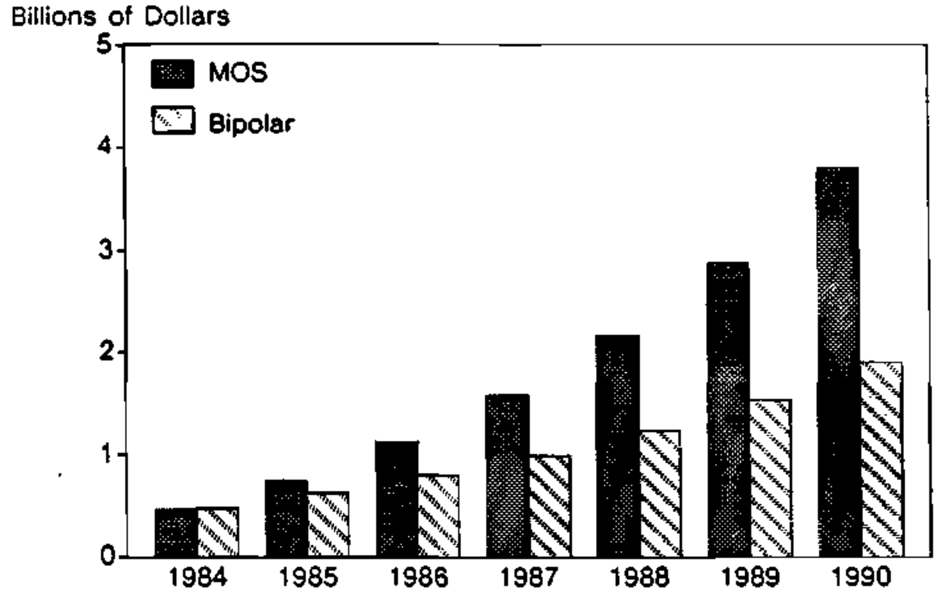
Astonishing Results

The worldwide gate array market has captured the attention of all IC manufacturers with a surprising 1985 growth rate of 45.5 percent while the total worldwide IC market dropped 18 percent from 1984. Furthermore, 1985 MOS gate array revenues grew 60 percent compared to 1984. The bipolar gate array market also had a healthy 31 percent growth rate in 1985. Figure 1 shows the growth of the MOS and bipolar markets. Table 4 indicates that the 1985 ECL market had a strong 39 percent growth rate from 1984, while the TTL market showed a modest increase of 14 percent. DATAQUEST expects the 1985 through 1990 CAGR for MOS and bipolar gate arrays will be 38.7 percent and 25.0 percent, respectively. Moreover, we believe that the factors contributing to these high growth rates will be:

- Increasing design starts
- Rising NRE revenues
- Captive suppliers going merchant
- Declining gate array pricing

Figure 1

ESTIMATED WORLDWIDE GATE ARRAY SHIPMENTS



Source: DATAQUEST
January 1986

Table 4

ESTIMATED WORLDWIDE GATE ARRAY SHIPMENTS BY TECHNOLOGY
(Millions of Dollars)

	1984	1985	1986	1987	1988	1989	1990
Total	$937.6	$1,363.8	$1,906.3	$2,567.5	$3,396.0	$4,406.8	$5,698.4
MOS Digital	$445.5	$ 722.9	$ 1092.1	$1,555.9	$2,135.4	$2,843.2	$3,755.9
Bipolar Digital	$400.7	$ 537.7	$ 695.6	$ 874.8	$1,101.9	$1,379.2	$1,727.4
TTL	133.7	152.3	170.6	184.2	193.4	187.6	174.5
ECL	209.7	291.9	399.9	543.9	728.8	976.6	1,308.6
Other	57.3	93.5	125.1	146.7	179.7	215.0	244.3
Linear	$ 91.4	$ 103.2	$ 118.7	$ 136.9	$ 158.6	$ 184.4	$ 215.1

Source: DATAQUEST
January 1986

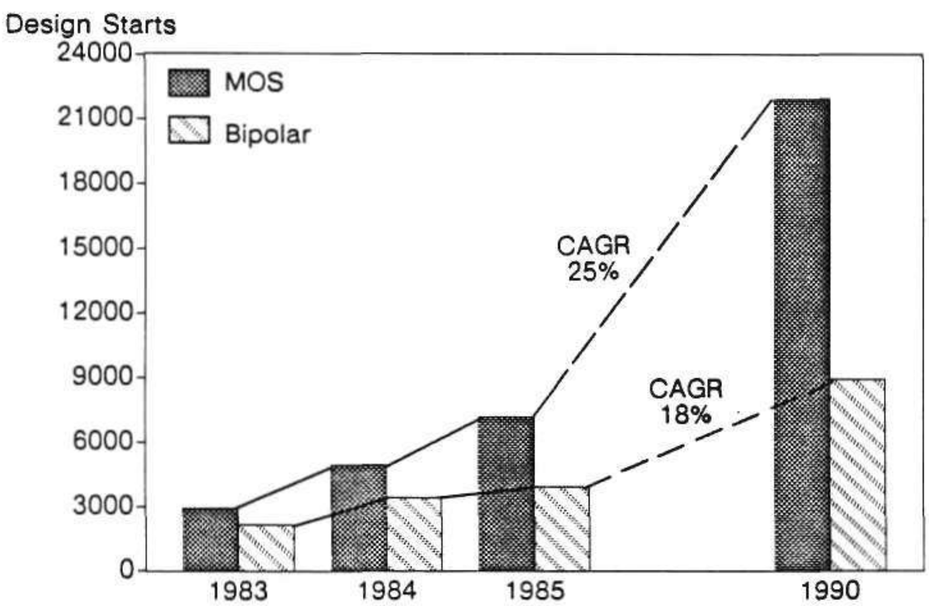
Increasing Design Starts

Design starts are a good leading indicator of future revenues. Figure 2 shows that 1985 worldwide gate array design starts grew 33 percent over the 8,357 starts captured in 1984. In 1985, MOS gate array design starts rose an astounding 45.8 percent over 1984, while bipolar design starts grew more modestly at 14.6 percent. DATAQUEST analysis indicates that the designs captured in 1985 will take an average of six months to one year to reach the production phase. Thus, high design revenues in 1985 will result in high production revenues in 1986. However, the percentage of designs that ultimately reach the production place can vary widely. Our analysis indicates that the percentage of designs that go into production for the industry ranges from 40 percent during a depressed semiconductor economy to 70 percent in a thriving semiconductor economy.

One reason for the rising number of design starts is that product life cycles have decreased from an industry average of four to five years in the early 1980s to the current three to four years.

Figure 2

ESTIMATED WORLDWIDE GATE ARRAY DESIGN STARTS



Source: DATAQUEST
January 1986

NRE Trends

The role of NRE charges is a little more difficult to see, but noteworthy. Four NRE trends need to be examined when analyzing the gate array market:

- Total NRE dollars
- Average NRE charge per design
- Average NRE charge per gate
- NRE as a percent of shipment revenue

Perhaps the most important trend is the rising total NRE revenue. In 1985, the total NRE gate array revenue grew 44.4 percent compared to the $243.3 million dollar base in 1984. The MOS NRE revenue increased an unbelievable 54.1 percent, while bipolar NRE revenue showed a more modest growth rate of 29.7 percent. This growth has been a major factor in the rising revenues of the gate array market.

An important measurement in determining design captures is the average NRE charge per design. Table 5 shows the growth of the industry average NRE charge for 1983 through 1985.

Table 5

AVERAGE NRE CHARGES PER DESIGN
(Thousands of Dollars)

	1983	1984	1985
MOS	$26.9	$29.6	$31.3
Bipolar	$26.6	$28.4	$32.1

Source: DATAQUEST
January 1986

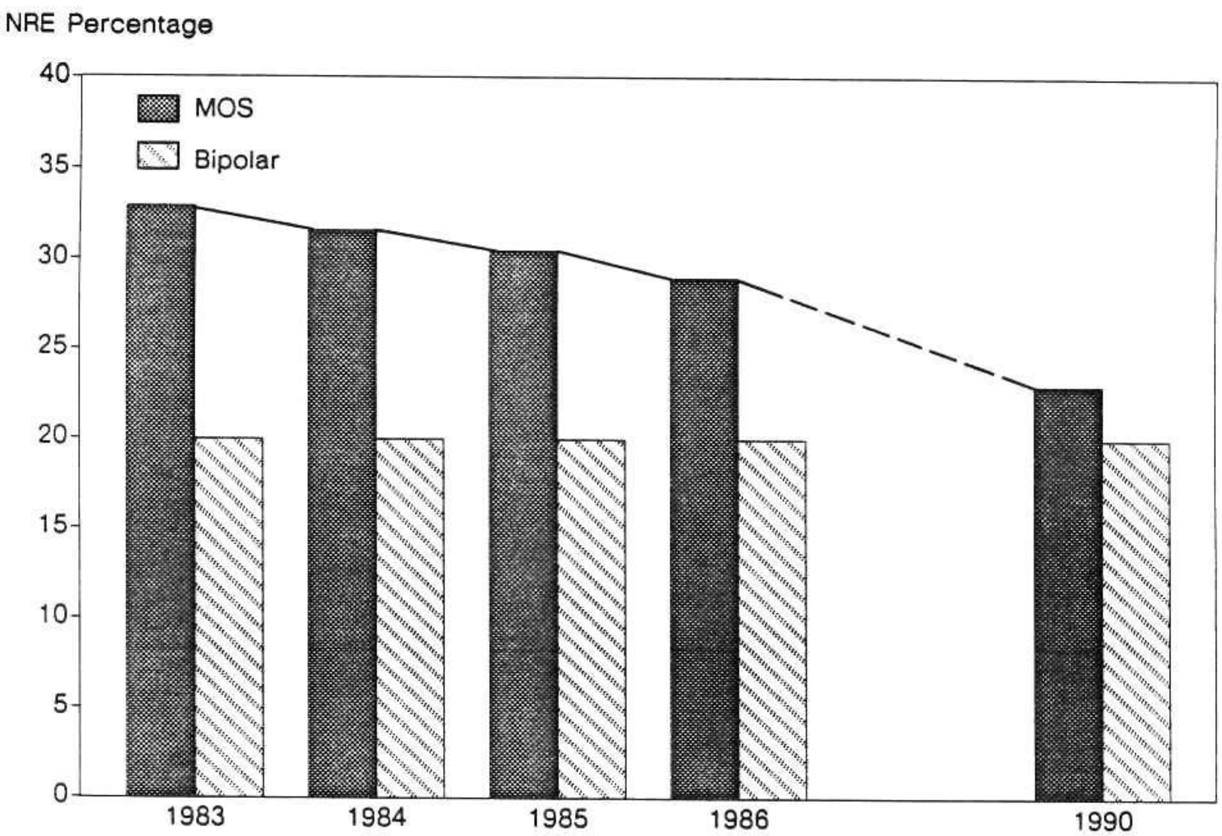
Despite better CAD tools and the user's increased capability, the average NRE charge per design is increasing due to the increasing complexity per design.

While the average NRE charge per design trend is important, perhaps more important is the average NRE charge per gate. Better performance CAD tools and experience curve cost reductions have lowered the average NRE per gate. Thus the cost of designing a given array over time has dropped, which has increased their overall cost effectiveness.

Another interesting way to look at NRE is on an industry-wide basis. While looking at it this way does not contribute to the overall growth of the gate array market, it does show how the role of NRE is changing over time. As shown in Figure 3, the total NRE as a percentage of total gate array revenue is decreasing and we expect it to continue to do so. This trend can be accounted for by examining the MOS segment. Our long-range forecast indicates that MOS NRE as a percent of total MOS gate array revenue is declining 1 percent to 2 percent per year, and should stabilize at 20 percent in seven to ten years when the market reaches maturity. The bipolar market, however, appears to have reached maturity and is holding constant with 20 percent NRE.

Figure 3

ESTIMATED WORLDWIDE NRE REVENUE
AS A PERCENT OF GATE ARRAY SHIPMENT REVENUE



Source: DATAQUEST
January 1986

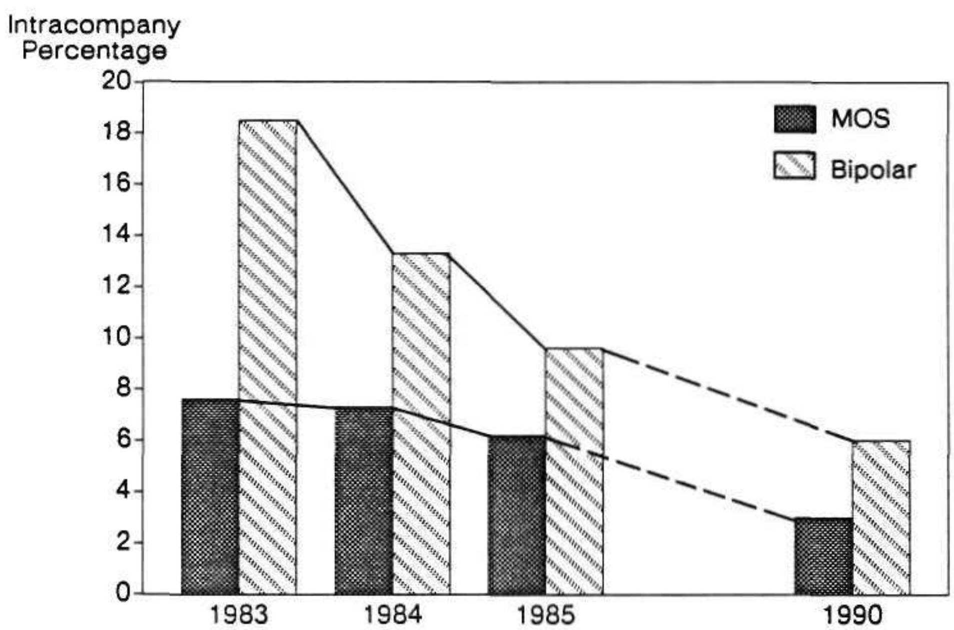
Captive Suppliers Going Merchant Expands the Market

Captive IC manufacturers with internally developed gate arrays and extra fab capacity historically have taken their arrays to the merchant market. Honeywell is the most recent example of a large ECL gate array manufacturer going merchant with its products. As more captive suppliers go merchant, the dollar value of gate array shipments will continue to rise.

Part of DATAQUEST's forecasts of dollar shipments growth is due to our way of measuring sales for companies that offer product to their own divisions as well as to the merchant marketplace. If a captive supplier goes merchant with its arrays, shipments are then equal to merchant sales plus intracompany sales. Figure 4 shows the derived trends of intracompany revenue as a percent of shipment revenue.

Figure 4

ESTIMATED WORLDWIDE INTRACOMPANY REVENUE AS A PERCENT OF WORLDWIDE GATE ARRAY SHIPMENT REVENUE



Source: DATAQUEST
January 1986

Declining Price per Gate Fuels Growth

The price per unit is difficult to estimate because prices vary widely due to technology, gate count, and packaging configurations. Thus, a CMOS 2000 gate device may sell for as low as $3.00 in high quantities, while an ECL 2500 gate device may sell for approximately $170. A better way to monitor gate array pricing is on a price per gate basis.

Analysis of a typical low gate count gate array against standard SSI/MSI logic shows a widening price differential over the past year. This difference is attracting more and more users to try gate arrays. The most popular gate arrays (CMOS, 2000 gates, plastic package, in quantities of thousands), took a sharp price per gate drop from between $0.01 and $0.012 in 1984, to between $0.002 and $0.004 in 1985. Higher gate count CMOS devices took a much smaller drop. The ECL gate arrays took only an estimated 15 percent drop. Price decreases did occur in gate arrays, but not equally across all the product lines. Standard SSI/MSI logic, which historically has been the most common alternative solution, also has experienced some price erosion, but remains fairly constant at $0.02 to $0.04 a gate.

The cost effectiveness of gate arrays is quite apparent, and has added fuel to the explosive gate array market.

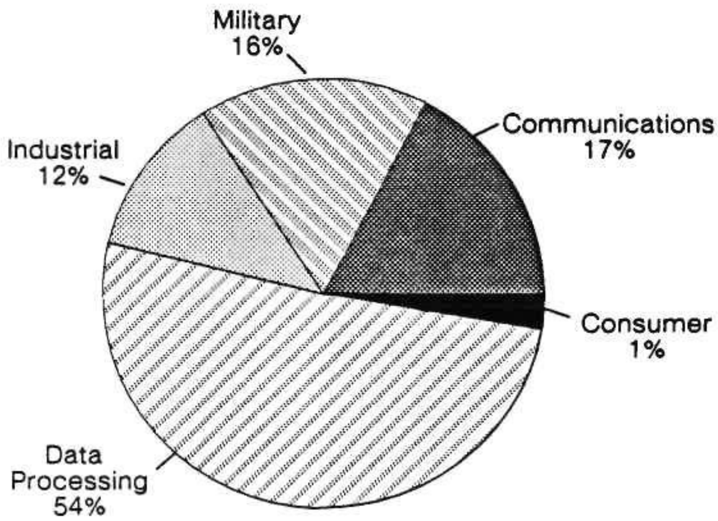
WHERE ARE ALL THESE GATE ARRAYS GOING?

According to DATAQUEST's Semiconductor Application Markets (SAM) Service, the largest user of gate arrays in North America is the Electronic Data Processing (EDP) market segment, followed by the communications and military segments. Mainframe and superminicomputers consume large quantities of high-performance ECL arrays. Key consumers of these high-performance arrays include IBM, Digital Equipment Corporation, Amdahl, CDC, Cray, and Honeywell. Applications within the communications sector include local area networks (LANs), public broadcast communications (PBCs), satellite communications, digital switching, and multiplexing. Products within the industrial category that use gate arrays include logic analyzers, oscilloscopes, automatic test equipment, medical diagnostic devices, and commercial aviation products. There are many military applications in North America. The 1984 consumer sector is at 1 percent because the majority of consumer products now come from the Asian Pacific basin. Figure 5 shows 1984 North American consumption by application market.

North American end-use consumption in 1985 was similar to that of 1984, with the exception of a decrease in the data processing and communications sectors, which shifted to the military sector. In 1986, end-use market percentages should shift back toward those of 1984 due to the expected resurgence in the data processing and telecommunications sectors.

Figure 5

ESTIMATED 1984 NORTH AMERICAN GATE ARRAY CONSUMPTION
BY APPLICATION MARKET



1984 $482 Million

Source: DATAQUEST
January 1986

DATAQUEST ANALYSIS

Who Will Prosper?

DATAQUEST is currently tracking 67 MOS gate array suppliers and 44 bipolar suppliers. The gate array market is experiencing substantial growth, which, in turn, has expanded the number of suppliers. Will the market support this many suppliers in the future? We suggest that a series of fallouts will occur over the next three years. To survive these fallouts, suppliers will have to adjust to a series of critical trends involving:

- Strategic alliances
- Products
- Marketing channels
- Customer service

An increasing number of companies are forming strategic alliances through legal agreements. These agreements are occurring on a multinational level as well as intracountry. The agreements range from two North American companies forming a second-source agreement on an array to a multinational joint-venture agreement such as the one between LSI Logic and Kawasaki Steel.

Suppliers offering increasingly complex products are being rewarded with higher profit margins. While most of today's revenue in gate arrays is generated in the low gate count segment (less than 3,000 gates), where margins are very thin or absent, the real future growth is expected in high gate count devices. Most suppliers appear to be migrating to more complex arrays where margins are believed to be wider. However, these higher gate count products require very costly advanced technology that only a few suppliers can afford.

Most gate array suppliers are using a mix of direct sales, design centers, and distributors to market products to the wide variety of users. Each sales channel is focused according to the unit volumes being purchased. These channels need to be well oiled and scaled to suit the end market. The proper mix can vary widely, depending on the end user. Military users require completely different channels from large OEM computer manufacturers. It is this diversity that will tax the resources of the most astute suppliers.

Gate array consumers are using customer service as a key criteria when evaluating suppliers. When there is a large number of suppliers all offering a host of similar products, service becomes the issue.

Will There Be More of the Same in 1986?

The answer is yes and no. Both the gate array and IC markets will grow. DATAQUEST has forecasted that the worldwide total gate array market will grow 39.8 percent and the worldwide IC market will rise 11 percent. These percents may even be conservative.

Furthermore, we expect 1986 to be a good year for gate array suppliers who have done their research. Namely, selecting the appropriate technologies, capturing the right designs, selecting the proper marketing channels, and choosing the right alliances. The market will reward the suppliers, that have positioned themselves for growth. We expect a handful of suppliers to increase their market share. For suppliers who are not in the top ten, the future is not as clear. They must decide which role to play: to be a major supplier or become a niche supplier. Each role requires a completely different set of resources, strategies, and technologies.

Bryan G. Lewis
Andrew M. Prophet

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RESEARCH BULLETIN

SIS Code: 1986-1987 Newsletters, January
1986-2

1985 MICROPROCESSOR REVIEW

Based on estimated microprocessor, microcontroller, and microperipheral shipments for the first three quarters of 1985, DATAQUEST reviews the year's micro industry activity below.

- The estimated 1985 revenue for total micro devices was $2,498 million. Micro device revenue was down approximately 22 percent in 1985 from 1984's revenue of $3,217 million.

- Micro devices were down 22 percent versus 28 percent for the total semiconductor industry, so micros are still holding the traditional pattern of having a higher growth rate than ICs.

- The year 1985 was the first time micro units or dollars had a decline from the previous year.

- For the first time, 16-bit microprocessor revenue was higher than 8-bit revenue, even though only 14 percent of all microprocessors shipped during 1985 were 16-bit.

- Eight-bit microprocessors may appear to have reached their peak due to the severe decline in unit and dollar shipments in 1985. However, 8-bit MPUs' lives will be extended due to high integration of I/O functions.

- Microcontrollers were not as affected by the 1985 recession as other areas were. Unit shipment volumes remained relatively flat from 1984 shipments.

- High growth areas during the year were 32-bit microprocessors and 16-bit microcontrollers.

MICROPROCESSORS

Table 1 summarizes unit shipments and revenue for microprocessors from 1983 through 1985.

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Table 1

UNIT SHIPMENTS AND REVENUE FOR MICROPROCESSORS, 1983 THROUGH 1985 (Millions)

	1983	1984	1985	Percent Change 1984-1985
8-Bit MPU Units	68.1	75.5	48.4	(35.9%)
8-Bit MPU Revenue	$221.3	$306.4	$178.0	(41.9%)
16-Bit MPU Units	7.1	10.0	7.9	(21.0%)
16-Bit MPU Revenue	$101.4	$289.0	$239.0	(17.3%)
32-Bit MPU Units	0.0	0.0	0.1	900.0%
32-Bit MPU Revenue	$ 1.6	$ 1.2	$ 16.8	1,300.0%
Total Units	75.2	85.5	56.4	(34.0%)
Total Revenue	$324.3	$596.6	$433.8	(27.3%)

Source: DATAQUEST
January 1986

MICROCONTROLLERS

Table 2 summarizes unit shipments and revenue for microcontrollers from 1983 through 1985.

Table 2

UNIT SHIPMENTS AND REVENUE FOR MICROCONTROLLERS, 1983 THROUGH 1985 (Millions)

	1983	1984	1985	Percent Change 1984-1985
4-Bit MCU Units	172.0	193.4	180.4	(6.7%)
4-Bit MCU Revenue	$258.0	$ 475.9	$ 383.0	(19.5%)
8-Bit MCU Units	92.7	164.4	161.3	(1.8%)
8-Bit MCU Revenue	$273.5	$ 935.2	$ 722.0	(22.8%)
16-Bit MCU Units	0.1	0.1	0.2	100.0%
16-Bit MCU Revenue	$ 1.1	$ 0.6	$ 4.0	567.0%
Total Units	264.8	357.9	341.9	(4.5%)
Total Revenue	$532.6	$1,411.7	$1,109.0	(21.4%)

Source: DATAQUEST
January 1986

Janet Rey-Oncel

Dataquest
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RESEARCH NEWSLETTER

SIS Code: 1986-1987 Newsletters: January
1986-1

**1985 PRELIMINARY MARKET SHARE
DATA REVEALS SHAKE-UP AT THE TOP**

The depressed 1985 semiconductor market had a severe impact on major world suppliers. Regional sales varied dramatically in 1985--while U.S. sales were down 28 percent, Japanese and European sales declined only about 2 percent. The regional company base largely determined the strength or weakness of company sales, since the bulk of sales appear in the home base region. Thus, the depressed U.S. market negatively affected the U.S.-based companies. From a market rank standpoint, Japanese and European suppliers did well. Almost all of these suppliers moved up in rank, with the exception of companies that are strongly entrenched in MOS memory, which was severely hit worldwide.

1985 MARKET SUMMARY

Tables 1 through 6 rank the top 50 major worldwide suppliers by total semiconductor, integrated circuits, bipolar, MOS, linear, and discrete/opto product areas. In each instance, these suppliers accounted for at least 90 percent of the total world market and thus give a good preliminary snapshot of 1985. These tables indicate that the linear and discrete/opto markets declined 3.7 percent and 6.8 percent, respectively. Bipolar and MOS technologies declined 21.4 and 22.6 percent, respectively. The total market registered a 16.4 percent decline in 1985. Suppliers with market presence in the discrete and linear areas were generally better off than their peers with pure IC mixes.

SEMICONDUCTOR MARKET SHARE

Most notable among our semiconductor market share findings is NEC's rise to number one. Throughout DATAQUEST's history, Texas Instruments had always maintained its number one position. TI lost market share in 1985 because, from a geographical and applications standpoint, it had a large percentage of sales in weak markets; for example, TI's memory

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market was focused on computers. In contrast, Motorola's broad product mix and strength in discrete products worked to its advantage in 1985, holding it in second place. Coupling Signetics with its parent, Philips, places a European company in the top ten. A strong presence in the weak U.S. market, however, caused this pair's ranking to remain flat in contrast to that of many other European companies. Intel maintained its position at number eight, while National fell to ninth place worldwide. AMD also dropped in ranking, from eleventh to twelfth place. RCA maintained its position in seventeenth place. RCA's strength can be attributed to its large presence in discrete products and the solid-end markets of automotive and telecommunications. Our ranking of the top 50 worldwide semiconductor suppliers follows in Table 1.

IC MARKET SHARE

In integrated circuits, Texas Instruments continues to hold the top position, and NEC remains number two. In fact, the top four positions remain unchanged relative to 1984. Slippage can be noted, however, in the top ten by National and Philips/Signetics, and AMD barely retained its position in tenth place. Aggressive position moves of five or more ranks may be noted for LSI Logic, Plessey, VLSI Technology, Samsung, Telefunken, Siliconix, Sprague, and Honeywell. Please reference the 1985 World IC Market Share Rankings shown in Table 2.

BIPOLAR MARKET SHARE

TI retains its lead in bipolar by more than a two-to-one margin over Motorola, although Motorola moved up to second place. Fairchild also moved up to fourth place in bipolar, while MMI jumped two rank positions to number 7. Further down in the listing, SGS gained five rank positions, moving to number 18. The bipolar market share ranking follows in Table 3.

MOS MARKET SHARE

In the MOS market area, the strongest performance came from companies based abroad. Companies focusing on the relatively strong automotive and telecommunications end markets fared well, as did companies supplying gate arrays in the MOS logic area. The world MOS memory product area dropped about 38 percent in 1985, and companies supplying these products fell dramatically in ranking.

NEC maintained the top position in MOS technology, followed by Intel, which beat Hitachi for second place. Many minor ranking changes were made throughout the listing, as shown in Table 4. Very remarkable ranking gains were made by LSI Logic, VLSI Technology, Samsung, Matra-Harris, and Plessey. All of these companies moved up five or more positions.

LINEAR MARKET SHARE

In the linear market area, National maintains the lead, although its margin over TI, the number two participant, is small. Motorola and Philips/Signetics dropped down in the top ten ranking to six and eight respectively, as shown in Table 5. The total sales of the top 50 world suppliers for 1985 totaled $4.5 billion. This represents a 3.7 percent decline for the year. The top 50 suppliers represent about 96 percent of the total linear market.

DISCRETE/OPTO MARKET SHARE

Motorola continues to hold a lead of about $100 million over Toshiba, the number two discrete/opto supplier. Both Motorola and Toshiba, however, declined more than the sum of the top 50 suppliers. The rankings of the top nine companies remained unchanged, while Rohm moved into the tenth position. The total for the top 50 suppliers was $5.5 billion in 1985, down approximately 6.8 percent from 1984.

Definitions

DATAQUEST includes in its data semiconductor revenues from products shipped to nonsemiconductor segments of the same company where those products are initiated in the semiconductor group. These products are marked up as if they were sold on the merchant market. By using this definition, DATAQUEST seeks to account for true manufacturing capability of semiconductor suppliers. Because of our definition, we differ from publicly reported semiconductor sector data for companies such as Motorola. DATAQUEST includes hybrid circuits, if they are manufactured in the semiconductor group, and NRE costs affiliated with gate arrays.

DATAQUEST's Preliminary Market Share Service Section is currently being completed and will be available to all binder holders this month.

Barbara A. Van

Table 1

PRELIMINARY 1985 WORLD SEMICONDUCTOR MARKET SHARE RANKING
(Millions of Dollars)

1985 Rank	1984 Rank	Company	1984	1985	Percent Change
1	3	NEC	2251	1984	-11.9%
2	2	Motorola	2320	1850	-20.3%
3	1	Texas Instruments	2480	1766	-28.8%
4	4	Hitachi	2052	1671	-18.6%
5	5	Toshiba	1561	1459	-6.5%
6	6	Philips/Signetics	1325	1068	-19.4%
7	9	Fujitsu	1190	1020	-14.3%
8	8	Intel	1201	1020	-15.1%
9	7	National	1263	940	-25.6%
10	12	Matsushita	928	906	-2.4%
11	10	Mitsubishi	964	706	-26.8%
12	11	AMD	936	603	-35.6%
13	13	Fairchild	665	494	-25.7%
14	15	Sanyo	455	457	0.4%
15	16	Siemens	450	420	-6.7%
16	20	Sharp	354	329	-7.1%
17	17	RCA	402	325	-19.2%
18	22	Thomson	301	324	7.6%
19	19	Oki	362	307	-15.2%
20	21	SGS-Ates	335	300	-10.4%
21	18	General Instrument	362	280	-22.7%
22	25	ITT	250	270	8.0%
23	23	Harris	275	265	-3.6%
24	24	Rohm	252	250	-0.8%
25	26	Analog Devices	210	206	-1.9%
26	27	MMI	200	200	0.0%
27	30	Fuji Electric	176	173	-1.7%
28	33	Telefunken	161	170	5.6%
29	29	Sony	177	168	-5.1%
30	28	Hewlett-Packard	182	155	-14.8%
31	32	Sanken Electric	162	149	-8.0%
32	31	AMI	164	140	-14.6%
33	38	IR	115	128	11.3%
34	47	LSI Logic	84	125	48.8%
35	14	Mostek	467	125	-73.2%
36	35	TRW	142	120	-15.5%
37	36	General Electric	136	114	-16.2%
38	42	Siliconix	97	114	17.5%
39	40	Unitrode	106	104	-1.9%
40	49	Plessey	82	99	20.7%
41	41	Ferranti	105	98	-6.7%
42	57	Samsung	60	95	58.3%
43	39	Seiko Epson	115	93	-19.1%
44	46	NCR	85	90	5.9%
45	48	Sprague	84	87	3.6%
46	34	Inmos	146	85	-41.8%
47	44	Intersil	89	80	-10.1%
48	43	Raytheon	95	80	-15.8%
49	55	Honeywell	64	79	23.4%
50	53	VLSI Technology	69	78	13.0%
		Top 50 total	26507	22169	-16.4%

Source: DATAQUEST
January 1986

Table 2

PRELIMINARY 1985 WORLD IC MARKET SHARE RANKING
(Millions of Dollars)

1985 Rank	1984 Rank	Company	1984	1985	Percent Change
1	1	Texas Instruments	2373	1677	-29.3%
2	2	NEC	1838	1603	-12.8%
3	3	Motorola	1693	1298	-23.3%
4	4	Hitachi	1570	1236	-21.3%
5	6	Intel	1201	1020	-15.1%
6	9	Toshiba	1035	995	-3.9%
7	7	Fujitsu	1098	940	-14.4%
8	5	National	1203	892	-25.9%
9	8	Philips/Signetics	1090	808	-25.9%
10	10	AMD	936	603	-35.6%
11	13	Matsushita	592	595	0.5%
12	11	Mitsubishi	766	510	-33.4%
13	12	Fairchild	595	451	-24.2%
14	16	Sanyo	305	314	3.0%
15	15	Oki	343	289	-15.7%
16	18	Harris	275	265	-3.6%
17	19	SGS-Ates	263	240	-8.7%
18	17	RCA	303	235	-22.4%
19	22	Analog Devices	210	206	-1.9%
20	21	Siemens	230	205	-10.9%
21	20	Sharp	238	201	-15.5%
22	23	MMI	200	200	0.0%
23	24	Thomson	174	197	13.2%
24	25	AMI	164	140	-14.6%
25	26	General Instrument	162	140	-13.6%
26	29	ITT	125	140	12.0%
27	28	Sony	132	130	-1.5%
28	36	LSI Logic	84	125	48.8%
29	14	Mostek	467	115	-75.4%
30	32	Rohm	111	105	-5.4%
31	31	Seiko Epson	115	93	-19.1%
32	35	NCR	85	90	5.9%
33	38	Plessey	75	89	18.7%
34	27	Inmos	146	85	-41.8%
35	34	Ferranti	85	78	-8.2%
36	43	VLSI Technology	69	78	13.0%
37	40	Burr-Brown	71	75	5.6%
38	41	PMI	70	75	7.1%
39	62	Samsung	33	75	127.3%
40	37	Intersil	78	70	-10.3%
41	46	Telefunken	63	68	7.9%
42	49	Siliconix	54	66	22.2%
43	48	Sprague	57	60	5.3%
44	39	Raytheon	73	59	-19.2%
45	33	Zilog	88	59	-33.0%
46	59	Honeywell	37	57	54.1%
47	42	Standard Micro.	70	56	-20.0%
48	44	Western Digital	68	56	-17.6%
49	45	Silicon Systems	64	51	-20.3%
50	51	Mitel	50	50	0.0%
		Top 50 total	21227	17265	-18.7%

Source: DATAQUEST
January 1986

Table 3

PRELIMINARY 1985 WORLD BIPOLAR MARKET SHARE RANKING
(Millions of Dollars)

1985 Rank	1984 Rank	Company	1984	1985	Percent Change
1	1	Texas Instruments	1048	781	-25.5%
2	3	Motorola	456	381	-16.4%
3	2	Philips/Signetics	589	372	-36.8%
4	5	Fairchild	410	329	-19.8%
5	4	AMD	428	285	-33.4%
6	6	Fujitsu	305	267	-12.5%
7	9	MMI	200	200	0.0%
8	7	National	290	200	-31.0%
9	8	Hitachi	224	194	-13.4%
10	10	NEC	134	129	-3.7%
11	11	Mitsubishi	123	79	-35.8%
12	12	Harris	74	61	-17.6%
13	14	Honeywell	37	50	35.1%
14	13	Ferranti	46	49	6.5%
15	18	Siemens	35	41	17.1%
16	16	Toshiba	37	33	-10.8%
17	19	Plessey	27	30	11.1%
18	23	SGS-Ates	20	26	30.0%
19	22	Thomson	21	24	14.3%
20	15	Raytheon	37	23	-37.8%
21	17	Intel	35	22	-37.1%
22	20	Oki	25	22	-12.0%
23	24	AMCC	18	21	16.7%
24	21	Matsushita	22	21	-4.5%
25	25	Sanyo	18	18	0.0%
26	26	Rohm	15	15	0.0%
27	27	Rifa	9	9	0.0%
28	29	Interdesign	6	6	0.0%
29	28	Sony	8	5	-37.5%
30	34	Goldstar	1	4	300.0%
31	31	Matra-Harris	4	4	0.0%
32	30	Cherry	4	3	-25.0%
33	32	Fuji Electric	2	1	-50.0%
34	35	LSI Logic	1	0	-100.0%
35	33	Teledyne	2	0	-100.0%
		Top 35 total	4711	3705	-21.4%

Source: DATAQUEST
January 1986

Table 4

PRELIMINARY 1985 WORLD MOS MARKET SHARE RANKING
(Millions of Dollars)

1985 Rank	1984 Rank	Company	1984	1985	Percent Change
1	1	NEC	1414	1174	-17.0%
2	3	Intel	1166	998	-14.4%
3	2	Hitachi	1167	853	-26.9%
4	6	Toshiba	770	727	-5.6%
5	4	Motorola	967	685	-29.2%
6	7	Fujitsu	753	631	-16.2%
7	5	Texas Instruments	917	524	-42.9%
8	8	Mitsubishi	541	320	-40.9%
9	11	National	430	301	-30.0%
10	9	AMD	480	299	-37.7%
11	13	Matsushita	283	269	-4.9%
12	12	Oki	315	264	-16.2%
13	14	Philips/Signetics	266	228	-14.3%
14	15	Sharp	214	173	-19.2%
15	16	RCA	210	165	-21.4%
16	17	AMI	164	140	-14.6%
17	28	LSI Logic	83	125	50.6%
18	10	Mostek	467	115	-75.4%
19	19	General Instrument	132	111	-15.9%
20	23	Harris	105	111	5.7%
21	25	Thomson	93	107	15.1%
22	22	Seiko Epson	115	93	-19.1%
23	20	Siemens	126	92	-27.0%
24	29	ITT	80	90	12.5%
25	27	NCR	85	90	5.9%
26	24	SGS-Ates	102	88	-13.7%
27	18	Inmos	146	85	-41.8%
28	31	VLSI Technology	69	78	13.0%
29	33	Sanyo	67	68	1.5%
30	26	Zilog	88	59	-33.0%
31	30	Standard Micro.	70	56	-20.0%
32	32	Western Digital	68	56	-17.6%
33	48	Samsung	25	55	120.0%
34	36	Sony	51	49	-3.9%
35	21	Micron Technology	120	46	-61.7%
36	34	Rockwell	57	44	-22.8%
37	41	IDT	34	41	20.6%
38	43	Hughes	32	36	12.5%
39	42	Matra-Harris	33	36	9.1%
40	47	Plessey	26	35	34.6%
41	35	SEEQ	53	34	-35.8%
42	46	UMC	27	33	22.2%
43	39	Xicor	39	33	-15.4%
44	38	SSSI	40	30	-25.0%
45	45	IMP	28	27	-3.6%
46	44	ERSO	30	25	-16.7%
47	37	Fairchild	45	22	-51.1%
48	51	Eurosil	20	21	5.0%
49	52	MEDL	16	20	25.0%
50	54	Micropower Systems	15	20	33.3%
		Top 50 total	12644	9782	-22.6%

Source: DATAQUEST
January 1986

Table 5

PRELIMINARY 1985 WORLD LINEAR MARKET SHARE RANKING
(Millions of Dollars)

1985 Rank	1984 Rank	Company	1984	1985	Percent Change
1	1	National	483	391	-19.0%
2	2	Texas Instruments	408	372	-8.8%
3	4	Matsushita	287	305	6.3%
4	3	NEC	290	300	3.4%
5	7	Toshiba	228	235	3.1%
6	5	Motorola	270	232	-14.1%
7	8	Sanyo	220	228	3.6%
8	6	Philips/Signetics	235	208	-11.5%
9	9	Analog Devices	210	206	-1.9%
10	10	Hitachi	179	189	5.6%
11	11	SGS-Ates	141	126	-10.6%
12	13	Mitsubishi	102	111	8.8%
13	12	Fairchild	140	100	-28.6%
14	14	Harris	96	93	-3.1%
15	16	Rohm	91	85	-6.6%
16	17	Sony	73	76	4.1%
17	18	Burr-Brown	71	75	5.6%
18	19	PMI	70	75	7.1%
19	20	Siemens	69	72	4.3%
20	15	RCA	93	70	-24.7%
21	22	Thomson	60	66	10.0%
22	26	Siliconix	50	63	26.0%
23	23	Sprague	57	60	5.3%
24	28	Telefunken	50	55	10.0%
25	24	Intersil	55	53	-3.6%
26	21	Silicon Systems	64	51	-20.3%
27	30	ITT	45	50	11.1%
28	25	Mitel	50	50	0.0%
29	29	Sanken Electric	47	46	-2.1%
30	31	Fujitsu	40	42	5.0%
31	27	TRW	50	38	-24.0%
32	32	Raytheon	36	36	0.0%
33	33	Exar	35	35	0.0%
34	34	General Instrument	30	29	-3.3%
35	38	Sharp	24	28	16.7%
36	37	Fuji Electric	24	24	0.0%
37	39	Plessey	22	24	9.1%
38	36	Ferranti	27	23	-14.8%
39	44	Goldstar	10	22	120.0%
40	41	Linear Technology	16	22	37.5%
41	46	Samsung	8	20	150.0%
42	35	AMD	28	19	-32.1%
43	40	Interdesign	20	18	-10.0%
44	43	Micropower Systems	11	13	18.2%
45	42	Cherry	12	11	-8.3%
46	48	GTE Microcircuits	5	10	100.0%
47	49	KEC	5	8	60.0%
48	51	Solitron	4	8	100.0%
49	45	Unitrode	9	6	-33.3%
50	47	Holt	7	5	-28.6%
		Top 50 total	4657	4484	-3.7%

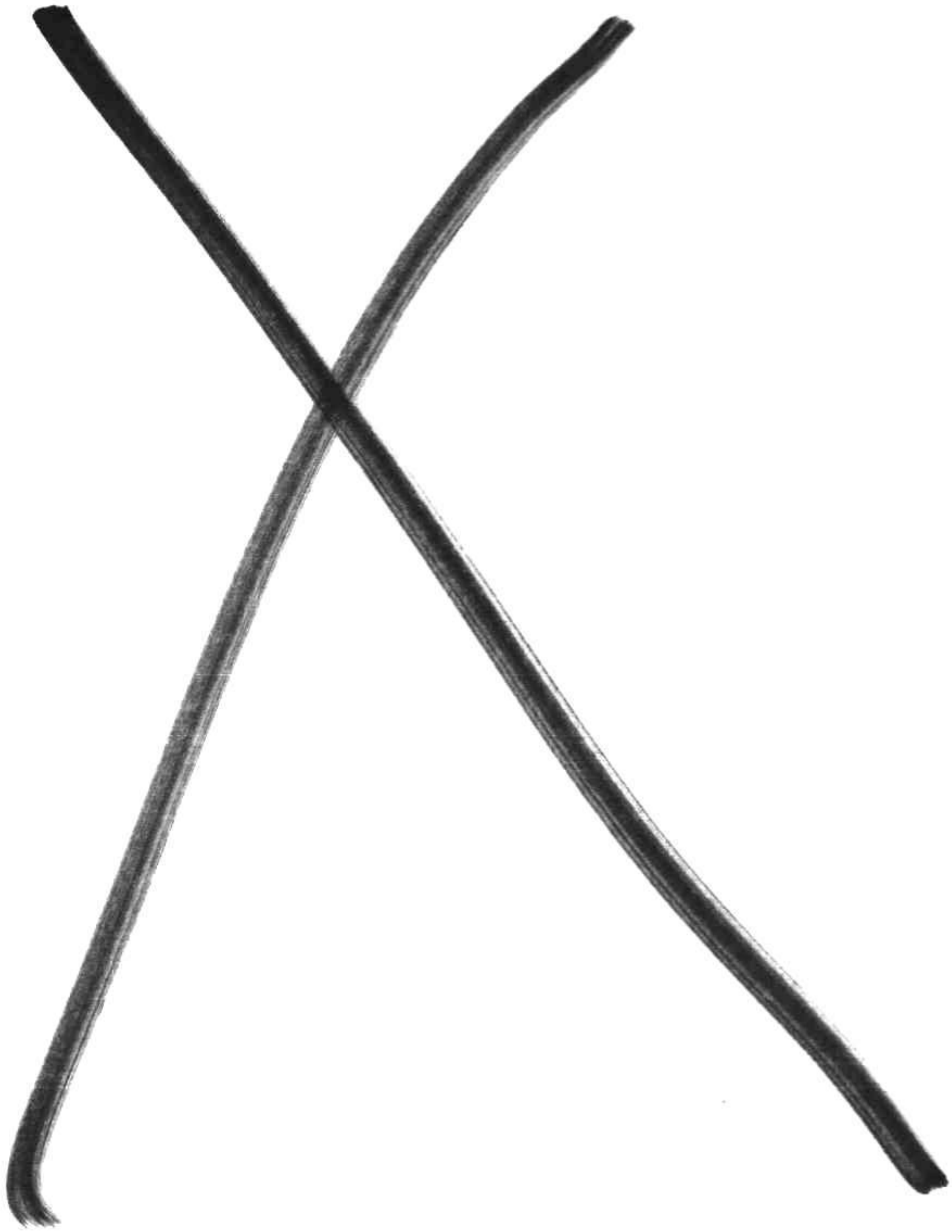
Source: **DATAQUEST**
January 1986

Table 6

PRELIMINARY 1985 WORLD DISCRETE/OPTO MARKET SHARE RANKING
(Millions of Dollars)

1985 Rank	1984 Rank	Company	1984	1985	Percent Change
1	1	Motorola	627	552	-12.0%
2	2	Toshiba	526	464	-11.8%
3	3	Hitachi	482	435	-9.8%
4	4	NEC	413	381	-7.7%
5	5	Matsushita	336	311	-7.4%
6	6	Philips/Signetics	235	260	10.6%
7	7	Siemens	220	215	-2.3%
8	8	Mitsubishi	198	196	-1.0%
9	9	Hewlett-Packard	182	155	-14.8%
10	13	Rohm	141	145	2.8%
11	11	Sanyo	150	143	-4.7%
12	12	Fuji Electric	144	142	-1.4%
13	10	General Instrument	181	140	-22.7%
14	16	ITT	125	130	4.0%
15	18	IR	115	128	11.3%
16	17	Sharp	116	128	10.3%
17	15	Thomson	127	127	0.0%
18	14	General Electric	132	112	-15.2%
19	19	Sanken Electric	115	103	-10.4%
20	22	Telefunken	98	102	4.1%
21	23	Unitrode	97	98	1.0%
22	21	RCA	99	90	-9.1%
23	20	Texas Instruments	107	89	-16.8%
24	25	TRW	92	82	-10.9%
25	24	Fujitsu	92	80	-13.0%
26	26	SGS-Ates	72	60	-16.7%
27	29	Westinghouse	52	49	-5.8%
28	28	National	60	48	-20.0%
29	32	Semikron	40	48	20.0%
30	31	Siliconix	43	48	11.6%
31	27	Fairchild	70	41	-41.4%
32	30	Sony	45	38	-15.6%
33	33	KEC	33	34	3.0%
34	34	Solitron	31	30	-3.2%
35	39	Brown-Boveri	25	29	16.0%
36	37	Sprague	27	27	0.0%
37	41	Acrian	21	23	9.5%
38	35	Honeywell	27	22	-18.5%
39	38	Varo	27	22	-18.5%
40	40	Raytheon	22	21	-4.5%
41	42	Ferranti	20	20	0.0%
42	36	Samsung	27	20	-25.9%
43	44	Oki	19	18	-5.3%
44	43	TAG	20	18	-10.0%
45	45	MEDL	15	15	0.0%
46	47	Asea-Hafo	9	10	11.1%
47	46	Intersil	11	10	-9.1%
48	49	Piher	6	10	66.7%
49	48	Plessey	7	10	42.9%
50	51	Supertex	3	4	33.3%
		Top 50 total	5882	5483	-6.8%

Source: **DATAQUEST**
January 1986



February Newsletters

The following is a list of the newsletters in this section:

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(continued)

February Newsletters

Dataquest
a company of The Dun & Bradstreet Corporation

RESEARCH NEWSLETTER

SIS Code: 1986-1987 Newsletters, February
1986-11

WORLD CONSUMPTION UPDATE: WORLD SEMICONDUCTOR CONSUMPTION REBOUNDS IN 1986

WORLD OVERVIEW

In 1985, semiconductor sales were down sharply in all major regions of the world. Of the four major regions--North America, Japan, Europe, and Rest of World (ROW)--North American sales showed the strongest decline at 27.0 percent. DATAQUEST believes that the worst is behind us, however. We expect growth in the first quarter of 1986 in all world regions, including North America. This projected first quarter growth should point the industry on the way to recovery and allow it to realize world growth of 16.4 percent in 1986. We believe that 1987 will be an exceptional year in all regional markets, with the world averaging 32.6 percent growth.

JAPAN BECOMES THE LARGEST MARKET

Our regional forecast points to some startling news in market size. As shown in Table 1, the Japanese market is projected to exceed the North American market in 1986.

Table 1

REGIONAL GROWTH RATES AND MARKET SHARE
(In Percent)

	Yearly Growth			Market Share		
	1985	1986	1987	1985	1986	1987
North America	(27.0%)	10.8%	34.9%	38.8%	36.9%	37.5%
Japan	(2.8)	28.4	30.6	34.8	38.4	37.8
Europe	(3.6)	6.3	29.8	18.7	17.1	16.7
ROW	(16.6)	14.7	37.1	7.7	7.6	8.0
Total	(15.0%)	16.4%	32.6%	100.0%	100.0%	100.0%

Source: DATAQUEST
February 1986

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The U.S. market is expected to pick up some share again in 1987, although it is not expected to recover its former status. Note that much of the growth that Japan realizes in 1986 is due to currency exchange. Japan gains about 19.0 percent merely from currency exchange because of a strengthening yen to dollar. Our forecast also indicates that European consumption will decline as a percentage of the total between 1985 and 1987. The European market, however, gained considerable market share in 1985 relative to its 1984 level. That market is actually leveling to a normal growth cycle. Our data also indicate that the ROW region will grow slightly to 8.0 percent in 1987.

END MARKETS KEY TO MARKET STRENGTHS AND WEAKNESSES

The severity of regional market declines in 1985 was determined largely by each region's end-market focus. The computer/data processing market was exceptionally weak and, consequently, hurt those markets focusing heavily on this area. More stable were the applications areas of consumer electronics and telecommunications.

North America/U.S. Market

With a heavy 40 percent emphasis on computers, the North American market witnessed the most severe decline of all regional markets. The U.S. market noted a sales decline of 27.0 percent. Key to the weakness of the computer market was the computer OEMs' misjudgement of actual consumption. A buying/production cycle was created at the computer level that impacted component suppliers. Inventory in 1984 was accumulated far in excess of actual needs. This inventory is now perceived to be leveling to a more normal volume, which will lead to steady booking and shipment activity. Booking and shipment levels appear to be correcting in many product areas. It is this expectation that points to a 3.9 percent North American market growth in the first quarter of 1986. DATAQUEST believes that normal inventory depletion will continue the quarterly growth pattern through 1986, for a yearly total of 10.8 percent. In 1987, we expect quarterly growth to continue. We believe that 1987 will be a year of strong growth (34.9 percent) in the U.S. market. In terms of levels of consumption, however, it is not until 1987 that we expect consumption to return to the level of 1984.

Japanese Market

The Japanese market was among the more favorable in terms of the 1985 market decline. A heavy emphasis on consumer applications was largely responsible for this stability. DATAQUEST identifies the sales decline in the Japanese market at a modest 2.8 percent in 1985. As stated earlier, we expect the Japanese market to surpass the U.S. market in dollar volume in 1986. The exchange rate is responsible for a good portion of this increase. In yen, the Japanese market is expected to grow about 9.4 percent. Current exchange notes that the U.S. dollar is worth about 203 yen, down significantly from 1985's average of about 237 yen. Our current forecast, incorporating the yen valuation, shows the Japanese market growing 28.4 percent in 1986, far beyond the world average of 16.4 percent. In 1987, we expect Japanese market growth to be on a par with the world, at 32.6 percent.

European Market

With end-market focus primarily in the relatively stable and growing area of telecommunications, the European market was not as seriously affected as either the North American market or ROW market. The European market declined by approximately 3.6 percent in 1985. This modest decline allowed Europe to pick up market share relative to the world in 1985. It is expected, however, that this market share will revert to its normal level of about 16.6 percent (in 1984) of total sales. Note that Table 1 overstates Europe's market share because Europe gained over 2.0 percentage points in total market size in 1985. The decline in total percentage shown for years 1986 and 1987 brings Europe back to its 1984 market share of 16.6 percent.

ROW Market

The ROW region, like the Japanese market, focuses primarily on consumer-oriented products, a market that was relatively stable in 1985. Yet the ROW region also sees a large amount of activity from foreign and North American companies building computer equipment abroad. It is the balance of these factors that caused a market decline of 16.6 percent in 1985. As in other regions, we expect quarterly growth to be effective throughout 1986 and 1987. DATAQUEST projects ROW growth at 14.7 percent in 1986 and 37.3 percent in 1987.

WORLD PRODUCT TRENDS

In our quarterly world product forecast shown in Table 2, we project that MOS products will make a comeback in 1986. MOS and bipolar digital were the areas most strongly affected in 1985; both were down approximately 21 percent. The product area that noted the strongest decline, however, was MOS memory, which dropped about 36.3 percent worldwide. In this memory area, steep quarterly growth is required to pull it up from its 1985 trench. We believe that this growth is realistic and forecast that MOS memory will be up 12.0 percent in 1986. MOS microprocessor devices and MOS logic are also expected to show good growth that will continue to build momentum into 1987. Our estimated MOS technology growth in 1987 is a lofty 49.5 percent, raised through high recovery expectations for MOS memory and MOS micro devices. Bipolar products are also projected for growth, but they are not as dramatic in percentage terms as MOS digital products. Other product areas of linear, discrete, and optoelectronics that did not decline severely in 1985 are not expected to ramp up as quickly as harder hit product areas.

Barbara A. Van
Howard Z. Bogert

Table 2

ESTIMATED WORLDWIDE QUARTERLY SEMICONDUCTOR CONSUMPTION
(Millions of Dollars)

	1985	Q1/86	Q2/86	Q3/86	Q4/86	1986	% CHG 1985-86
Total Semiconductor	24737	6354	6862	7389	8178	28783	16.4%
Total IC	18858	4751	5176	5642	6334	21903	16.1%
Bipolar Digital	3778	895	962	1053	1172	4082	8.0%
Memory	595	143	154	167	178	642	7.9%
Logic	3183	752	808	886	994	3440	8.1%
MOS Digital	10313	2551	2834	3147	3653	12185	18.2%
Memory	4008	903	1048	1186	1446	4583	14.3%
Micro Devices	2751	735	792	857	971	3355	22 0%
Logic	3554	913	994	1104	1236	4247	19 5%
Linear	4767	1305	1380	1442	1509	5636	18.2%
Discrete	4691	1258	1323	1370	1450	5401	15.1%
Optoelectronic	1189	345	363	377	394	1479	24.4%

	Q1/87	Q2/87	Q3/87	Q4/87	1987	% CHG 1986-87
Total Semiconductor	8657	9240	9827	10439	38163	32.6%
Total IC	6800	7339	7920	8439	30498	39.2%
Bipolar Digital	1233	1275	1302	1299	5109	25.2%
Memory	179	183	188	194	744	15.9%
Logic	1054	1092	1114	1105	4365	26.9%
MOS Digital	3973	4332	4746	5156	18207	49.4%
Memory	1584	1733	1928	2103	7348	60.3%
Micro Devices	1071	1192	1325	1467	5055	50.7%
Logic	1318	1407	1493	1586	5804	36.7%
Linear	1594	1732	1872	1984	7182	27.4%
Discrete	1445	1471	1468	1540	5924	9.7%
Optoelectronic	412	430	439	460	1741	17.7%

Source: DATAQUEST
February 1986

Dataquest
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RESEARCH NEWSLETTER

SIS Code: 1986-1987 Newsletters: March
1986-10

BIPOLAR MEMORY MARKET SHARES 1984 - 1985

MARKET SIZE

DATAQUEST estimates that worldwide bipolar memory revenues were $550 million in 1985. This is a 19 percent decrease from 1984 revenues of $675 million. Table 1 shows 1984 and 1985 revenues by product area.

Table 1

ESTIMATED WORLDWIDE BIPOLAR MEMORY REVENUES BY PRODUCT
(Millions of Dollars)

	1984	1985	Percent Change
Total Market	$675	$550	(19%)
Total RAM	$201	$195	(3%)
ECL RAM	114	125	10
TTL RAM	87	70	(20)
Total PROM	$441	$319	(28%)
ECL PROM	9	9	0
TTL PROM	432	310	(28)
Other Bipolar Memory	$ 33	$ 36	9%

Source: DATAQUEST
March 1986

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ECL RAM revenues were $125 million in 1985, up from $114 million in 1984. ECL RAMs were the only bipolar memory market that grew in 1985, with the exception of the "other" category, which includes FIFOs and shift registers. Both price stability and unit growth contributed to the ECL RAM revenue increase.

The TTL RAM market declined 20 percent in 1985, from $87 million in 1984 to $70 million. TTL RAM revenues have been gradually decreasing over the last several years, as users shift away from TTL RAMs toward ECL or CMOS SRAMs.

ECL PROM revenues were flat from 1984 to 1985. However, at $9 million, this is a very small part of the total market. There is some potential for growth in this market, although growth does depend on the introduction of new, higher-density and higher-priced devices. The existing devices are generally low density and therefore do not have very high ASPs, and demand is stable but not growing at tremendous rates.

TTL PROM revenues declined 28 percent in 1985, from $432 million to $310 million. The PROM market grew 41 percent in 1984, and will be growing for the next few years, but by 1988, DATAQUEST expects to see it begin to decline several percentage points a year as MOS devices replace bipolar PROMs in many applications.

Other bipolar memory, including FIFOs and shift registers, grew 9 percent, from $33 million in 1984 to $36 million in 1985. These devices are more application specific and have higher performance than PROMs or TTL RAMs. Therefore, they tend to be in more protected end markets, and pricing as well as demand is generally more stable.

MARKET SHARE BY REGION

Revenues of most companies declined during 1985. The companies participating in the ECL RAM market did better than those companies involved in the PROM market, because of the performances of those markets. Table 2 shows total bipolar memory market share by region in 1984 and 1985.

Table 2

ESTIMATED SHARE OF BIPOLAR MEMORY MARKET BY REGION
(Percent of Dollars)

	1984	1985
North America	58%	56%
Japan	23	29
Europe	19	15
Total	100%	100%

Source: DATAQUEST
March 1986

The U.S. manufacturers' share of the bipolar memory market declined from 58 percent to 56 percent in 1985. The U.S. decline is not just due to the significant U.S. presence in the weakened PROM market, but also to the fact that the U.S. suppliers do not have a significant portion of the high-ASP portion of the ECL RAM market: the dense, fast parts.

Since the Japanese suppliers dominate the ECL RAM market and do not have a large stake in the PROM market, the Japanese vendors increased their revenues and market share in 1985. The Japanese share went from 23 percent of the total bipolar memory market in 1984 to 29 percent in 1985.

The European suppliers went from 19 percent of the total market in 1984 to 15 percent in 1985. Most of the European revenues are attributable to Signetics. When Signetics is excluded from the totals, the European share of market went from 2 percent in 1984 to 3 percent in 1985, because of the revenue growth of Thomson.

MARKET SHARE BY COMPANY

Tables 3 and 4 show bipolar memory market share in 1984 and 1985 by company.

Table 3

1984 WORLDWIDE BIPOLAR MEMORY REVENUES
(Millions of Dollars)

Company	ECL RAM	TTL RAM	Total RAM	ECL PROM	TTL PROM	Total PROM	Other BIP MEM	Total Bipolar
Total Market	$114	$87	$201	$9	$432	$441	$33	$675
U.S. Companies	$ 17	$70	$ 87	$5	$269	$274	$32	$393
Advanced Micro Devices	3	36	39	0	88	88	3	130
Fairchild Semiconductor	5	22	27	2	10	12	1	40
Harris	0	0	0	0	44	44	0	44
Monolithic Memories	0	0	0	0	41	41	25	66
Motorola	5	5	10	3	9	12	0	22
National Semiconductor	4	3	7	0	21	21	0	28
Raytheon	0	0	0	0	10	10	0	10
Texas Instruments	0	4	4	0	46	46	3	53
Japanese Companies	$ 94	$ 1	$ 95	$0	$ 62	$ 62	$ 0	$157
Fujitsu	47	1	48	0	45	45	0	93
Hitachi	45	0	45	0	1	1	0	46
NEC	2	0	2	0	14	14	0	16
Others	0	0	0	0	2	2	0	2
European Companies	$ 3	$16	$ 19	$4	$101	$105	$ 1	$125
Matra-Harris	0	0	0	0	4	4	0	4
Philips/Signetics	1	16	17	3	90	93	1	111
Signetics	0	16	16	3	90	93	0	109
Siemens	1	0	1	1	0	1	0	2
Thomson Semiconductors	1	0	1	0	7	7	0	8

Source: DATAQUEST
March 1986

Table 4

1985 WORLDWIDE BIPOLAR MEMORY REVENUES
(Millions of Dollars)

Company	ECL RAM	TTL RAM	Total RAM	ECL PROM	TTL PROM	Total PROM	Other BIP MEM	Total Bipolar
Total Market	$125	$70	$195	$9	$310	$319	$36	$550
U.S. Companies	$ 13	$56	$ 69	$4	$195	$199	$36	$304
Advanced Micro Devices	2	27	29	0	56	56	2	87
Fairchild Semiconductor	3	20	23	2	7	9	1	33
Harris	0	0	0	0	33	33	0	33
Monolithic Memories	0	0	0	0	33	33	28	61
Motorola	3	3	6	2	4	6	0	12
National Semiconductor	5	3	8	0	16	16	0	24
Raytheon	0	0	0	0	11	11	0	11
Texas Instruments	0	3	3	0	35	35	5	43
Japanese Companies	$109	$ 1	$110	$0	$ 51	$ 51	$ 0	$161
Fujitsu	54	1	55	0	40	40	0	95
Hitachi	50	0	50	0	0	0	0	50
NEC	5	0	5	0	10	10	0	15
Others	0	0	0	0	1	1	0	1
European Companies	$ 3	$13	$ 16	$5	$ 64	$ 69	$ 0	$ 85
Matra-Harris	0	0	0	0	4	4	0	4
Philips/Signetics	2	10	12	4	50	54	0	66
Signetics	1	10	11	4	50	54	0	65
Siemens	1	0	1	1	0	1	0	2
Thomson Semiconductors	0	3	3	0	10	10	0	13

Source: DATAQUEST
March 1986

Vendor positions in the various markets are described below.

ECL RAMs

In the ECL RAM market, Fujitsu was the 1985 market leader, both in terms of revenues and technology. Hitachi was close behind in second place. NEC was the third-place Japanese supplier with $5 million in revenues and tied with National Semiconductor for third place worldwide. Fujitsu and Hitachi together owned 83 percent of the ECL RAM market in 1985. The U.S. vendors are far behind the two leading Japanese companies in ECL RAM revenues--the top U.S. supplier in 1985, National Semiconductor, sold $5 million into the world market, and Fairchild and Motorola each had revenues of $3 million.

TTL RAMs

In the TTL RAM market, the U.S. vendors supply almost all of the parts produced worldwide. AMD was the leading supplier and Fairchild the second-place supplier in 1985. Motorola announced in December that it plans to deliver its last TTL RAM on March 31, 1986.

ECL PROMs

The ECL PROM market is small and growing slowly. Fairchild, Motorola, and Signetics all produce devices that tend to be low density and fast. Siemens also produces some ECL PROMs in Europe, and AMD has indicated its intentions to enter this market with some higher-density devices.

TTL PROMs

U.S. suppliers have traditionally dominated the PROM market. Signetics was the leader in 1984, but AMD was right behind, having doubled its revenues between 1983 and 1984. In 1985, AMD was the largest supplier of PROMs, followed closely by Signetics.

Fujitsu was the third-place PROM supplier in 1985, just ahead of Texas Instruments. This was a reversal of the previous year, when Texas Instruments' revenues were slightly ahead of Fujitsu's.

Harris announced in 1985 that it would be withdrawing from the bipolar PROM market, so its revenues will continue to decrease over the next year or so. Motorola also announced in late 1985 that it would take orders for TTL PROMs only until December 31, 1985. It will stop production of TTL PROMs in March of this year.

Other Memory

Monolithic Memories was the leading supplier of bipolar memories other than RAMs and PROMs. Its $28 million in revenues in 1985 was largely FIFOs. AMD, Fairchild, and Texas Instruments also participated in this market.

Susan Scibetta

ADDENDUM TO NEWSLETTER:
BIPOLAR MEMORY MARKET SHARES
1984-1985

The following information refers to the Bipolar Memory Market Share newsletter, published March 1, 1986. This is to convey confidence levels on the numbers published in this newsletter. Most of these comments will be such that you can them give to clients without any problem.

OVERALL MARKET SIZE:

The following is a summary of the confidence levels of the data on total market sizes.

RAM market

ECL RAMs--high level of confidence. I feel these numbers are very accurate for 1984 and 1985.

TTL RAM-- moderate level of confidence. This is a bottoms-up estimate and has not been closely examined from a top-down level.

PROM market

ECL PROM--moderate level of confidence. This is a rough estimate. It's a small market, and thus hard to get a handle on. This is bottoms-up, looking at the three or four producers who make ECL PROMs.

TTL PROM--high level of confidence. I feel confident about the TTL PROM estimate. The 1985 number has been moved down a bit from the number published in the December 1985 newsletter. We published $320M then and currently feel the 1985 market was $310M. The "other bipolar" estimate has also been moved down from a few months ago. I think the original estimate was $44M in 1984 and higher than that in 1985, but we revised our estimates of the "other bipolar memory" numbers for Monolithic Memories, which is a big percentage of the total, and the number came down. I have a fairly high confidence level in "other bipolar memory."

COMPANY DATA

U.S. Companies

AMD--high level of confidence. There were some comments from AMD's competitors that their ECL RAM number look low, but according to AMD, $3M was as much as they shipped in 1984, and they shipped only $2M in 1985. They commented that they are trying very hard to get into the market, but they're not there yet, and they will be introducing a number of parts this year. AMD is the largest supplier of TTL RAMs. As far as PROMs go, I have a high level of confidence in the AMD number. They are rapidly gaining on Signetics as the largest supplier, and Signetics admits that AMD is growing by leaps and bounds. In the "other bipolar memory" area, it's really a SWAG. I wasn't able to get any confirmation from AMD, so I estimated their participation at a few million dollars, but it's not certain how accurate that number is.

Fairchild--moderate level of confidence. I did not get confirmation from Fairchild on these numbers. I discussed the PROM numbers with them back in October of 1985, so the 1984 number is reasonably accurate. The 1985 number is an estimate, based on the October conversations. The ECL and TTL RAM numbers were roughly confirmed, but we didn't get final confirmation. The "other bipolar memory" is a complete assumption. I know that they do have a small shift register and I gave them $1M in 1984 and $1M again in 1985, but it's a SWAG.

Harris--high level of confidence in 1984.
--low level of confidence in 1985. This was commented on by Harris, but was not confirmed with data.

Monolithic Memories--high level of confidence. Monolithic Memories has a fiscal year that ends in September or October. We are working on a calendar year, while their reporting is generally fiscal year, so there is a conversion factor there. But I think the PROM numbers are accurate, and the other bipolar memory number came directly from them, and I think it is a good indication, as they are by far the largest supplier of other memories, primarily FIFOs.

Motorola--moderate level of confidence. The Motorola numbers came directly from Motorola. They read me their numbers over the phone, and the ECL RAM numbers sounded low to a number of people--they were surprised, but people who are in touch with that market tell me that Motorola has not been doing that well recently, so it's not that hard to accept. The TTL RAM numbers are also a little bit low, but I have a fairly high level of confidence that those are in the ballpark. The PROM numbers for Motorola were also supplied by them, and they have been adjusted down since the PROM newsletter was published in December. The problem that I have with Motorola is that I am not very in touch with the extent of their product line, and what the revenue numbers would be looking at the market from a bottoms-up approach.

National Semiconductor--high level of confidence. National was very cooperative when we did the ECL RAMs study, and I have a high level of confidence in the ECL and TTL RAM numbers. The PROM numbers are somewhat lower than what National had estimated, but in looking at the total market, I had to move those numbers down just a little bit to reflect their participation as a percentage of the total market. They were still comfortable with the numbers.

Raytheon--high level of confidence.

Texas Instruments--moderate level of confidence. The TI numbers are primarily Dataquest estimates; some discussion with TI occurred. We got some confirmation of the PROM numbers, and I think they are pretty close to reality. The TTL RAM number was more of a guess, and we did not talk to anyone at TI about them. We were not able to reach the person who could confirm the TTL RAM data. The "other bipolar memory" number was confirmed by TI.

Japanese Companies

Fujitsu--high confidence in the U.S. segment.
--low level of confidence in Japanese segments (internal and external). The U.S. arm of Fujitsu has been very cooperative and we have a high level of confidence in the U.S. percentage of this number. Unfortunately, we were not able to get confirmation on the Fujitsu numbers from Japan, but we believe that a large percentage, (70% to 80%), of Fujitsu's sales are into the U.S. So, we have a fairly good handle on most of the market. The level of uncertainty is dependent on the percentage of Fujitsu's sales that are internal, and that are into Japan, because that is where we have the smallest level of confidence. I have a high level of confidence in the ECL RAM number. TTL RAMs is a guess. There is probably less than $1M in TTL RAMs, but there is some participation in that market to a small degree. I have a high level of confidence in the PROMs. There is much less internal usage of PROMs at Fujitsu than ECL RAMs.

Hitachi--moderate level of confidence in U.S. segment --low confidence levels in Japanese segments. Internal consumption and sales into Japan are also an unknown factor with Hitachi. We received some top level numbers from Hitachi that seemed very high. Those were adjusted down to match the bottoms up analysis that we did of the bipolar memory market. The percentage of Hitachi sales that go into the U.S. is a smaller percentage than for Fujitsu, so the level of uncertainty is somewhat higher. We have heard from a number of sources that Hitachi is probably about 10% below Fujitsu in terms of ECL RAM sales, so those numbers we feel confident about. The PROMs number is virtually non-existent, so it's really ECL RAMs that we're concerned with and that level of confidence is moderate.

European Companies

When we looked at the total European market, the number that we came up with was much lower than the ESIS estimate of the European bipolar memory market. This was using a bottoms up approach as well as taking the total markets and dividing them out by region. For this reason, a number of these company estimates were much lower than the ESIS numbers, but we've received confirmation on most of these from the European marketing managers.

Matra-Harris--low level of confidence. Matra-Harris participates in the PROM market only.

Philips--high level of confidence. Philips and Signetics are treated as one company in this newsletter, with Signetics broken out below. The Philips number came via RTC through the local Signetics office here in Santa Clara.

Siemens--moderate level of confidence.

Thomson Semiconductors--moderate level of confidence.

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RESEARCH NEWSLETTER

SIS Code: 1986-1987 Newsletters: February
1986-9

NOW THE GLIMMER OF HOPE BRINGS A SIGH OF RELIEF

SUMMARY

The semiconductor industry gave a collective sigh of relief as the January book-to-bill ratio rose above 1 for the first time in sixteen months. Not only does this confirm earlier DATAQUEST projections, it gives industry leaders much more confidence about a healthy year in 1986.

Although this forecast is slightly higher, the fundamentals remain unchanged from our December forecast. Even though the projected growth in North American semiconductor consumption is a modest 11 percent by industry standards, it belies the fact that growth from December of 1985 to December of 1986 will be 37 percent. With such robust growth rates, the industry will experience many of the conditions observed during the boom times of 1984. In fact, some of the following are already evident:

- Some product managers report that leading-edge product lines have had a book-to-bill greater than 1 for several weeks.
- Selected products have been on allocation for two or three months.
- Double ordering has already been detected by some marketing managers.
- "Some large customers want large quantities right now," was the comment by one product manager. Much of this demand appears to be for add-in boards to PCs. These customers may be repeating the mistakes of 1984 by overestimating the size of that market and overestimating their own participation.
- Prices of commodity products are rising rapidly.
- Part shortages are being predicted for later this year, especially those products that require 1.2-micron processes.

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THE FORECAST--ON-TRACK FOR GROWTH

Our forecast of North American semiconductor consumption for 1986 and 1987 is shown in Table 1.

Table 1

SEMICONDUCTOR FACTORY SALES INTO NORTH AMERICA
(Millions of Dollars)

	1985	Q1	Q2	Q3	Q4	1986
Total Semiconductor	$9,590	$2,293	$2,533	$2,731	$3,067	$10,624
Total IC	$7,693	$1,807	$2,008	$2.181	$2,470	$ 8,466
Bipolar	$2,000	$ 451	$ 487	$ 530	$ 487	$ 2,055
Memory	$ 315	$ 79	$ 84	$ 89	$ 94	$ 346
Logic	$1,685	$ 372	$ 403	$ 441	$ 493	$ 1,709
MOS	$4,236	$ 988	$1,135	$1,259	$1,467	$ 4,849
Memory	$1,774	$ 371	$ 435	$ 485	$ 585	$ 1,876
Micro	$1,195	$ 277	$ 327	$ 363	$ 432	$ 1,399
Logic	$1,267	$ 340	$ 373	$ 411	$ 450	$ 1,574
Linear	$1,457	$ 368	$ 386	$ 392	$ 416	$ 1,562
Discrete	$1,528	$ 381	$ 409	$ 427	$ 465	$ 1,682
Opto	$ 369	$ 105	$ 116	$ 123	$ 132	$ 476

	1986	Q1	Q2	Q3	Q4	1987
Total Semicondcutor	$10,624	$3,234	$3,467	$3,688	$3,940	$14,328
Total IC	$ 8,466	$2,664	$2,849	$3,034	$3,229	$11,776
Bipolar	$ 2,055	$ 620	$ 637	$ 646	$ 631	$ 2,534
Memory	$ 346	$ 97	$ 99	$ 102	$ 104	$ 402
Logic	$ 1,709	$ 523	$ 538	$ 544	$ 527	$ 2,132
MOS	$ 4,849	$1,608	$1,744	$1,898	$2,068	$ 7,318
Memory	$ 1,876	$ 660	$ 720	$ 797	$ 880	$ 3,057
Micro	$ 1,399	$ 462	$ 504	$ 544	$ 599	$ 2,109
Logic	$ 1,574	$ 486	$ 520	$ 556	$ 590	$ 2,152
Linear	$ 1,562	$ 437	$ 467	$ 491	$ 530	$ 1,925
Discrete	$ 1,682	$ 435	$ 470	$ 498	$ 543	$ 1,946
Opto	$ 476	$ 135	$ 148	$ 156	$ 168	$ 606

Source: DATAQUEST
February 1986

FORECAST COMPARISONS

A comparison of the current and previous forecasts for total semiconductor consumption is shown in Table 2. Our current forecast shows a slight uptick. The fact that the fourth quarter of 1986 has been lowered each time is not a prelude to a downturn in 1987, but merely reflects a shift to higher growth in the early quarters of 1986. Turns in business continue to strengthen the general business conditions. This effect will soon moderate, however, because manufacturers are depleting their inventories of finished goods.

Table 2

COMPARISON OF RECENT DATAQUEST FORECASTS
(Millions of Dollars)

Total Semiconductor Forecasts	Q4 1985	Q1	Q2	Q3	Q4	1986
September	$1,793	$1,867	$2,289	$2,664	$3,222	$10,042
December	$2,156	$2,255	$2,528	$2,724	$3,090	$10,597
February	$2,207	$2,293	$2,533	$2,731	$3,067	$10,624

Source: DATAQUEST
February 1986

IS THIS A FALSE START?--WE DON'T THINK SO

The semiconductor industry has been fooled in past years by apparent recoveries that soon fizzled out, and there are market dynamics at work now that may lead to the same result. We believe, however, that this will not be the case. Some manufacturers are not booking orders beyond six months, presumably to avoid committing to present low prices for the rest of the year. To counteract, buyers may be placing their full year's requirement now, but with several distributors. Thus the apparent double ordering.

DATAQUEST CONCLUSIONS

During the fourth quarter of 1985, the semiconductor industry began a slow recovery from one of the worst slumps in its history. That slump bottomed in the fourth quarter as we predicted, and the present signs evince a solid recovery. We believe that both 1986 and 1987 will be years of good growth. In fact, we now believe that the industry will return to its 1984 level during the fourth quarter of 1987.

Mel Thomsen

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RESEARCH NEWSLETTER

SIS Code: 1986-1987 Newsletters: February
1986-8

MOS MEMORY MARKET SHARES
1984-1985

The worldwide MOS memory market declined an estimated 39 percent from 1984 to 1985, dropping from $6.53 billion to $3.97 billion. Detailed product market revenues are shown in Table 1.

Table 1

WORLDWIDE MOS MEMORY MARKET SIZE
(Millions of Dollars)

	1984	1985	Percent Change
DRAM	$3,472	$1,653	(52%)
Total SRAM	1,203	906	(25%)
Fast SRAM	354	365	3%
Slow SRAM	849	541	(36%)
EPROM	1,179	878	(26%)
EEPROM	123	117	(5%)
NVRAM	24	20	(17%)
ROM	513	367	(28%)
Other MOS Memory	19	26	37%
Total Market	$6,533	$3,967	(39%)

Source: DATAQUEST
February 1986

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Demand stagnation and severe price erosion in the dynamic RAM market resulted in a reduction in revenues by more than 50 percent, the greatest decline among any major MOS memory product area. Slow static RAMs suffered much the same fate, dropping 36 percent, as a result of a supply/demand imbalance. This was made worse by the failure of the portable computer market to materialize as expected.

Fast static RAMs fared much better, increasing by 3 percent, due both to a steadiness in demand from a more stable user base and to the emergence of newer 64K devices. The EPROM market dropped an estimated 26 percent from 1984 to 1985, with the most severe price competition coming in the second half of the year. The mask ROM market declined 28 percent, but the fall was cushioned by the emergence of a modest video games business in Japan in the second half of the year. The market for EEPROMs combined with NVRAMs was only down 7 percent to $137 million, although price declines were severe.

Tables 2a and 2b show the worldwide MOS memory market shares by home base of producer. U.S. manufacturers' revenues declined about 46 percent, and Japanese manufacturers, despite their strong presence in the commodity static and dynamic RAM and EPROM markets, declined 35 percent. Asian-Pacific companies (Korea, Taiwan, and Hong Kong) managed to increase their revenues 50 percent over their small 1984 base.

Table 2a

MOS MEMORY MARKET SHARES BY HOME BASE OF PRODUCER
(Millions of Dollars)

	1984	1985	Percent Change
United States	$2,695	$1,453	(46%)
Japan	3,540	2,285	(35%)
Europe	291	190	(35%)
ROW	26	39	50%
Total	$6,533	$3,967	(39%)

Table 2b

MOS MEMORY MARKET SHARES
BY HOME BASE OF PRODUCER
(Percent of Worldwide Market)

	1984	1985
United States	41%	37%
Japan	54	58
Europe	4	5
ROW	0	1
Total	100%	100%

Totals may not add due to rounding.

Source: DATAQUEST
February 1986

1984 MARKET SHARES

Table 3 shows the estimated worldwide MOS memory market shares for 1984.

Table 3

ESTIMATED 1984 MOS MEMORY MARKET SHARES
(Millions of Dollars)

COMPANY	DRAM	FAST SRAM	SLOW SRAM	TOTAL SRAM	EPROM	EEPROM	NVRAM	ROM	OTHER	TOTAL
TOTAL MARKET	3472	354	849	1203	1179	123	24	513	19	6533
US COMPANIES	1350	98	225	323	586	105	22	290	19	2695
AMD	22	26	42	68	155	0	0	12	5	262
AMI	0	0	0	0	0	0	0	29	0	29
ATT Tech	69	0	0	0	0	0	0	0	0	69
Cypress	0	4	0	4	0	0	0	0	0	4
Exel	0	0	0	0	0	1	0	0	0	1
Fairchild	0	0	2	2	0	0	0	1	2	5
Genl Inst	0	0	0	0	0	25	2	48	2	77
GTE Micro	0	0	4	4	0	0	0	3	0	7
Harris	0	0	27	27	0	0	0	2	0	29
Hughes SSD	0	0	0	0	0	1	0	1	0	2
IMP	0	0	0	0	0	0	0	4	0	4
IDT	0	18	13	31	0	0	0	0	3	34
Intel	108	24	12	36	202	22	1	0	2	371
Intersil	0	0	0	0	2	0	0	4	0	6
Micron Tech	122	0	0	0	0	0	0	0	0	122
Mostek	286	2	21	23	2	0	0	35	2	348
Motorola	228	7	18	25	17	5	0	28	0	303
NCR	0	0	0	0	0	2	2	18	0	22
National	28	5	15	20	45	12	0	5	0	110
RCA	0	0	28	28	0	0	0	12	0	40
Rockwell	0	0	2	2	0	1	0	2	0	5
Seeq	0	0	0	0	35	14	0	0	0	49
Signetics	0	0	0	0	0	0	0	18	0	18
SSSI	0	0	3	3	0	0	0	5	0	8
Supertex	0	0	0	0	0	0	0	1	0	1
Synertek	0	2	13	15	0	0	0	15	0	30
Texas Inst	487	10	25	35	128	0	0	25	3	678
VLSI Tech	0	0	0	0	0	0	0	22	0	22
Xicor	0	0	0	0	0	22	17	0	0	39

(Continued)

Table 3 (Continued)

ESTIMATED 1984 MOS MEMORY MARKET SHARES
(Millions of Dollars)

COMPANY	DRAM	FAST SRAM	SLOW SRAM	TOTAL SRAM	EPROM	EEPROM	NVRAM	ROM	OTHER	TOTAL
JAPANESE COMPANIES	1978	160	588	748	572	14	0	208	0	3520
Fujitsu	445	68	42	110	158	0	0	30	0	743
Hitachi	516	41	171	212	145	2	0	50	0	925
Matsushita	61	0	0	0	1	5	0	0	0	67
Mitsubishi	206	14	23	37	155	7	0	0	0	405
NEC	515	12	103	115	70	0	0	28	0	728
Oki Elect	100	0	10	10	5	0	0	29	0	144
Sanyo	6	0	0	0	0	0	0	5	0	11
Seiko-Epson	0	0	20	20	0	0	0	9	0	29
Sharp	4	1	18	19	0	0	0	17	0	40
Sony	0	2	6	8	0	0	0	0	0	8
Toshiba	125	22	195	217	38	0	0	40	0	420
EUROPEAN COMPANIES	136	96	29	125	21	4	2	3	0	291
Inmos	61	85	0	85	0	0	0	0	0	146
Matra-Harris	0	5	7	12	3	0	0	0	0	15
Philips	0	0	0	0	0	2	0	0	0	2
SGS-Ates	1	0	5	5	8	0	2	3	0	19
Siemens	50	0	6	6	0	2	0	0	0	58
STC	16	5	0	5	0	0	0	0	0	21
Thomson	8	1	11	12	10	0	0	0	0	30
REST OF WORLD	7	0	7	7	0	0	0	12	0	26
ElCap	1	0	0	0	0	0	0	2	0	3
ERSO	0	0	1	1	0	0	0	4	0	5
Gold Star	3	0	1	1	0	0	0	0	0	4
Samsung	3	0	2	2	0	0	0	1	0	6
UMC	0	0	3	3	0	0	0	5	0	8

Source: DATAQUEST
February 1986

1985 MARKET SHARES

A sharp reduction in demand growth and tremendous amounts of new capacity, installed to serve another expected strong year of demand, combined to produce the worst price erosion and the largest financial losses in the industry's history. Table 4 shows estimated vendors' 1985 revenues in each of eight MOS memory markets. Although for MOS memory as a whole, total bits shipped increased by more than 36 percent from 1984 to 1985 (about one-third the 1970-1984 annual average), enough capacity was put in place to serve bit growth of probably 150 percent.

Table 4

ESTIMATED 1985 MOS MEMORY MARKET SHARES
(Millions of Dollars)

COMPANY	DRAM	FAST SRAM	SLOW SRAM	TOTAL SRAM	EPROM	EEPROM	NVRAM	ROM	OTHER	TOTAL
TOTAL MARKET	1653	365	541	906	878	117	20	367	26	3967
US COMPANIES	481	124	126	250	431	97	16	152	26	1453
AMD	8	29	27	56	117	1	0	6	5	193
AMI	0	0	0	0	0	0	0	10	0	10
ATT Tech	51	0	1	1	0	0	0	0	0	52
Cypress	0	12	0	12	5	0	0	0	1	18
Exel	0	0	0	0	0	4	0	0	0	4
Fairchild	0	3	0	3	0	0	0	0	1	4
Genl Inst	0	0	0	0	2	15	1	30	5	53
GTE Micro	0	0	1	1	0	0	0	2	0	3
Harris	0	4	24	28	0	0	0	2	0	30
Hughes SSD	0	0	0	0	0	1	0	1	0	2
IDT	0	24	16	40	0	0	0	0	5	45
Intel	44	18	5	23	197	15	1	0	3	283
Intersil	0	0	0	0	0	0	0	1	0	1
Lattice	0	3	0	3	0	1	0	0	0	4
Micron Tech	39	0	0	0	0	0	0	0	0	39
MOSel	0	1	0	1	0	0	0	0	0	1
Mostek	55	2	8	10	0	0	0	10	2	77
Motorola	53	12	4	16	10	2	0	12	0	93
NCR	0	0	0	0	0	4	3	7	0	14
National	11	4	10	14	22	14	0	3	0	64
RCA	0	0	20	20	0	0	0	5	0	25
Rockwell	0	0	0	0	0	1	0	1	0	2
Seeq	0	0	0	0	11	18	0	0	0	29
Signetics	0	0	0	0	0	0	0	20	0	20
SSSI	0	1	0	1	0	0	0	1	0	2
Supertex	0	0	0	0	0	0	0	1	0	1
Texas Inst	220	6	10	16	65	0	0	25	4	330
Visic	0	1	0	1	0	0	0	0	0	1
VLSI Tech	0	4	0	4	2	0	0	15	0	21
Xicor	0	0	0	0	0	21	11	0	0	32

(Continued)

Table 4 (Continued)

ESTIMATED 1985 MOS MEMORY MARKET SHARES
(Millions of Dollars)

COMPANY	DRAM	FAST SRAM	SLOW SRAM	TOTAL SRAM	EPROM	EEPROM	NVRAM	ROM	OTHER	TOTAL
JAPANESE COMPANIES	1096	170	395	565	419	16	1	188	0	2285
Fujitsu	248	62	28	90	118	1	1	30	0	488
Hitachi	305	55	124	179	113	2	0	47	0	646
Matsushita	45	0	0	0	8	5	0	0	0	58
Mitsubishi	80	5	9	14	66	5	0	4	0	169
NEC	270	27	68	95	55	1	0	40	0	461
Oki Elect	53	0	10	10	2	1	0	25	0	91
Sanyo	1	0	0	0	1	0	0	0	0	2
Seiko-Epson	0	0	48	48	1	0	0	7	0	56
Sharp	4	2	12	14	0	0	0	10	0	28
Sony	0	2	6	8	0	0	0	0	0	8
Toshiba	90	17	90	107	55	1	0	25	0	278
EUROPEAN COMPANIES	53	70	16	86	28	3	3	17	0	190
Inmos	19	57	0	57	0	0	0	0	0	76
Matra-Harris	0	6	6	12	3	0	0	0	0	15
Philips	0	0	0	0	0	2	0	3	0	5
SGS-Ates	7	0	0	0	15	0	3	7	0	32
Siemens	19	0	4	4	0	1	0	2	0	26
STC	3	5	0	5	0	0	0	0	0	8
Thomson	5	2	6	8	10	0	0	5	0	28
REST OF WORLD	23	1	4	5	0	1	0	10	0	39
ElCap	1	0	0	0	0	0	0	2	0	3
ERSO	0	0	1	1	0	0	0	1	0	2
Gold Star	4	0	0	0	0	0	0	0	0	4
Samsung	18	0	1	1	0	1	0	1	0	21
UMC	0	1	2	3	0	0	0	6	0	9

Source: DATAQUEST
February 1986

Dynamic RAMs

The dynamic RAM market declined 52 percent from an estimated $3.47 billion to an estimated $1.65 billion in 1985. The suppliers to this market suffered the worst losses and faced the worst price erosion of any market. Several companies made well-publicized withdrawals from the market during the year. Manufacturers who fared best were those who were well positioned in the 256K dynamic RAM market, which enabled them to shift their revenue base over as the 64K market declined.

Fast Static RAMs

The fast static RAM market grew by $11 million, or 3 percent, from an estimated $354 million in 1984 to $365 million in 1985. Fast MOS static RAMs have a high presence in military markets, which remained more stable throughout the year, and also tend to be sold into high-end systems markets and not into consumer areas. The market is highly differentiated--by density, performance, organization, and special features--thereby offering opportunities for greater price stability.

Slow Static RAMs

Slow static RAMs are much more commodity products than fast static RAMs. In 1985, the slow static RAM market declined an estimated 36 percent from 1984 to $541 million. State-of-the-art products at the 16K and 64K density suffered tremendous price erosion throughout the year, and 256K devices were not sufficiently close to production to make up the difference.

EPROMs

The EPROM market held up reasonably well in the first half of the year, and was the third market to suffer severe price erosion after dynamic and static RAMs. In 1985, the market declined an estimated 26 percent from 1984 to $878 million. Aggressive sales strategies by Japanese manufacturers beginning in the second quarter, especially in 256K devices, resulted in severe price erosion and contributed to legal actions taken by AMD, Intel, and National Semiconductor.

ROMs

The ROM market showed a significant shift in 1985. It declined 28 percent to $367 million, with the U.S. and Japanese manufacturers flip-flopping in their market dominance. The strongest elements of demand in the ROM market in 1985 were megabit ROMs, supplied almost exclusively into the Far East market by Japanese suppliers, as well as a modest video games market in Japan--also supplied predominantly by Japanese suppliers.

EEPROMs and NVRAMs

Despite severe price erosion, the combined revenues of the EEPROM and NVRAM markets stayed nearly even with 1984 revenues, dropping 7 percent to $137 million, although there were some significant shifts in vendors' market shares. Japanese manufacturers are still not present to any great extent in the EEPROM market. The leading manufacturers from 1984, General Instrument, Intel, and Xicor, saw their revenues decline in 1985. This was made up by increases coming from National Semiconductor and Seeq, and newcomers AMD and Exel.

DEFINITIONS

- "NVRAMs" are monolithic silicon only (no battery backup).
- Dual-Port SRAMs are "Fast SRAMs."
- Video RAMs are "DRAMs."
- "Fast SRAMs" are $\leqslant$70ns, "Slow SRAMs" are $>$70ns.
- CCD Memories, FIFOs, and Shift Registers are "Other."
- Cypress-type PROMs, based on EPROM technology, are "EPROMs."
- Keyboard Encoders and Character Generators are "ROMs."
- Pseudostatic and iRAMs are "DRAMs."

WTSP DATA COMPARISON

The top level data contained in these tables compare reasonably well with statistics published by the World Trade Statistics Program (WTSP), if adjustments are made for nonparticipants. Primarily, these include AT&T Technologies, which is included in the DATAQUEST data, Rest of World manufacturers (Korea and Taiwan), plus a few U.S. and Japanese companies whose production is not included in the WTSP data.

Lane Mason
Sue Kelly

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a company of
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RESEARCH NEWSLETTER

SIS Code: 1986-1987 Newsletters: February
1986-7

1985 MICROPROCESSOR MANUFACTURER RANKINGS

SUMMARY

The top 10 companies shown in Table 1 accounted for more than 77 percent of the microprocessor market, and 6 of the 10 had revenues of more than $100 million each. In 1985, Intel, NEC, and Motorola remained numbers 1, 2, and 3, respectively. AMD lost significant market share in 1985, changing positions from number 4 in 1984 to number 9. Five of the top 10 microprocessor manufacturers were Japanese, the other five were U.S. manufacturers. Total worldwide microprocessor revenue decreased 15.9 percent in 1985 from 1984. Any microprocessor manufacturer whose revenue decreased more than 15.9 percent lost market share.

GEOGRAPHIC MARKET SHARES

Geographic market shares shifted slightly from 1984 to 1985, as shown in Table 2. Market shares for Japanese, Western European, and Rest of World companies rose, while market share for U.S. companies decreased slightly.

GROWTH RATES

The manufacturers with the highest growth rates in the microprocessor segment are shown in Table 3. Only six companies had positive growth during the year. The company with the greatest growth was Taiwan's United Microelectronic (UMC), followed closely by a European company, Thomson.

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REGIONAL MARKET SHARES

Tables 4 through 8 rank the worldwide microprocessor suppliers by total revenue by region.

Total worldwide microprocessor revenue was down 15.9 percent in 1985 from 1984. Any microprocessor manufacturer whose revenue decreased more than 15.9 percent during 1985 lost market share. U.S. manufacturers took the hardest hit during the year, with revenues decreasing 19.1 percent. Japanese manufacturers were also affected by the 1985 downturn with a revenue decrease of 13.4 percent. Western European and Rest of World companies had a strong year with increases of 4.3 percent and 54.6 percent, respectively. Typically, Western European economic conditions lag those in the United States by one year. Korean microprocessor manufacturers entered the market with phenomenal growth during 1985, equal to the unprecedented high growth in 1984.

Janet Rey-Oncel

Table 1

TOP 10 1985 MICROPROCESSOR MANUFACTURERS
(Millions of Dollars)

1984 Rank	1985 Rank	Company	Revenue 1984	Revenue 1985	Growth
1	1	Intel	$743	$670	(9.8%)
2	2	NEC	$411	$375	(8.8%)
3	3	Motorola	$256	$255	(0.4%)
5	4	Matsushita	$119	$111	(6.7%)
6	5	Hitachi	$120	$110	(8.3%)
7	6	Fujitsu	$121	$106	(12.4%)
10	7	Mitsubishi	$156	$ 97	(37.8%)
9	8	Texas Instruments	$117	$ 94	(19.7%)
4	9	AMD	$202	$ 88	(26.1%)
8	10	National Semiconductor	$115	$ 85	(26.1%)

Table 2

GEOGRAPHIC MICROPROCESSOR MARKET SHARES

	1984	1985
United States	59.1%	56.8%
Japan	37.0	38.2
Western Europe	3.6	4.4
Rest of World	0.3	0.6
Total	100.0%	100.0%

Source: DATAQUEST
February 1986

Table 3

TOP GROWTH 1985 MICROPROCESSOR MANUFACTURERS
(Millions of Dollars)

	Revenue 1984	Revenue 1985	Growth
United Microelectronic	$ 4	$ 7	75.0%
Thomson	$23	$40	73.9%
Harris	$52	$58	11.5%
ITT	$10	$11	10.0%
Matra-Harris	$11	$12	9.0%
Sanyo	$35	$36	2.9%

Source: DATAQUEST
February 1986

Table 4

PRELIMINARY WORLDWIDE 1985 MICROPROCESSOR MARKET SHARE RANKINGS
(Millions of Dollars)

	1984	1985	Growth
Intel	$ 743	$ 670	(9.83%)
NEC	411	375	(8.76%)
Motorola	256	255	(0.39%)
Matsushita	119	111	(6.72%)
Hitachi	120	110	(8.33%)
Fujitsu	121	106	(12.40%)
Mitsubishi	156	97	(37.82%)
Texas Instruments	117	94	(19.66%)
AMD	202	88	(56.44%)
National	115	85	(26.09%)
Toshiba	70	69	(1.43%)
Zilog	88	59	(32.95%)
Harris	52	58	11.54%
Sharp	71	46	(35.21%)
Oki	46	43	(6.52%)
Mostek	55	40	(27.27%)
SMC	50	40	(20.00%)
Thomson	23	40	73.91%
Sanyo	35	36	2.86%
Signetics	75	35	(53.33%)
Philips	29	29	0.00%

(Continued)

Table 4 (Continued)

PRELIMINARY WORLDWIDE 1985 MICROPROCESSOR MARKET SHARE RANKINGS
(Millions of Dollars)

	1984	1985	Growth
RCA	$ 34	$ 28	(17.65%)
Rockwell	32	26	(18.75%)
Sony	26	26	0.00%
SGS	31	20	(35.48%)
Siemens	19	16	(15.79%)
Seiko	18	15	(16.67%)
Matra-Harris	11	12	9.09%
GI	15	11	(26.67%)
ITT	10	11	(10.00%)
Western Digital	12	11	(8.33%)
Fairchild	17	10	(41.18%)
Japan Others	11	9	(18.18%)
NCR	12	8	(33.33%)
ROW Others	6	8	33.33%
AMI	8	7	(12.50%)
United Microelectronic	4	7	75.00%
Intersil	5	5	0.00%
Hughes	3	3	0.00%
Eurosil	2	2	0.00%
GTE	3	2	(33.33%)
Inmos	0	2	N/A
Rohm	2	2	0.00%
VLSI	0	2	N/A
Erso	0	1	N/A
Exel	0	1	N/A
Gold Star	1	1	0.00%
Commodore	0	0	N/A
Eurotechnique	0	0	N/A
Ferranti	1	0	(100.00%)
Synertek	15	0	(100.00%)
U.S. Others	5	7	40.00%
Total	$3,257	$2,739	(15.90%)

Source: DATAQUEST
February 1986

Table 5

PRELIMINARY 1985 WORLDWIDE
MARKET SHARE RANKINGS OF U.S. MANUFACTURERS
(Millions of Dollars)

	1984	1985	Growth
Intel	$ 743	$ 670	(9.83%)
Motorola	256	255	(0.39%)
Texas Instruments	117	94	(19.66%)
AMD	202	88	(56.44%)
National	115	85	(26.09%)
Zilog	88	59	(32.95%)
Harris	52	58	11.54%
Mostek	55	40	(27.27%)
SMC	50	40	(20.00%)
Signetics	75	35	(53.33%)
RCA	34	28	(17.65%)
Rockwell	32	26	(18.75%)
GI	15	11	(26.67%)
ITT	10	11	(10.00%)
Western Digital	12	11	(8.33%)
Fairchild	17	10	(41.18%)
NCR	12	8	(33.33%)
AMI	8	7	(12.50%)
Intersil	5	5	0.00%
Hughes	3	3	0.00%
GTE	3	2	(33.33%)
VLSI	0	2	N/A
Exel	0	1	N/A
Commodore	0	0	N/A
Synertek	15	0	(100.00%)
Others	5	7	40.00%
Total	$1,924	$1,556	(19.13%)

Source: DATAQUEST
February 1986

Table 6

PRELIMINARY 1985 WORLDWIDE
MARKET SHARE RANKINGS OF JAPANESE MANUFACTURERS
(Millions of Dollars)

	1984	1985	Growth
NEC	$ 411	$ 375	(8.76%)
Matsushita	119	111	(6.72%)
Hitachi	120	110	(8.33%)
Fujitsu	121	106	(12.40%)
Mitsubishi	156	97	(37.82%)
Toshiba	70	69	(1.43%)
Sharp	71	46	(35.21%)
Oki	46	43	(6.52%)
Sanyo	35	36	2.86%
Sony	26	26	0.00%
Seiko	18	15	(16.67%)
Rohm	2	2	0.00%
Others	11	9	(18.18%)
Total	$1,206	$1,045	(13.35%)

Source: DATAQUEST
February 1986

Table 7

PRELIMINARY 1985 WORLDWIDE
MARKET SHARE RANKINGS OF WESTERN EUROPEAN MANUFACTURERS
(Millions of Dollars)

	1984	1985	Growth
Thomson	$ 23	$ 40	73.91%
Philips	29	29	0.00%
SGS	31	20	(35.48%)
Siemens	19	16	(15.79%)
Matra-Harris	11	12	9.09%
Eurosil	2	2	0.00%
Inmos	0	2	N/A
Ferranti	1	0	(100.00%)
Eurotechnique	0	0	
Total	$116	$121	4.31%

Table 8

PRELIMINARY 1985 WORLDWIDE MARKET SHARE
RANKINGS OF REST OF WORLD MANUFACTURERS
(Millions of Dollars)

	1984	1985	Growth
United Microelectronic	$ 4	$ 7	54.55%
Erso	0	1	N/A
Gold Star	1	1	0.00%
Others	6	8	33.33%
Total	$11	$17	54.55%

Source: DATAQUEST
February 1986

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RESEARCH NEWSLETTER

SIS Code: 1986-1987 Newsletters: February
1986-6

ECL RAMs--MEMORY MARKET GROWTH IN 1985

SUMMARY

Total semiconductor memory revenues dropped dramatically during the market crunch of 1985. Total MOS memory revenues dropped 39 percent and bipolar PROM revenues fell 27 percent. However, one bipolar memory market grew in 1985--ECL RAMs. DATAQUEST estimates that ECL RAM revenues were $125 million in 1985, up 10 percent from 1984 revenues of $114 million.

Most of the worldwide ECL RAM demand is met by the Japanese vendors, principally Fujitsu and Hitachi, and this was especially true in 1985. The Japanese vendors earned 87 percent of ECL RAM revenues in 1985, up from 82 percent in 1984. Fujitsu and Hitachi alone controlled 83 percent of the market in 1985. European vendor revenues remained flat in a growing market and comprised only 2 percent of the total in 1985 and 3 percent of the total in 1984. U.S. companies did not fare as well; their revenues and market share in 1985 dropped relative to the previous year. Only National Semiconductor was able to increase its revenues and maintain market share in 1985.

Much of the growth in this market has been fed by the growth at the high-performance end of the electronic data processing (EDP) market. ECL RAMs are the highest-performance RAM devices available in the merchant market, and demand for them has grown with the increasing demand for fast, large computers. Approximately 80 percent of all ECL RAMs go into the EDP market for use in mainframes, superminicomputers, and supercomputers; so growth in these markets provides tremendous opportunities for growth in the ECL RAM arena.

Another area where ECL RAMs are in high demand is the automatic test equipment (ATE) market. About 15 percent of ECL RAMs go into this market. (ATE is categorized by DATAQUEST as belonging to the industrial segment of end-use equipment).

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A third end-use area of interest to ECL RAM suppliers is communications, specifically telecommunications. The percentage of ECL RAMs that are sold into the telecommunications market is still very small at 2 to 3 percent, but will probably increase quite a bit during the next five years. Very few ECL RAMs currently go into the military, but military interest in the devices may be increasing.

In 1985, 65 percent of ECL RAM use was in the United States, 22 percent was in Japan, and the balance was in Europe.

MARKET STABILITY IN 1985

The growth that occurred in the ECL RAM market in 1985 was unmatched within the rest of the memory market. There were a number of reasons for the ECL RAM revenue growth. The biggest factor was price stability. Overall, ECL RAM prices dropped only 14.2 percent in 1985. This percentage is in line with historical annual price declines that still allow for revenue growth. Combined with unit shipments that increased 27.6 percent, this caused a revenue increase of 9.5 percent.

A second reason for ECL RAM market stability was the shift from TTL RAMs to ECL RAMs that has been occurring for the last several years. DATAQUEST estimates that in 1980 the TTL RAM market was $90 million, while the ECL RAM market was $59 million. In 1985, the TTL RAM market was $70 million, and the ECL RAM market had grown to $125 million. Some of the equipment that used TTL five years ago has been redesigned to incorporate faster ECL parts, which has contributed to an increase in ECL RAM consumption over the last few years. However, some equipment has been redesigned to take advantage of low-power CMOS, so not all TTL RAM use has shifted to ECL.

Another factor contributing to the market strength in 1985 was ECL RAM applications. DATAQUEST estimates that North American computer revenues for mainframes, superminicomputers, and supercomputers grew 7 percent in 1985 relative to 1984. Since about 80 percent of ECL RAMs go into the EDP market, the stability of this end market in 1985 contributed to the growth of ECL RAM revenues. Although high-end computer market growth is not nearly as large as the growth of personal computers (PCs) and workstations that use slower MOS memory, high-end computer market growth has been more stable. The PC market grew 73 percent in 1984 and only 32 percent in 1985. This dramatic drop contributed to the tremendous inventory and over-supply problems seen in the MOS memory market in 1985.

The market for ATE is estimated to have dropped 15 percent in 1985, so the demand for ECL RAMs from that end also declined; but since about 15 percent of ECL RAMs go into ATE, the effect of the market drop was masked somewhat by the growth in EDP demand.

ECL RAM MARKET SHARE ESTIMATES

Table 1 gives 1984 and 1985 market share estimates for all ECL RAM vendors. These numbers include merchant sales and internal consumption.

Table 1

ESTIMATED ECL RAM REVENUES
(Millions of Dollars)

Vendor	1984	1985
Advanced Micro Devices	$ 3	$ 2
Fairchild	5	3
Motorola	5	3
National Semiconductor	4	5
Total United States	$ 17	$ 13
Fujitsu	$ 47	$ 54
Hitachi	45	50
NEC	2	5
Total Japan	$ 94	$109
Philips/Signetics	$ 1	$ 2
Siemens	1	1
Thomson Semiconductors	1	0
Total Europe	$ 3	$ 3
Total Worldwide	$114	$125

Source: DATAQUEST
February 1986

Fujitsu was the leading supplier of ECL RAMs in 1984 and 1985, and Hitachi was the second largest supplier. The market grew 10 percent from 1984 to 1985, and both of these companies grew at a faster rate than the market did. In the past, Fujitsu reportedly has consumed approximately 30 to 40 percent of its ECL RAM production internally. DATAQUEST believes, however, that about 15 to 20 percent of ECL RAMs produced by Fujitsu in 1984 and 1985 were consumed internally. This percentage will probably decrease as Fujitsu moves toward alternative high-performance technologies, such as gallium arsenide (GaAs) and HEMT, for use in its large-scale computers.

Hitachi's internal consumption is probably also about 15 to 20 percent of production, and varies over time with market conditions in end-equipment areas and with shifts to alternative RAM technologies for use in its computers.

It is believed that both Hitachi and Fujitsu use some of their highest-performance parts internally for quite a while before they become available to end customers.

NEC sales in 1984 were almost completely internal or in Japan, but most of their revenues in 1985 were gathered in the merchant market, including the United States and Europe. NEC has been in the merchant market for just a few years, but it already has some of the fastest parts available.

Revenues of the European ECL RAM suppliers, Siemens, Thomson, and Philips (including Signetics) were flat from 1984 to 1985. European vendor market share was 3 percent in 1984 and 2 percent in 1985. Philips' revenues increased by $1 million in 1985. Philips' production in Europe actually remained flat from 1984 to 1985, but in 1985, Signetics produced $1 million worth of ECL RAMs. Thomson's revenues were $1 million in 1984 and zero in 1985. Siemens' revenues remained flat.

U.S. company revenues dropped from 1984 to 1985, although consumption in the U.S. market was up slightly. National Semiconductor was the only U.S. vendor whose revenues increased from 1984 to 1985. The other three U.S. suppliers' revenues declined. AMD is just beginning to penetrate the ECL RAM market, although they have had a good position in TTL RAMs for a number of years. Fairchild and Motorola have both had good positions in this market in the past, but their market shares have declined over the past few years. One reason for the U.S. vendors' situation is that they do not have 16K parts on the market yet, nor, in general, do they have the fastest parts available at the densities where they do have parts. Since the areas of biggest growth in this market are the high-density, high-speed parts, and since these parts also command a significantly higher ASP, the U.S. suppliers have not been able to capture much of the revenue growth in the market. A second problem for the U.S. suppliers has been their production capabilities. Several vendors have had production problems in the last few years, and they had a hard time increasing their production during the demand surge of 1984.

MARKET SEGMENTATION BY ORGANIZATION

Table 2 shows estimated ECL RAM revenues by density and organization for 1984 and 1985, and expected revenues for 1986. In 1985, nearly half the market was 4K devices. However, the 16K market is rapidly becoming a significant portion of the total, and this trend is expected to continue.

Table 2

ESTIMATED ECL RAM REVENUES BY DENSITY AND ORGANIZATION
(Millions of Dollars)

Organization	1984	1985	1986
256 x 1	$ 5	$ 4	$ 3
1K x 1	15	13	11
256 x 4	17	19	21
4K x 1	25	27	30
1K x 4	31	34	40
16K x 1	21	24	32
4K x 4	0	4	11
64K x 1	0	0	3
Total	$114	$125	$151
Percent Change from Previous Year		10%	21%

Source: DATAQUEST
February 1986

Fujitsu is the density leader, with 16Kx1 and 4Kx4 parts available now, and 64Kx1 production scheduled to begin in the first part of this year. The 25ns 16Kx1 parts became available from Fujitsu in 1983 and 15ns parts in 1985. The Fujitsu 4Kx4 was shipped in volume in 1985. Hitachi began shipping a 16Kx1 in 1984, and a 4Kx4 in late 1985. Several other companies expect to begin sampling 16K parts in 1986, including National Semiconductor and NEC.

END-USE MARKETS

Table 3 shows estimated consumption of ECL RAMs in the various end-use categories for 1984 through 1986.

Table 3

ESTIMATED ECL RAM END-USE MARKETS
(Percent of Dollars)

Market	1984	1985	1986
EDP	78%	80%	79%
Industrial (ATE)	17	14	14
Communications	2	3	4
Military	3	3	3
Total	100%	100%	100%

Source: DATAQUEST
February 1986

Approximately 80 percent of ECL RAMs go into the EDP market. Within that market, most of the parts go into control store, cache memory, or buffer memory in mainframes, superminicomputers, and supercomputers. Few parts are used in main memory, as even supercomputer manufacturers such as Cray are using fast MOS SRAMs in the main memory of many of their machines.

The second major application for ECL RAMs is automatic test equipment. Approximately 14 percent of ECL RAMs went into that market in 1985. ATE is an interesting application for high-performance memories, since the growth in high-speed devices has contributed to the increased demand for high-performance testers, which in turn feeds back to increase the demand for fast ICs to go into those testers. This end-use market was more affected by the drop in semiconductor sales in 1985 than the other ECL RAM end-use areas, since the testers are sold into the semiconductor industry. DATAQUEST believes that in 1985, ATE revenues dropped approximately 15 percent. Therefore, the percentage of ECL RAMs used in test equipment was down somewhat, from 17 percent in 1984 to 14 percent in 1985. The ATE market requires the fastest components on the market, since the machines must be able to test the fastest parts available. Fast 256x4 ECL RAMs are often used in this application. A shift to 1Kx4 parts is occurring as 1Kx4 speeds catch up to 256x4 speeds.

A third application for ECL RAMs, which seems to be growing, is telecommunications. Although only 2 to 3 percent of ECL RAMs are used in telecommunications applications now, we expect the percentage to grow over the next few years.

There are no ECL RAMs in automotive or consumer applications and very few go into the military, although the military reportedly is showing increasing interest in ECL RAMs.

REGIONAL CONSUMPTION

About 65 to 70 percent of ECL RAM consumption is in the United States. Table 4 shows the breakout by region for 1984 through 1986.

Table 4

ESTIMATED REGIONAL ECL RAM CONSUMPTION
(Millions of Dollars)

Region	1984	1985	1986
North America	$ 79	$ 81	$ 98
Japan	21	28	35
Europe	14	16	18
Rest of World	0	0	0
Total	$114	$125	$151

Source: DATAQUEST
February 1986

Consumption in the European market is principally by mainframe computer manufacturers. Consumption is low since very little test equipment and no supercomputer manufacturing occurs there. Demand for ECL RAMs from the EDP market is very strong in Japan, and several of the top test equipment manufacturers, including Takeda Riken Company, Ltd., are Japanese.

The area of greatest uncertainty in the Japanese market is internal consumption by Fujitsu and Hitachi. As discussed earlier in this newsletter, internal consumption seems to be dropping, but could still be a significant portion of the market.

TECHNICAL ISSUES

One of the driving forces behind the growth of this market is the system houses' need for high-speed memory. It is unlikely that CMOS static RAMs will get fast enough to displace any ECL RAMs in the next few years. Perhaps by the end of the decade there will be some CMOS parts that can take away some of the designs that might have otherwise gone to ECL, but it is more likely that the biggest threat to ECL will come from GaAs RAMs.

Many of the ECL RAMs on the market today dissipate as much as 1 watt of power. NEC offers some 1K x 4 parts with access times as low as 4.5ns, but power dissipation of 2 watts. However, in certain applications, users seem willing to deal with the heat generated by that power. In situations where squeezing a few nanoseconds out of a cache memory can significantly improve the performance of a machine, the designer will work with high power requirements to get increased performance. In the ATE market, for example, a few very fast parts can make an entire system much faster. Price and power become no object in a very large system using a few very fast parts.

The shift from 4K to 16K devices has occurred much more slowly than was expected several years ago, primarily because of delayed introduction and production by manufacturers. The 16K and 64K devices are difficult to make and generally require state-of-the art manufacturing skills, and a number of manufacturers have had soft error problems. As devices and die sizes get larger, the likelihood that alpha particles will strike a cell increases. Alpha particles can cause significant problems by shifting the state of the cells they strike, causing soft errors. At a number of manufacturers, these problems have held up development. The percentage of the market at the 16K level is expected to increase in 1986, as more vendors begin shipping the part and production levels increase.

Fujitsu has introduced a 20ns 64Kx1 ECL RAM, which is being sampled now. A 15ns version should be available in the first half of 1986, and 10ns is targeted by the end of 1986. Hitachi has chosen to go with a Hi-BiCMOS part at the 64K level. Hitachi does not plan to make any ECL RAMs beyond the 16K density, but will begin production of a Hi-BiCMOS 64K RAM with ECL I/Os in the first part of 1987. Several other companies have developed or are working on a bi-CMOS process, including Motorola and Texas Instruments.

There is a question whether bi-CMOS RAMs will be fast enough to be used in the applications where ECL RAMs are used now (in high-performance computers and ATE). We believe that there will definitely be applications for bi-CMOS parts because of their relatively high speed and low power. In the design of office systems, for instance, designers often do not want to use extensive cooling, so these parts could be used to get TTL performance while saving power. Portable systems that demand performance will also be able to use the power savings of bi-CMOS. In addition, there is the possibility of replacement of those CMOS fast SRAMs used in ECL machines, since a bi-CMOS part with ECL outputs has the low power advantages of CMOS, is high speed, and eliminates the need for translation from TTL to ECL output levels, thus further increasing system savings in access time. For cache, buffer, and control store applications in large computers, however, it seems unlikely that most high-performance users will be willing to give up any speed to save power. Since bi-CMOS is a very new technology, it is likely that speeds will improve over the next few years. As this happens, bi-CMOS may become a more attractive alternative to ECL RAM.

1986 OUTLOOK

DATAQUEST expects ECL RAM revenues to increase approximately 21 percent in 1986. An increase in 16K shipments and the initial 64K shipments (with very high ASPs) will contribute to the revenue growth, as will a general strengthening of the EDP market. DATAQUEST expects North American high-end EDP revenues to grow 9 percent in 1986. The test equipment market is also expected to grow, which will provide additional opportunities for ECL RAM revenue growth.

A number of companies are planning to introduce new parts to the market in 1986. Mitsubishi will enter the ECL RAM market this year with 256x4, 1Kx4, and 4Kx1 parts.

ECL RAMs have high-end applications and supply growing markets. The parts themselves are high performance, in demand, and priced relatively well. The outlook for this market in 1986 and for the next few years is optimistic given the existing set of applications and end-use markets. In addition, new opportunities and applications for ECL RAMs seem to be developing, and this will further increase the opportunities within this market.

Susan Scibetta

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RESEARCH NEWSLETTER

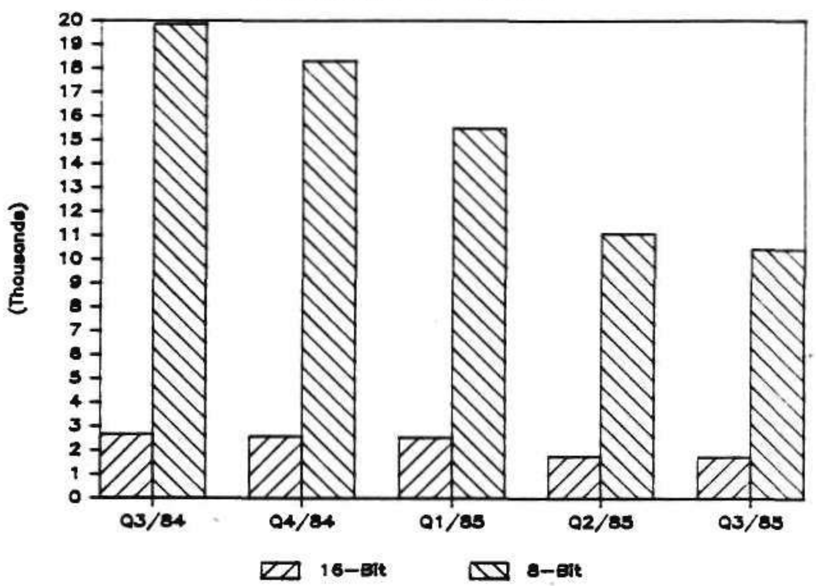
SIS Code: 1986-1987 Newsletters: February
1986-5

THIRD QUARTER 1985 MICROPROCESSOR AND MICROCONTROLLER UNIT SHIPMENT UPDATE

During the third quarter of 1985, worldwide microprocessor and microcontroller unit shipments decreased approximately 3.0 million units or 3.6 percent from second quarter 1985. Estimated shipments of all microcontroller devices totaled approximately 81.3 million units. Shipments of 4-bit MCUs remained flat and 8-bit MCU shipments decreased 7.4 percent. Estimated shipments of all microprocessor devices totaled approximately 12.5 million units. Shipments of 16-bit MPUs were down approximately 1.9 percent, while 8-bit MPU shipments decreased approximately 4.2 percent. Figure 1 shows MCU and MPU unit shipments from the third quarter of 1984 through the third quarter of 1985.

Figure 1

**MICROCONTROLLER AND MICROPROCESSOR UNIT SHIPMENTS
THIRD QUARTER 1984 THROUGH THIRD QUARTER 1985
(Millions of Units)**



Source: DATAQUEST
February 1986

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Table 1 shows the quarterly revenue for microcontrollers and microprocessors from the third quarter 1984 through the third quarter 1985.

Table 1

TOTAL MICROCONTROLLER AND MICROPROCESSOR REVENUE
THIRD QUARTER 1984 THROUGH THIRD QUARTER 1985
(Millions of Dollars)

	Q3/84	Q4/84	Q1/85	Q2/85	Q3/85
MCU	$380.9	$372.2	$293.9	$255.6	$260.0
MPU	161.0	169.9	131.0	102.0	96.0
Total	$541.9	$542.1	$424.9	$357.6	$356.0

Source: DATAQUEST
February 1986

Table 2 shows the change in total microcontroller unit shipments from the second quarter of 1985 through the third quarter of 1985.

Table 2

TOTAL MICROCONTROLLER UNIT SHIPMENTS
SECOND QUARTER 1985 THROUGH THIRD QUARTER 1985
(Thousands of Units)

	Q2/1985		Q3/1985		Percent
MCU	Units	Percent of Shipments	Units	Percent of Shipments	Growth Q2 to Q3
4-Bit	44,809	53.1%	44,649	54.9%	(0.0%)
8-Bit	39,462	46.8	36,549	45.0	(7.4%)
16-Bit	55	0.1	56	0.1	1.8%
Total	84,326	100.0%	81,254	100.0%	(3.6%)

Source: DATAQUEST
February 1986

Table 3 shows the change in total microprocessor unit shipments from the second quarter of 1985 through the third quarter of 1985.

Table 3

TOTAL MICROPROCESSOR UNIT SHIPMENTS
SECOND QUARTER 1985 THROUGH THIRD QUARTER 1985
(Thousands of Units)

	Q2/1985		Q3/1985		Percent
		Percent of		Percent of	Growth
MPU	Units	Shipments	Units	Shipments	Q2 to Q3
8-Bit	11,170	86.0%	10,699	85.7%	(4.2%)
16-Bit	1,780	13.7	1,746	14.0	(1.9%)
Others	37	0.3	40	0.3	8.1%)
Total	12,987	100.0%	12,485	100.0%	(3.9%)

Source: DATAQUEST
February 1986

Table 4 shows the change in the shipments of the leading 8-bit MPUs from the second quarter of 1985 through the third quarter of 1985.

Table 4

LEADING 8-BIT MICROPROCESSOR SHIPMENTS
SECOND QUARTER 1985 THROUGH THIRD QUARTER 1985
(Thousands of Units)

	Q2/1985		Q3/1985		Percent
		Percent of		Percent of	Growth
Device	Units	Shipments	Units	Shipments	Q2 to Q3
Z80	3,309	29.6%	3,535	33.0%	6.8%
8085	3,429	30.7	2,636	24.6	(23.1%)
6802	1,155	10.3	1,102	10.3	(4.6%)
8088	674	6.0	724	6.8	7.4%
6809	770	6.9	690	6.5	(10.4%)
Others	1,833	16.5	2,012	18.8	9.8%
Total	11,170	100.0%	10,699	100.0%	(4.2%)

Source: DATAQUEST
February 1986

Table 5 shows the changes in estimated shipments of 16-bit microprocessors from the second quarter of 1985 through the third quarter of 1985.

Table 5

16-BIT MICROPROCESSOR SHIPMENTS
SECOND QUARTER 1985 THROUGH THIRD QUARTER 1985
(Thousands of Units)

	Q2/1985		Q3/1985		Percent
Device	Units	Percent of Shipments	Units	Percent of Shipments	Growth Q2 to Q3
68000	447	25.1%	406	23.3%	(9.2%)
80286	375	21.1	405	23.2	8.0%
8086	388	21.8	400	22.9	3.1%
80186	260	14.6	215	12.3	(17.3%)
Z8000	97	5.5	97	5.6	-
32016	75	4.2	75	4.3	-
Others	138	7.7	148	8.4	7.3%
Total	1,780	100.0%	1,746	100.0%	(1.9%)

Source: DATAQUEST
February 1986

Table 6 shows the changes in estimated shipments of 8-bit microcontrollers from the second quarter of 1985 through the third quarter of 1985.

Table 6

8-BIT MICROCONTROLLER SHIPMENTS
SECOND QUARTER 1985 THROUGH THIRD QUARTER 1985
(Thousands of Units)

	Q2/1985		Q3/1985		Percent
Device	Units	Percent of Shipments	Units	Percent of Shipments	Growth Q2 to Q3
8049	7,117	18.0%	6,382	17.5%	(10.3%)
6805	4,755	12.1	4,490	12.3	(5.6%)
8048	5,259	13.3	4,186	11.5	(20.4%)
8051	4,045	10.3	4,036	11.0	(0.2%)
Others	18,286	46.3	17,455	47.7	(4.5%)
Total	39,462	100.0%	36,549	100.0%	(7.4%)

Source: DATAQUEST
February 1986

Table 7 shows market share by technology for 8-bit microcontroller and microprocessor devices from the third quarter of 1984 through the third quarter of 1985, and indicates increased shipments of 8-bit CMOS microcontrollers and microprocessors.

During third quarter 1985, approximately 79 percent of all 8-bit CMOS MCU shipments and approximately 43.0 percent of all 8-bit CMOS MPU shipments were Japanese manufactured and shipped. Even though U.S. manufacturers ship more 8-bit CMOS MPUs--approximately 1.0 million units--their Japanese counterparts shipped six times as many or approximately 5.9 million 8-bit CMOS MCUs. DATAQUEST believes that as CMOS technology progresses, the Japanese position will become stronger than it is now in both the MPU and MCU market segments.

Table 7

MARKET SHARE BY TECHNOLOGY FOR MICROCONTROLLERS AND MICROPROCESSORS THIRD QUARTER 1984 THROUGH THIRD QUARTER 1985

Device	Tech	Q3/84	Q4/84	Q1/85	Q2/85	Q3/85
8-Bit MCU	CMOS	9.7%	15.3%	16.9%	20.4%	20.3%
8-Bit MCU	NMOS	90.3	84.7	83.1	79.6	79.7
Total		100.0%	100.0%	100.0%	100.0%	100.0%
8-Bit MPU	CMOS	10.3%	11.6%	12.0%	15.2%	17.2%
8-Bit MPU	NMOS	89.7	88.4	88.0	84.8	82.8
Total		100.0%	100.0%	100.0%	100.0%	100.0%

Source: DATAQUEST
February 1986

ANALYSIS

DATAQUEST estimates that revenue from microprocessor and microcontroller shipments for third quarter 1985 was $356 million, flat from the second quarter of 1985. For the remainder of the year, the impact of declining prices and unit volumes will continue, with a slight upturn in the fourth quarter. Revenue shipments for fourth quarter 1985 are expected to be $403 million, with the year's MPU/MCU revenue shipments at $1,542 million, down 23 percent from 1984 revenue.

OUTLOOK FOR 1986

- CMOS technology will be the dominant growth area.
- Growth will resume in 1986.
- Inventories will stabilize.
- Prices will be firmer.
- There will be pressure to finalize second-source agreements for 32-bit MPUs.
- More high-integration chips will be available on the market.
- Personal computers will be used as workstations.
- Integration of office factory automation will be planned.
- Lap-top computers will be an emerging market.

Janet Rey-Oncel

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RESEARCH NEWSLETTER

SIS Code: 1986-1987 Newsletters: February
1986-4

LOGIC DEFINITION BROADENS

The synergism of application-specific integrated circuits (ASICs) and the demands of certain end markets is creating a whole new breed of products and business opportunities. These are logic products aimed at very specific applications and are based on a sharp departure from the traditional role of standard products.

Recently, we have observed the growth of a family of catalog products aimed at unique applications, such as telecommunications and digital signal processing (DSP). This newsletter broadens the definition for products that are standard catalog parts but which are aimed at a unique application.

ASICs MERGE WITH CATALOG PRODUCTS

The forces that created the ASIC market have spread into the catalog product portion of the semiconductor business. Some of today's products are both catalog products and application-specific products. The basic trend is still in force; as VLSI chip complexities increase, the applications become narrower. However, they do not become so narrow that a single chip can only be used by a single user.

For example, suppose that nuts and bolts are analogs of flip-flops and gates. Like flip-flops and gates, they are used almost universally in all mechanical devices. However, when many nuts and bolts are combined to build a product of higher complexity, that product becomes less generally applicable. If it is a bridge, it may be unique to the particular river crossing for which it was designed. If it is a car, it may appeal to a class of users, say racing drivers, but not to all users.

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THE DESIGN DILEMMA

The design dilemma results from the fact that chip complexity is increasing as competitive pressures increase. As suppliers attempt to differentiate their products, there is a continual search for unique niches where they can have a dominant position. Meanwhile, design costs escalate because of complexity and the number of units over which the design costs can be amortized decreases, leading to increased design cost per unit. This has led many standard product manufacturers to seek larger and larger markets for their chips even though the application windows are narrowing.

The advent of ASICs has led to the creation of a design technology aimed directly at solving this problem. Forces in the ASIC market demand that design costs be kept low. Often design costs are even reduced at some penalty of higher manufacturing cost. The most conspicuous example of this is the gate array, which may require twice the chip area of a handcrafted chip performing the same logic function. Extensive development of new CAD tools has also helped reduce design costs.

Traditionally, designers of catalog items have been "micron fiddlers," devoted to saving every last square micron of chip area and to designing and redesigning to achieve optimum chip performance. This design strategy may be appropriate for memory products and for some other types of products, but it is probably inappropriate for some unique applications.

Ironically enough, the silicon real estate in standard products is often wasted in spite of the best efforts of the "micron fiddlers." This comes about because many chips are used in applications that do not make use of all the circuitry on the chip. One of the outputs of a flip-flop may not be used, an internal feedback loop of a counter may be disabled, or a microcontroller may not use all its internal memory or have all inputs or outputs connected. This situation is so prevalent in the microcontroller market that some manufacturers routinely strip off the unused circuitry for customers with high-volume applications.

One solution to the design dilemma is to apply ASIC design technology to end-market applications resulting in catalog applications logic. This solution is illustrated in Figure 1. Some companies are already doing this; in fact, one major manufacturer is even using gate arrays to design some of its microperipherals.

THE LOGIC FAMILY TREE

Figure 2 shows the proposed expansion of logic segments to include application-specific logic products (ASLPs). This new term covers standard or catalog products that have a limited use in certain end markets. Note that the term ASIC has been expanded to include all cell-based products, thus encompassing standard cells and compiled-cell products.

Table 1 gives some examples of the types of products found in the ASLP segment. We believe that this segmentation allows for a finer cut of our existing categories and offers an opportunity for further divisions in the future. If an ASLP grows rapidly, a separate category will be established.

DATAQUEST ANALYSIS

Which type of company will be best equipped to address this emerging market for ASLP? Will the traditional catalog product vendor or the ASIC vendor be more successful?

Standard product firms have the advantages of being more likely to have serious product planning disciplines and being more accustomed to engaging their customers in applications dialogs. However, their engineers are likely to be "micron fiddlers," a disadvantage that leads to high design costs and a tendency to miss market windows because of long design times.

ASIC companies have the advantages of being familiar with the design tools and employing engineers that are not "micron fiddlers." While some ASIC companies leave all the applications work to their customers and do not have a well-developed product planning discipline, they are in touch with thousands of systems engineers who are all developing new applications. These ideas represent a greater diversity than can be encompassed by a single product planning group within a single company.

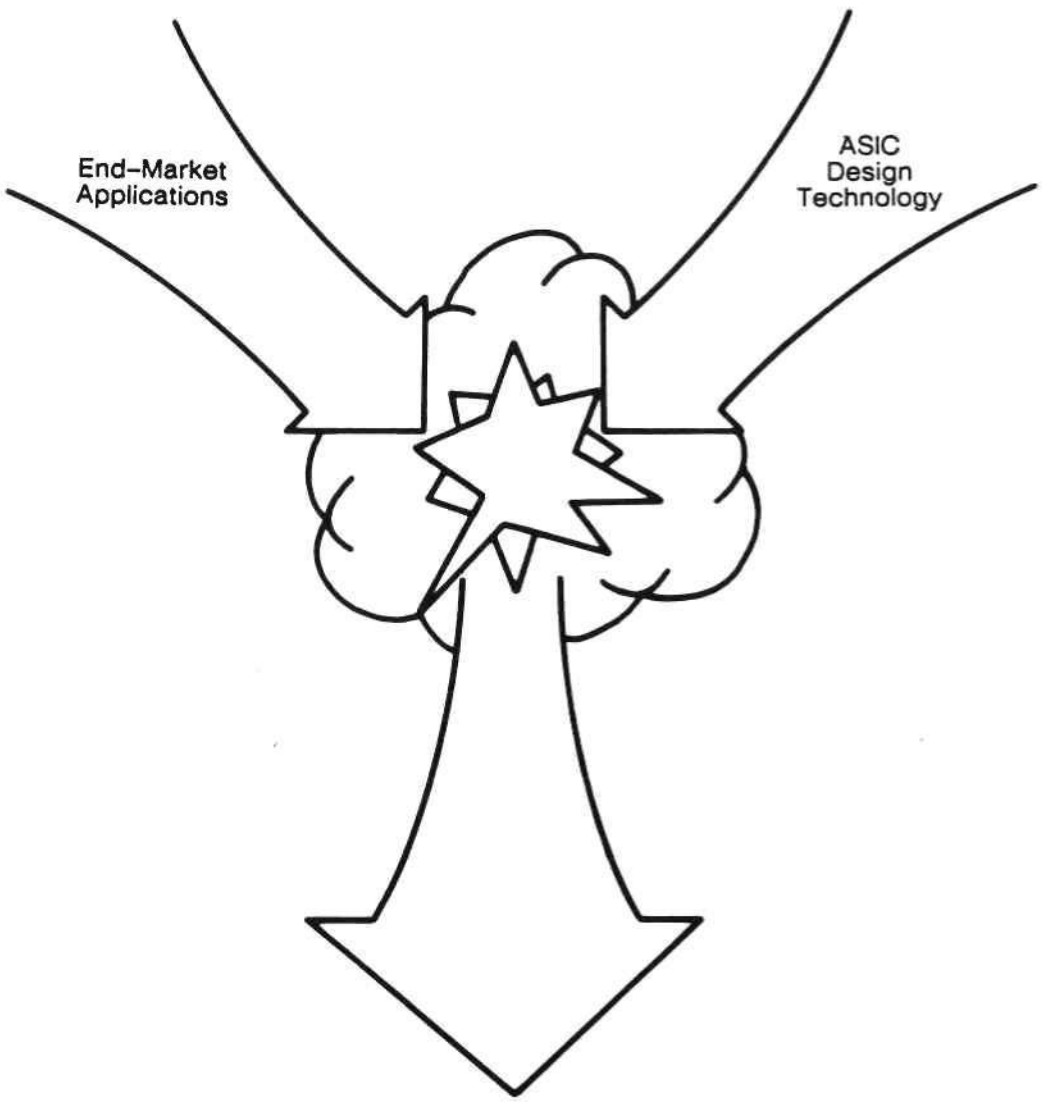
Excellence in manufacturing technology may create advantages for either the ASLP or the ASIC vendors. However, DATAQUEST believes that the basic thrust here is to create added value through applications in silicon, with manufacturing being of secondary importance.

The opportunity is available and it will go to the companies that can best combine the skills of the traditional catalog product and ASIC companies. The real key to success in ASLP is the ability to select, design, and market products that become the universally accepted standard. If this is done well, these companies will provide superior application solutions and excel at meeting the systems' needs of the customer.

Howard Z. Bogert
Andrew M. Prophet

Figure 1

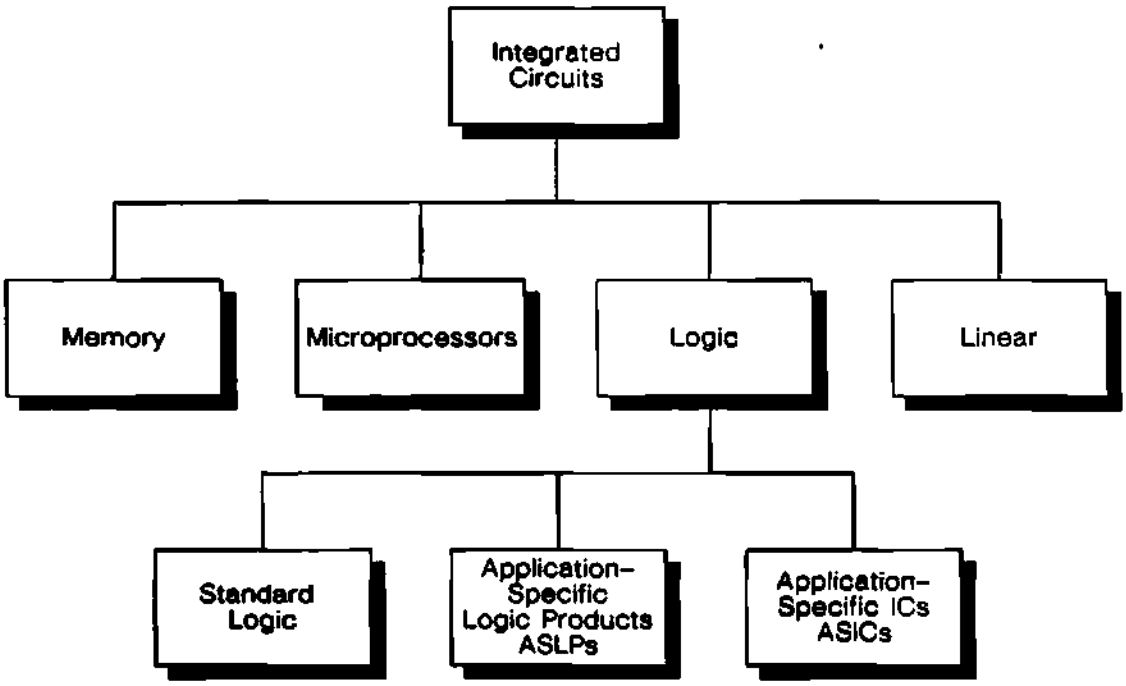
SOLVING THE DESIGN DILEMMA



Source: DATAQUEST
February 1986

Figure 2

PROPOSED EXPANSION OF LOGIC SEGMENTS



Source: DATAQUEST
February 1986

Table 1

PRODUCT TYPE EXAMPLES

Standard Logic	ASLP	ASIC
Bipolar logic ECL (10K, 100K, etc.)	Data communication	Cell-based designs (standard cells, compiled cells)
TTL (74/54LS, etc.)	Digital signal processing (DSP)	
CMOS 74/4000 series 74/54 hc, hct	Telecommunications circuits Display drivers Motion control	Field-programmable devices (PLDs) Full custom (hand-crafted designs) Gate arrays

Source: DATAQUEST
February 1986

March

March Newsletters

The following is a list of the newsletters in this section:

(continued)

March Newsletters

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RESEARCH BULLETIN

SIS Code: 1986-1987 Newsletters: March
1986-16

256K DRAM DUMPING MARGINS ANNOUNCED

U.S. SEMICONDUCTOR MANUFACTURERS WIN TWO IN ONE WEEK

For the second time this week, the U.S. Department of Commerce has ruled that Japanese companies are dumping semiconductors in the United States. Yesterday, the department announced its preliminary ruling on dumping margins to be imposed on Japanese 256K DRAM suppliers. The ruling is the result of a government-initiated antidumping petition filed late last year.

The average weighted dumping margin was determined to be 40 percent, with the margin by company as follows:

- Hitachi--20 percent
- Toshiba--50 percent
- Fujitsu--75 percent
- Mitsubishi--108 percent
- NEC--108 percent

As we stated in our March 11 Research Bulletin, these margins represent the percentage by which each company's price undercut its fully loaded cost of manufacturing plus an 8 percent profit margin. Beginning yesterday, the Japanese manufacturers will be required to post bonds to cover dumping duties on all imported 256K DRAMs; money collected during this period may or may not be refunded, depending on the final ruling by the U.S. International Trade Commission, which could take as long as 120 days from today. One year after the final ruling, the Japanese companies may appeal; if they can prove that they have been overcharged on dumping, money could be returned to them at that time.

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DATAQUEST ANALYSIS

We believe that it is very significant that the U.S. government is now establishing a pattern of supporting the domestic semiconductor industry through the EPROM and 256K DRAM antidumping rulings this week. We expect these rulings to give U.S. suppliers 6 to 12 months of breathing room in which to recover their strength and reposition themselves.

Several U.S. suppliers announced their withdrawal from the 256K DRAM market last year; however, in anticipation of yesterday's favorable ruling, Motorola announced last week that it is considering reentering the 256K DRAM market.

It is interesting to note that, although two suppliers (Mitsubishi and NEC) were assessed very high dumping duties (108 percent), the weighted average duty was only 40 percent. We believe that this is partially due to the fact that Hitachi, the number one supplier of 256K DRAMs in the world, was assessed at only 20 percent, possibly because of long-term contracts with large U.S. OEMs, such as IBM, which tend to have higher prices. Also, because Hitachi is the largest 256K DRAM seller in the United States, it is probably further down the learning curve.

We have observed that as a result of increased demand, market prices for the 256K DRAM have risen 10 to 15 percent since September 1985, and, at the same time, costs have been substantially reduced. Because of this, we doubt that there is much dumping actually occurring at current prices.

We expect the market price to increase further by less than 15 percent as a result of yesterday's ruling, and we believe that price erosion will return later this year. Regardless of price, we believe that Intel and National Semiconductor have left the DRAM market for good.

Lane Mason
Patricia S. Cox

Dataquest
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RESEARCH BULLETIN

SIS Code: 1986-1987 Newsletters: March 1986-15

EPROM DUMPING MARGINS ANNOUNCED

THE UNITED STATES RULES AGAINST JAPANESE EPROM MANUFACTURERS

The U.S. Department of Commerce today announced its preliminary ruling on dumping margins to be imposed on Japanese EPROM suppliers. The ruling is the result of an anti-dumping petition filed last fall by AMD, Intel, and National Semiconductor.

The average weighted dumping margin was determined to be 63.1 percent, with the margin by company as follows:

- Toshiba--21.7 percent
- Hitachi--30 percent
- Fujitsu--145 percent
- NEC--188 percent

These margins represent the percentage by which each company's price undercut its fully loaded cost of manufacturing plus an 8 percent profit margin. The margins will be applied across the board to all densities of EPROM sold in the United States by the assessed companies.

Beginning today, the Japanese manufacturers will be required to post bonds to cover dumping duties on all imported EPROMs; money collected during this period may or may not be refunded, depending on the final ruling by the U.S. International Trade Commission, which could take as long as 120 days from today. Figure 1 describes the procedural timetable for dumping disputes. It must be noted that one year after the final ruling, the Japanese companies may appeal; if they can prove that they have been overcharged on dumping, money could be returned to them at that time.

Still pending at the Commerce Department is the government-initiated 256K DRAM dumping preliminary ruling. That ruling on dumping margins is expected to occur March 14. We will issue a bulletin as soon as the ruling is announced.

DATAQUEST ANALYSIS

DATAQUEST believes that this ruling will result in more EPROM revenue for the major U.S. suppliers--AMD, Intel, National, and TI--because:

- Competition on price alone is softening.

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- Prices will go up.

- One or more Japanese companies may choose to stop selling EPROMs in the United States, thereby giving U.S. firms a greater share of the market.

Costs for U.S. manufacturers have been decreasing as they have struggled to remain competitive (particularly Intel, which has spent the recession learning how to build EPROMs on high-yielding 6-inch wafers in Albuquerque); so increased revenues will have a very positive effect on profits.

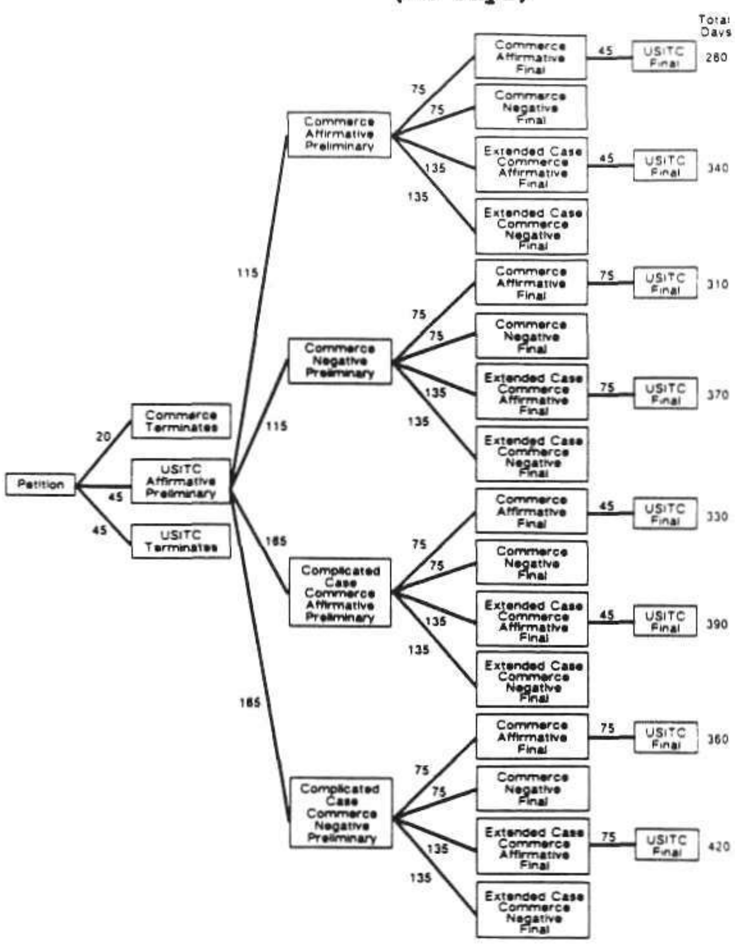
Higher profits will enable the U.S. companies to re-invest more money in efficient manufacturing of higher-density and future-generation EPROMs (i.e., 1Mb and 4Mb).

We believe that it is significant that the U.S. government has supported our domestic semiconductor manufacturers through this preliminary ruling, and we expect future decisions to have equally positive effects on the U.S. semiconductor industry.

Lane Mason
Patricia S. Cox

Figure 1

STATUTORY TIMETABLE FOR ANTIDUMPING INVESTIGATIONS
(In Days)



Source: International Trade Commission

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RESEARCH NEWSLETTER

SIS Code: 1986-1987 Newsletters: March 1986-14

ISSCC 1986: CAD TOOLS INFLUENCE DESIGNS-- DESIGNS CONTINUE TO STRETCH THE LIMITS

SUMMARY

The thirty-third annual International Solid State Circuits Conference (ISSCC) was held in Anaheim, California, from February 19 to 21. One hundred and two papers on a variety of topics were presented at 17 formal sessions. Ten informal sessions allowed for off-the-record discussion of high-interest topics. Table 1 lists the sessions and summarizes the papers presented by country of origin and technology.

The keynote address, delivered by James E. Soloman, president and CEO of SDA Systems in Santa Clara, California, was titled "Computer-Based Design for Tomorrow's Super Chip." This talk discussed the implications of CAD tools on the designs of the future.

Several statistics come out of the ISSCC papers that can yield information about the future of the industry. For example, authorship of the papers at the ISSCC can be examined for indications of the level of research going on in a given company, institution, or region of the world. Last year, papers presented by Japanese companies outnumbered those presented by U.S. companies for the first time. This year, however, U.S. companies presented significantly more papers than their Japanese counterparts.

Furthermore, the technologies employed in the devices described are indications of technology momentum. The dominant technology this year was CMOS, as it has been for the last several years. Of the 102 papers presented at the conference, 51 described CMOS devices. Twenty-six papers were presented on memories, the largest number for any single topic.

This newsletter presents an overview of the conference and keynote speech, followed by an analysis of paper authorship and device technology. The formal sessions are then summarized by product area, and the informal evening sessions are discussed. Included are four tables that summarize the product specifications of the static RAMs, dynamic RAMs, microprocessors, and ASICs presented at the conference.

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Table 1

1986 ISSCC SESSION SUMMARY

Session Number	Topic	Number of Papers	Authorship: North America Merch.	Authorship: North America Captive	Authorship: Japan	Authorship: Europe	Technology Employed: MOS CMOS	Technology Employed: MOS NMOS	Technology Employed: CCD	Technology Employed: Bipolar	Technology Employed: Bi-CMOS	Technology Employed: GaAs	Technology Employed: Other
I.	Analog Techniques	6	5			1	3	1		2			
II.	Microprocessors/Coprocessors	6		4	1	1	2	3		1			
III.	Nonvolatile and Application-Specific Memories	6	5		1		4	1		1			
VI.	Optical Data Links	4		3		1	2	1		1			
VII.	Semicustom Arrays	7	2		5		2			1	1	3	
VIII.	Digital Signal Processing	4			2	2	3	1					
IX.	Sensors and Interface Electronics	6		2	4		1	1	2	2			
X.	Special-Purpose Processors and Controllers	4	2	1	1		2	2					
XI.	D/A and A/D Converters	6	1	3	1	1	4			2			
XII.	Video and Image Signal Processing	6		1	3	2	4	1		1			
XIII.	VLSI Modeling and Packaging	6		6			2						4
XIV.	Voice-Band Telecommunications ICs	6	1	1	3	1	4			2			
XV.	High-Speed Digital Circuit Technology	7	2	1	3	1	1	1		2	1	1	1
XVI.	Static RAMs	7	1	2	4		3	1		2	1		
XVII.	Analog Processors	4	3	1			1	1		1			1
XVIII.	Reconfigurable Logic Arrays	4	4				4						
	and Static RAMs	5			5		3			2			
XIX.	Dynamic RAMs	8	3		5		6	2					
	Totals	102	29	25	38	10	51	16	2	20	3	4	6

Wednesday Evening Informal Sessions

Architecture for DSP VLSI
Practical Limits of IC Testers
4-16Mb DRAMs: Cost Performance Trade-Offs
Competing Technologies for Ultrahigh-Speed SRAMs and their Application
Microprocessors in the Year 2001

Thursday Evening Informal Sessions

Reduced Instruction Set Computers
ISDN: The Future for Telecom VLSI
Application-Specific Memory Designs and Their Reality
Implementing the VLSI Transition to 3 Volts
Liquid-Nitrogen-Cooled CMOS

Source: 1986 ISSCC Digest of Technical Papers
DATAQUEST
March 1986

KEYNOTE SPEECH AND CONFERENCE OVERVIEW

The devices discussed at the ISSCC are at the leading edge of semiconductor design and processing. For example, this year's static RAM offering consisted of all high-speed, high-performance products. As always, the next generation of dynamic RAMs were presented and some impressive processors were discussed, including an IBM 370 on a chip. Sessions on digital signal processing and video and image signal processing addressed the growing interest in signal processing technology. In addition, discussion of analog techniques and analog processors illustrated the need for analog communications as we move toward high-speed communications.

One of the most interesting conclusions of Mr. Soloman's keynote speech was that in years to come, designers will use hierarchical and structured design styles to develop new ICs. When that happens, the design techniques used now for ASICs (including the use of macrocells and block libraries) will be used to design almost all ICs. As a result, the biggest challenge for talented IC designers will be to develop circuit or block compilers that will let anyone specify the capabilities of a chip and that will then automatically generate the desired chip.

A number of the papers presented at the conference seemed to support Mr. Soloman's assertion. For instance, a paper presented by Peter A. Ruetz and coauthored by Robert W. Broderson, both of the University of California at Berkeley, described an eight-chip set for real-time image processing. Circuit blocks were designed so that they could be used in several different chips, and the chips were designed as functional blocks that could be used in different applications. In addition, CAD tools were used to generate circuits automatically. The entire chip set was designed in just 15 person-months.

AUTHORSHIP AS A RESEARCH BAROMETER

Authorship of ISSCC papers can be an indication of the R&D levels in a given institution or region of the world. This must be tempered, however, by the understanding that emphasis on publishing varies from one institution to another. Table 2 shows that last year, for the first time, Japanese companies presented more papers at the ISSCC than U.S. companies did. This year the statistics were reversed, with U.S. companies presenting 53 percent of the papers. However, the 54 U.S. papers presented in 1986 represented the work of 30 institutions and companies (an average of 1.8 papers per institution or company), while the 38 Japanese papers were generated by only 9 companies (4.2 papers per company).

Table 2

ISSCC TECHNICAL PAPERS BY COUNTRY OF ORIGIN
(Percent)

Country	1980	1981	1982	1983	1984	1985	1986
United States	68%	61%	66%	50%	51%	43%	53%
Japan	25	25	29	42	39	45	37
Western Europe	7	14	5	8	10	12	10
Total	100%	100%	100%	100%	100%	100%	100%
Total Papers*	89	88	100	97	112	108	102

*Excluding panel sessions and keynote speakers

Source: DATAQUEST
March 1986

Table 3 lists the top eight suppliers of ISSCC papers in 1985 and 1986. Note that NEC was the top source of papers this year. Hitachi was the leading supplier of papers in 1985, but its contribution dropped somewhat this year, while IBM's contribution level rose quite a bit from 1985 to 1986.

Table 3

LEADING SOURCES OF ISSCC PAPERS IN 1986
(Number of Papers)

Company	1985	1986
NEC	8	8
IBM	2	7
Hitachi	14	6
Mitsubishi	4	6
Toshiba	9	6
AT&T Bell Laboratories	6	5
NTT	2	5
National Semiconductor	3	4
Others	60	55
Total	108	102

Source: DATAQUEST
March 1986

DEVICE TECHNOLOGY: MOVEMENT TOWARD CMOS

Exactly half of the papers presented at this year's ISSCC described devices that employed CMOS technology (see Table 1). Bipolar parts were the second most common device type discussed, followed by NMOS. Although the number of bipolar devices presented was much lower than the number of MOS devices, the parts that use bipolar technology continue to be high-speed, high-performance parts, as they have been in the past. At least half of the bipolar devices presented were ECL parts or had ECL I/Os.

FORMAL SESSIONS

Memories

Three formal sessions on memories were presented, and a session on reconfigurable logic arrays was expanded to include five late static RAM papers. In total, 26 of the 102 papers presented were on memory devices. In addition, 3 of the 10 informal evening sessions were on memory topics.

Static RAMs were a topic of very high interest this year. All of the devices presented in the SRAM session were high speed. Toshiba presented a megabit pseudostatic RAM that looks almost like a static RAM to the outside world but uses dynamic RAM cells. This device had an access time of 65ns and was the slowest SRAM described, as every other static RAM discussed was 30ns or faster. Motorola unveiled a 64K CMOS SRAM with an access time of 13ns and Hitachi discussed a 13ns 16Kx4 Hi-BiCMOS device.

Every bipolar RAM presented this year was faster than anything currently on the market. The fastest RAMs presented were from Fujitsu and IBM. Fujitsu unveiled a 2.8ns 16K ECL RAM with 1.2K gates of logic on-board. The primary advantage of having the logic and memory on the same chip is increased speed. The fastest 16K ECL RAM currently available is also from Fujitsu and runs at 10ns. However, it dissipates much less power than the device described this year. IBM discussed a 3ns 32K complementary transistor switch (CTS) RAM. There are no 32K bipolar RAMs on the commercial market. Table 4 summarizes the devices presented in the static RAM sessions.

The dynamic RAM session featured 256K to 4Mb devices. The specifications of those devices are summarized in Table 5. Six of the parts were CMOS, and three used NMOS technology. Of particular interest was Texas Instruments' 4M DRAM, which uses a three-dimensional, cross-point, one-transistor cell.

A session on nonvolatile and application-specific memories included papers on a 1Mb CMOS EPROM from Advanced Micro Devices (AMD), a 2Mb mask ROM from Toshiba, and a 25ns 128K TTL PROM from AMD. The AMD 128K PROM is the densest bipolar PROM available.

Table 4

STATIC RAM PRODUCT SYNOPSIS

Session Number	Company	Chip Org.	Process	Design Rule (u)	Metal Levels	Poly Levels	Cell Size (u)	Chip Size (mm)
16.1	Toshiba	8Kx9	NMOS	1.5	2	2	11.0 x 20.0	4.22 x 7.02
16.2	Sony	32Kx8	P-well CMOS	1.0	2	1	10.6 x 13.2	6.54 x 8.15
16.3	IBM	4Kx16	CMOS (NMOS cell)	1.35	1	1	$210u^2$	N/S
16.4	Motorola	16Kx1/ 16Kx4	P-well CMOS	1.5	2	2	11.4 x 16.6	3.4 x 8.86
16.5	IBM	4Kx8	CTS bipolar	1.5	3	N/S	$618u^2$	6.6 x 6.6
16.6	Hitachi	16Kx4	Hi-BiCMOS with ECL I/O	2.0	2	2	$230u^2$	4.4 x 6.8
16.7	Hitachi	4Kx4	ECL	1.0	N/S	N/S	$495u^2$	6.1 x 3.3
18.5	Mitsubishi	256Kx1/ 64Kx4	CMOS	1.0	1	2	7.5 x 12.0	4.48 x 10.59
18.6	NEC	256Kx1	CMOS	1.3	2	2	8.2 x 15.2	4.7 x 13.37
18.7	Toshiba	128Kx8	Twin-well CMOS	1.2	2	2	3.5 x 8.4	5.99 x 13.8
18.8	NEC	4Kx4	ECL	1.25	N/S	2	$700u^2$	5.5 x 4.9
18.9	Fujitsu	16K (variable organization) plus 1.2K gate logic array on-board	ECL	1.0	3	N/S	3.3 x 15 (Memory cell)	9.4 x 9.5

N/S = Not Specified

(Continued)

Table 4 (Continued)

STATIC RAM PRODUCT SYNOPSIS

Session Number	Company	Access Time	Power	Package	Comments
16.1	Toshiba	18ns	500mW-A 50mW-S	300-mil, 28-pin DIP	
16.2	Sony	30ns	85mW-A 500nW-S	600-mil, 28-pin DIP	At 10 MHz
16.3	IBM	15ns	325mW-A	N/S	
16.4	Motorola	13ns	120mW-A	300-mil, 22-pin DIP	
16.5	IBM	3ns	5W	N/S	
16.6	Hitachi	13ns	500mW-A 300mW-S	N/S	ECL 10K I/O
16.7	Hitachi	3.5ns	2W	N/S	
18.5	Mitsubishi	25ns	30/45mW-A 30uW-S	300-mil, 24-pin DIP	
18.6	NEC	25ns	350mW-A 10uW-S	300-mil, 24-pin DIP	
18.7	Toshiba	62ns	105mW-A 2mW-S	600-mil, 32-pin DIP	Pseudostatic RAM; uses DRAM cell
18.8	NEC	4ns	1.6W	28-pin, 0.4-inch square LCC	ECL 100K interface
18.9	Fujitsu	2.8ns (gate propogation delay = 280ps)	4.4W (plus 2.7W gate array)	180-pin flatpack	

A = Active power
S = Standby power
N/S = Not Specified

Source: 1986 ISSCC Digest of Technical Papers
DATAQUEST
March 1986

Table 5

DYNAMIC RAM PRODUCT SYNOPSIS

Session Number	Company	Chip Org.	Process	Design Rule (u)	Metal Levels	Poly Levels	Cell Size (u)	Chip Size (mm)
3.5	Mostek	64Kx4	LDD NMOS	1.5	2	2	4.5 x 12	N/S
19.1	Mitsubishi	64Kx4	N-well CMOS	1.2	1	2	4.4 x 8.1	3.08 x 6.93
19.2	Intel	256Kx4	CMOS	1.0	N/S	N/S	3.8 x 7.5	5.3 x 9.58
19.3	Texas Instruments	1Mb x 1/ 256Kx4	CMOS	1.0	1	2	2.5 x 8.5	4.3 x 11.7
19.4	Toshiba	1Mb x 1/ 256Kx4	N-well CMOS	1.2	N/S	3	3.24 x 9	4.4 x 12.32
19.5	Texas Instruments	1Mb x 4	Twin-well CMOS	1.0	2	N/S	2.6 x 3.4	9.8 x 10.2
19.6	NEC	4Mb x 1	NMOS	0.8	1	2	2.3 x 4.6	6.2 x 16.0
19.7	Toshiba	4Mb x 1/ 1Mb x 4	Twin-well CMOS	1.0	1	2	3.0 x 5.8	7.84 x 17.48
19.8	Matsushita	256Kx4	NMOS	1.2	2	2	4.5 x 7.8	5.88 x 11.2

N/S = Not Specified

(Continued)

Table 5 (Continued)

DYNAMIC RAM PRODUCT SYNOPSIS

Session Number	Company	Speed	Power	Package	Comments
3.5	Mostek	trac = 65ns tsca = 15ns	400mW-A 15mW-S	400-mil, 24-pin DIP	4 rows, 16 columns redundancy
19.1	Mitsubishi	trac = 16ns tras = 47ns	115mW-A N/S - S	N/S	
19.2	Intel	trac = 65ns tcac = 15ns	N/S	N/S	8ms refresh time
19.3	Texas Instruments	tras = 70ns tcas = 12ns	225mW-A 4mW-S	300-mil, 18/20-pin DIP	26-pin SOJ package option (300-mil, plastic)
19.4	Toshiba	trac = 56ns	175mW-A 250uW-S	300-mil, 18/20-pin DIP	26-pin SOJ option
19.5	Texas Instruments	tras = 170ns tscd = 30ns	500mW-A 40mW-A	N/S	Laser redundancy with 4 rows, 2 columns
19.6	NEC	taa = 95ns	425mW-A 15mW-S	350-mil, 18-pin DIP	1,024-cycle/16ms refresh
19.7	Toshiba	trac = 80ns tcac = 15ns	300mW-A 2.5mW-S	400-mil Ceramic DIP	8 rows x 8 columns redundancy 1,024-cycle refresh
19.8	Matsushita	serial taa = 25ns	N/S	600-mil, 40-pin DIP	Serial I/O ports

A = Active power
S = Standby power
N/S = Not Specified

Source: 1986 ISSCC Digest of Technical Papers
DATAQUEST
March 1986

Microdevices

Several sessions focused on microdevices. The first one was a session on microprocessors and coprocessors. The six devices presented at this session are summarized in Table 6. Three of the parts were NMOS devices, two were CMOS, and one was bipolar. IBM presented two microprocessors at this session. One of these was an IBM 370 on a chip. It is a 32-bit device built with NMOS technology that has built-in diagnostics and a 68000-bus interface on the chip.

NEC described a V60 processor that is 32-bit internally and has a 16-bit data bus. The V60 is part of NEC's V series and will be the foundation on which the V70, NEC's 32-bit processor, will be built. Of the processors presented this year, we believe that this part will be the only one that will be a factor in the commercial sector. The others will likely remain in captive production only. Three of the remaining four processors were described as 32-bit devices, and the fourth device, presented by Hewlett-Packard, was a 64-bit floating-point chip set that is accessed via a 32-bit bidirectional data bus.

A second session on microdevices focused on special-purpose processors and controllers. Included in this session were a CMOS disk data controller from National Semiconductor, an NMOS digital signal processor for motor control from SDA Systems, Inc., and two processors for video applications. This type of device will be seen more and more in the microprocessor arena. Many manufacturers are moving toward special-function or dedicated processors. We believe that the concepts of intelligent peripherals and special-function processors will eventually meet, so that disk controllers will incorporate some of the functionality of a microprocessor. This trend is illustrated by some of the devices discussed at this session.

ASICs

Two sessions on ASICs were presented. Table 7 summarizes the specifications of the products presented in those sessions. The first session covered gate arrays. Of the seven devices presented, two used CMOS technology, one used ECL, one was a biCMOS device, and three were made with gallium arsenide. No standard cells were presented at the conference.

The second ASIC session covered programmable logic devices (PLDs). Four U.S. companies presented CMOS devices. The PLDs from Lattice and Exel use EEPROM technology (EEPLD), while the Cypress and Altera parts use EPROM technology (EPLD). These are high-performance devices with short propogation delays and low power requirements; the part from Lattice has an input-to-output delay time of 16ns, and the delay for the Cypress part is 19ns with power consumption of 250mW.

Table 6

MICROPROCESSOR PRODUCT SYNOPSIS

Session Number	Company	Chip Org.	Process	Design Rule (u)	Metal Levels	Poly Levels	Description	Package
2.1	Sperry	36/72-bit	N-well CMOS	1.2	2	N/S	Micro/mainframe 6 chip set	224 PGA
2.2	IBM	32-bit	NMOS	2.0	2	1	Single chip uP	171 pins
2.3	IBM	32-bit	Bipolar CBCL (differential cascade ECL)	N/S	3	N/S	Processor chip	288 pins
2.4	U.C. Berkeley	32-bit	NMOS	4.0	1	N/S	Smalltalk uP	84 PGA
2.5	HP	64-bit 32-bit data bus	NMOS	1.5	N/S	N/S	Floating-point chip set	N/S
2.6	NEC	32-bit internal 16-bit data bus	CMOS	1.5	2	N/S	VLSI uP with on-chip virtual memory management	68 PGA

N/S = Not Specified

(Continued)

Table 6 (Continued)

MICROPROCESSOR PRODUCT SYNOPSIS

Session Number	Company	Transistor Count	Chip Size (mm)	Power	Comments
2.1	Sperry	786,000	9.47 x 9.47	N/S	
2.2	IBM	93,000 (200,000 sites)	10 x 10	3W	
2.3	IBM	22,400 equivalent	14.5 x 16.1	16W	60ns instruction cycle
2.4	U.C. Berkeley	35,700	8.13 x 10.97	3W	400ns cycle
2.5	HP	150,000	6.7 x 7.1	3W	1-12 MFLOPS
2.6	NEC	375,000	13.9 x 13.8	1.5W	3.5 MIPS at 16-MHz clock

N/S = Not Specified

Source: 1986 ISSCC Digest of Technical Papers
DATAQUEST
March 1986

Table 7

ASIC PRODUCT SYNOPSIS

Session Number	Company	Device	Process	Design Rule (u)	Metal Levels	Chip Size (mm)
7.1	NEC	Macroarray	N-well CMOS	1.6	2	4.5 x 4.5
7.2	National Semiconductor	FPLA	BiCMOS	3.0 bipolar 2.0 CMOS	N/S	3.56 x 5.13
7.3	NEC	3K GA	GaAs D-MESFET	1.4	N/S	7.5 x 7.4
7.4	TI	4K GA	GaAs HI^2L	5.0	2	5.8 x 5.8
7.5	Mitsubishi	18K GA	Bipolar	1.5	3	11.9 x 11.96
7.6	Mitsubishi	438K transistor master slice	CMOS	1.3	2	11.96 x 12.7
7.7	Fujitsu	1.5K GA	GaAs HEMT E/D DCFL	1.2	2	5.5 x 5.6
18.1	Lattice	EEPLA	N-well CMOS	1.3 PMOS 1.2 NMOS	1	2.95 x 3.10
18.2	Altera	EPLD	CMOS	N/S	N/S	N/S
18.3	Exel	EE ASIC	N-well CMOS	2.0	2	3.07 x 4.62
18.4	Cypress	EPLD	N-well CMOS	1.2	N/S	3.1 x 4.1

N/S = Not Specified

(Continued)

Table 7 (Continued)

ASIC PRODUCT SYNOPSIS

Session Number	Company	Speed	Power	Package/Pins	Comments
7.1	NEC	N/S	N/S	N/S	
7.2	National Semiconductor	tpd = 24ns	625mW-A 5uW-S	N/S	16 inputs, 64 product terms, 8 outputs; tungsten fuses
7.3	NEC	tpd = 88/56ps unloaded	2.3/4.6 mw/gate	136 PGA	CML I/O
7.4	TI	tpd = 400ps/ gate	5.5W	134 PGA	-100 to +200 degrees C operating temperature range
7.5	Mitsubishi	150ps/gate	N/S	312 PGA	ECL 100K interface
7.6	Mitsubishi	1.2ns/gate	N/S	107 pins	TTL interface
7.7	Fujitsu	tpd = 85ps at 300K	5.8W	88 pins	4.9ns 8 x 8 multiplier at 300 degrees K
18.1	Lattice	16ns input to output delay	N/S	N/S	100 W/E cycles max., 10-year retention, two-level poly
18.2	Altera	tpd = 25ns	N/S	N/S	Intel did the processing
18.3	Exel	15ns internal level +10ns I/O	50mW at 10 MHz	300-mil, 24-pin DIP	Two-level poly, 33,400 transistors
18.4	Cypress	19ns input to output	250mW-A 100mW-S		10^6 years retention at 75 degrees C

A = Active power
S = Standby power
N/S = Not Specified

Source: 1986 ISSCC Digest of Technical Papers
DATAQUEST
March 1986

Both EPROM and EEPROM technologies are beginning to emerge in the PLD area, and it is not yet clear which will be the technology of choice. There are some trade-offs between the two. EEPROM technology allows for erasing and reprogramming devices while they are still in the socket, but it can be argued that very few applications really need this feature. If that is true, then EPLDs may dominate in most PLD applications. In any case, the market for EEPLDs will very definitely need to be developed by the manufacturers, as has been the case in the EEPROM market.

Signal Processing

Two sessions on signal processing were presented. The first covered digital signal processors, and the second was on video and image signal processors.

Three of the most interesting parts unveiled were from NEC, Philips, and Toshiba. NEC presented a 32-bit digital signal processor that can do a floating-point multiply in 150ns. Philips discussed a 125ns machine that has two full-duplex serial channels for connecting together multiple processors. Toshiba unveiled a 20-MHz, 32-bit pipelined CMOS image processor.

The interest in signal processing at the ISSCC mirrors the interest within the industry. The number of client inquiries that DATAQUEST currently gets on digital signal processing, for example, is probably 10 times what it was a year ago. The reasons for this growing interest are manifold. First, interest in a hot topic like this seems to feed on itself. The more the topic is discussed and explored, the more people want to take advantage of the burgeoning interest. Second, this is another example of the trend toward application specificity and the desire of the industry to move toward dedicated processors. Another reason for the heightened interest is that digital signal processing (DSP) has been defined differently by different people. DSP is really a design technique more than an application, and many of the devices that use DSP techniques go into applications other than signal processing. For this reason, hugely different projections of the DSP market size have been made. In addition, with the growing interest in DSP, devices that have not historically been considered DSP devices are being lumped into that category. Examples would be D/A and A/D converters, which have traditionally been considered part of the linear market, and devices like multiplier/accumulators.

INFORMAL SESSIONS

Wednesday night's informal sessions covered the limits of some topical technologies and devices; interest in the sessions was high. The session covering 4Mb to 16Mb DRAMs was well attended. Some of the areas addressed in the discussion were standards issues, including packaging and pin-outs, and the question of how to test these very large DRAMs.

The high-speed SRAM debate pitted proponents of CMOS, bipolar, and gallium arsenide SRAMs against one another in a discussion of the role that each of those technologies will have in the fast SRAM arena. Attention was also focused on how dual-port memories and on-board registers could be used.

Another Wednesday session focused on microprocessors in the year 2001. The future of special-purpose processors and signal processors as well as the possible uses for processors with huge numbers of transistors were discussed. Some of the barriers that will need to be overcome to get microprocessor technology to the year 2001 were also discussed.

Thursday night's RISC architecture session featured some lively discussion on whether RISC should be used at all. The hottest debate seemed to be between individuals from universities, who have been pushing for RISC architecture, and industry representatives, some of whom have more doubts about the concept.

Application-specific memories were also the topic of a discussion on Thursday, and attention at that session seemed to focus on the types of applications where specialized memories could have the most impact. The applications included video RAMs, dual-port memories, and content-addressable memories.

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RESEARCH
NEWSLETTER

SIS Code: 1986-1987 Newsletters: March
1986-13

THE QUICK ASIC: TOMORROW'S PROTOTYPING TOOL

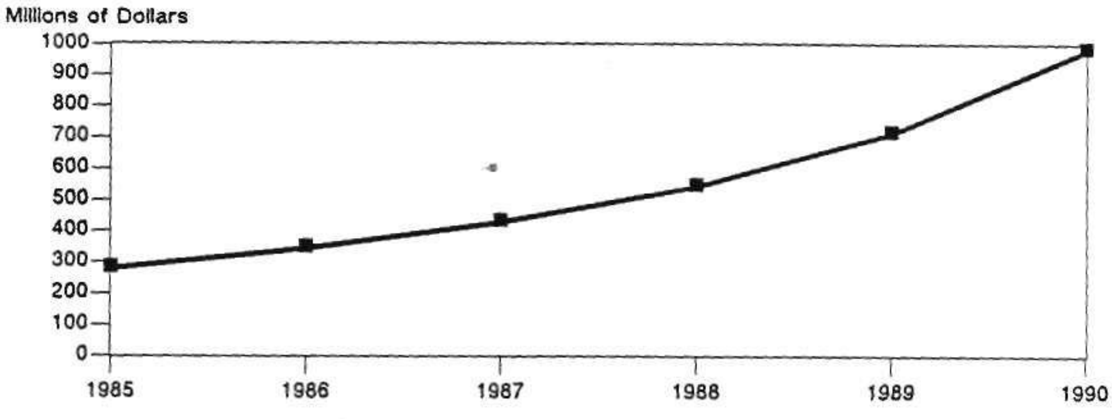
STRESS REDUCTION MEDICINE

If a thousand design engineers were asked about the cause of their anxiety and sleepless nights, they would unanimously respond, "Waiting for the prototype parts to arrive from the application-specific integrated circuit (ASIC) supplier." After months of work on a design, they wait anxiously for the first parts and hope that there are no errors. While today's electronic design automation (EDA) tools have eliminated a major portion of the errors in the design process, they cannot give advance warning of a missing logic element, or a change in the system requirements, or, even worse, the fact that the manufacturer is missing a market window.

Fortunately, this problem has not gone unnoticed. DATAQUEST believes that as the ASIC design methodologies expand into wider applications, there will be a very strong emphasis on reducing the ASIC design time and the prototype turnaround time; furthermore, there will be a group of suppliers that will bring their resources to bear on this problem. Figure 1 shows our estimate of this market and its robust growth from 1985 through 1990.

Figure 1

ESTIMATED WORLDWIDE CONSUMPTION OF QUICK ASIC



Source: DATAQUEST
March 1986

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This newsletter reviews a number of very different and creative technologies that could play a critical role in quick turnaround ASIC or, as we call it, Quick ASIC. Our definition of Quick ASIC is that the cycle time is less than two weeks from the time a verified logic schematic is submitted to the ASIC supplier to the time the prototype parts are returned. We will briefly examine three very different methods:

- Programmable logic devices (PLDs)
- Direct-write E-Beam systems
- Late-mask laser processing systems

Each method has its followers and each offers a very different way to get Quick ASIC. But, regardless of which approach wins, we believe that it will significantly alter both the entire ASIC market and the printed circuit market, and that it will ultimately precipitate a decline in the consumption of standard SSI and MSI logic for breadboarding.

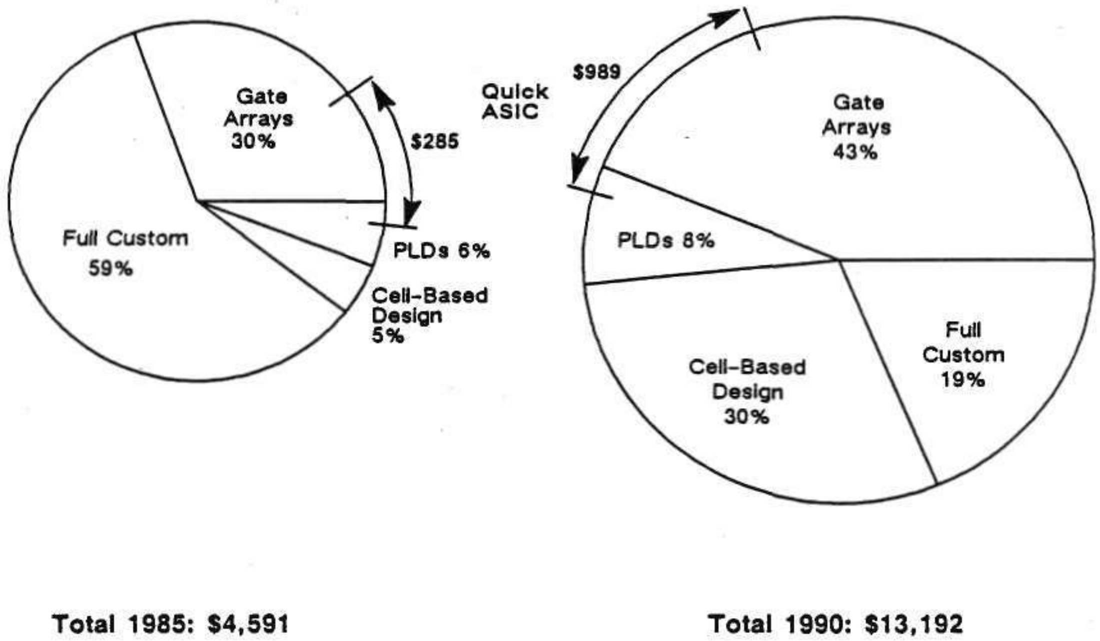
QUICK ASIC--A NEW WAY TO LOOK AT THE MARKET

The total ASIC market can be segmented into two major groups. The first group is composed of PLDs and gate arrays, and the second group is composed of cell-based and full custom designs. Both groups continually strive to reduce turnaround time for a design, but the first group offers the quickest prototype parts, largely because it tailors the fabrication process to the quickest turnaround. In the case of PLDs, the customer customizes the chip, while for gate arrays, the wafers are preprocessed up to the last two layers of metal and held in an unfinished inventory. When a supplier receives an order, the last two layers of metal are applied and the array is shipped. Therefore, both PLD and gate arrays can satisfy our definition of Quick ASIC. For the second group, the preprocessing of the wafer is not possible; thus, they are not considered candidates for our new definition of Quick ASIC.

A closer examination of PLDs and gate arrays (as shown in Figure 2) suggests that there is a growing potential subsegment to support quick-turnaround demand. This can be seen by looking at these markets in a new way, which shows that 6 percent of all ASICs in 1985 were Quick ASIC. Research through our data bases shows that as much as 5 percent of the 1985 PLD revenue and 27 percent of the gate array revenue was devoted to prototypes. In the case of gate arrays, the vast majority of the non-recurring engineering (NRE) charges can really be called Quick ASIC. We also believe that, as the overall ASIC market continues to grow, the Quick ASIC segment will grow to 7.5 percent of the total ASIC market by 1990. While market share appears to only gain a few percentage points, it is important to note that in 1985 this subsegment was $285 million, and that by 1990 it is expected to become a $989 million market.

Figure 2

ESTIMATED SUBSEGMENTATION OF QUICK ASIC
(Millions of Dollars)



Source: DATAQUEST
March 1986

PLDs--The Original Quick ASIC

While most PLDs are not used for prototyping, they have in the past six years frequently appeared on the designer's breadboard as a way to make those vital last minute changes. We estimate that in 1985 about $15 million of the total PLD consumption was used in prototype applications. But the future possibilities for the quick-turn arena are even more interesting. Recently, a proliferation of new processes have been applied in this market. For example, some young, aggressive companies such as Altera, Cypress, and Lattice have introduced CMOS products using UV or EE technology, and some larger companies, such as Monolithic Memories, Intel, AMD, and Signetics are expected to announce a host of parts in 1986. These new products have a much wider appeal than just prototypes. In fact, the vast majority of the current PLD consumption goes into production applications rather than prototypes; but as the total PLD market grows, so will the Quick ASIC share.

While critics say PLDs have a relatively rigid architecture compared to gate arrays, we have found a remarkable diversity in types of configurations offered and we expect this to continue. A growing cadre of designers have recognized this diversity. For example, Altera offers a family of products that have a degree of freedom far beyond that of the parts available in the early 1980s. Xilinix, a Silicon Valley start-up, offers the ultimate in swift-configured logic. In the logic cell array, as it is called, the interconnect of the logic can be reconfigured by loading interconnect patterns from a static RAM in less than 12 milliseconds; thus, the logic can be changed under program control even after the part is installed.

Part of the PLD growth is due to two important factors. First, PLDs can be manufactured like any other standard product, thus reaping all the benefits of economies of scale in semiconductor manufacturing. The second factor can be traced to the emergence of low-cost EDA tools. But perhaps the real advantage of PDL is that the user can customize a product rather than having the supplier do it; it is this freedom that continues to attract users.

Quick Gate Arrays

There is a small group of gate array suppliers that see a window of opportunity in expediting prototype parts for their customers. In Japan, for example, many of the large, vertically integrated consumer electronic companies such as Casio, Citizen, Pioneer, Ricoh, Seiko, and Yamaha process prototypes in less than two weeks. While these arrays are relatively low in gate count--less than 500 gates--it does show that there is a strong demand for rapid prototypes in certain applications. In North America, several companies are rushing to streamline their process flows to less than four weeks. Orbit Semiconductor (formerly Comdial) and California Devices deliver both 2- and 3-micron CMOS engineering prototypes in 15 working days. While most users are willing to wait longer for the more complex arrays (i.e., greater than 8,000 gates), we believe that there is latent demand for even faster prototypes, which will ultimately affect the high gate count arrays, too.

DATAQUEST believes that this growing demand will stimulate the creative use of two emerging technologies:

- Direct-write E-Beam lithography
- Late-mask laser processing

We think this may ultimately cause a segmentation of the gate array market into a Quick ASIC and a production ASIC market.

Direct-Write E-Beam Systems

To understand the role of direct-write E-Beam technology in ASIC, we must look at its origins at IBM. Direct-write E-Beam has been used in producing low-volume, fast-turn ASIC devices for more than ten years. More recently, the merchant ASIC companies, which also must manufacture low volumes of ICs with fast turnarounds, are beginning to purchase direct-write tools. Direct-write provides a faster turnaround than optical lithography because the mask fabrication is not necessary, which also eliminates the cost of the mask set. Thus, DATAQUEST believes that E-Beam lithography will find major use in low-volume ASIC production and fast-turn prototyping.

Table 1 shows the total worldwide installed base of direct-write systems by manufacturers through 1985. It is important to understand that as many as 50 of these systems are used in ASIC applications and that most of those systems are used in captive semiconductor operations. Nevertheless, we expect the merchant segment to grow significantly. DATAQUEST has identified three companies in this merchant segment that have made an early start in using direct-write E-Beam technology to do Quick ASIC.

Table 1

TOTAL WORLDWIDE INSTALLED BASE BY MANUFACTURER OF DIRECT-WRITE E-BEAM SYSTEMS THROUGH 1985

Manufacturer	Units
AT&T	1
Cambridge Instruments	43
Electron Beam Microfabrication*	6
Hewlett-Packard	3
Hitachi	9
IBM	35
Jeol	73
Philips	7
Texas Instruments	6
Carl Zeiss (Jena)	5
Others	10
Total Systems	198

*Includes units built by Radiant Energy Systems

Source: DATAQUEST
March 1986

Fairchild Camera and Instrument

The gate array division, located in Milpitas, California, has installed a Cambridge Instrument Model EBMF 10.5 with a pattern-writing speed greater than one million shapes per hour. The system will be used to customize Fairchild's 2-micron 500 to 6,000 gate CMOS gate array family. The company expects to deliver prototype parts in less than two weeks and special orders within a matter of days.

Qudos Ltd.

This U.K.-based firm, located in Cambridge Science Park, plans to offer low-cost design software to drive an E-Beam system. The company will first offer single-layer metalization, followed later by multilayer technology.

European Silicon Structures (ESS)

ESS is believed to be the best-financed ASIC start-up in Europe, with approximately $65 million in venture capital. ESS plans to offer a two-week turnaround, using a 2-micron double-metal CMOS process, followed in early 1987 with a 1.25-micron CMOS technology. ESS also plans to use silicon compilation tools developed by Lattice Logic, along with Perkin-Elmer's new AEBLE E-Beam system.

Late-Mask Laser Processing Systems

One of the most interesting technologies that could impact Quick ASIC is the laser. Here we have identified three major efforts to use laser processing for gate arrays: two are start-up companies and the third is a research laboratory based in Livermore, California.

Lasarray Corporation

Lasarray Corporation manufactures turnkey design and manufacturing systems, optimized for Quick ASIC. The heart of its system is a direct-write laser beam pattern generator using two lasers--one helium-cadmium and the other helium-neon--which customize the wafer using positive resist exposure. The laser control has been designed to accommodate wafer-sharing of up to four different designs.

All this is done in a compact module made up of three clean rooms with all the processing equipment required to apply photoresist, etch away metal, and then deposit and etch nitride passivation using plasma technology. The initial arrays will be double-layer metal, using a 2-micron CMOS process with gate counts ranging from 600 to 3,200 gates.

The module also includes complete assembly capability as well as test equipment for engineering analysis. All EDA tools are based on a silicon compiler developed by Lattice Logic, which includes an interface to a test system capable of performing both functional and parametric testing.

The total cost of the system is less than the investment required for one E-Beam system. The Lasarray concept is believed to have a throughput rate of 48 designs per 36-hour period by using wafer sharing.

It is interesting to note that Lasarray was jointly funded for $10 million by its parent company, Fela, and by a private Swiss equity venture that has evolved from the parent company. Fela is a well-known European supplier of low-volume, multilayer, printed circuit boards (PCBs), and chip-on-board technology. Fela believes that this technology will ultimately impact the low-volume PCB market, and it is positioning Lasarray in order to strengthen Fela's position in the marketplace. Thus, both parent and subsidiary see this venture as an opportunity to vertically integrate into a new market. To address the Quick ASIC market, Lasarray has formed two companies--Lasarray SA, which is financed in Europe to service that market, and Lasarray Corporation, which will be based in California and is presently going through its financial formation.

Laserpath--The One-Day Gate Array Company

Laserpath sees its role as a very-quick-turnaround gate array supplier that specializes in prototype quantities. Laserpath just announced a production partnership with GE Semiconductor and expects to announce similar arrangements with other major semiconductor suppliers before the end of the year. GE will pay Laserpath more than $2 million for non-exclusive production rights to the Laserpath gate array family and will offer the family in the merchant market as well as in its various system divisions.

Initially, Laserpath is offering both single-layer and double-layer metal gate arrays ranging from 880 to 3,200 gates. Larger arrays will be released near the end of 1986. The company uses pre-processed 2- and 3-micron CMOS wafers and customization is done by a yttrium-aluminum-garnet infrared laser that is used to etch away metal traces on each die. The laser programming is done on packaged parts; this eliminates overbuilding of inventory, a chronic problem found in most small lot orders.

Laserpath has been developing the technology for nearly three years and has received $8.25 million in funding. The company is ahead of plan and still has $2 million in its coffer. While the concept at the outset appears to be a challenging technological feat, we believe that Laserpath has perfected the concept and is now ready to take orders.

Lawrence Livermore National Laboratory

Under a contract funded by the U.S. Navy and the U.S. Department of Energy, the Livermore Laboratory is developing laser-pantography technology that uses a laser-stimulated chemical vapor deposition process to write lines of metal or polysilicon interconnection on gate array wafers.

Laser pantography is typically done in a small chamber only slightly larger than the wafer itself. The laser passes through a fixed-quartz window on the top of the chamber with orifices on the sides introducing gas.

While this technology will not be commercially available until the next decade, it does suggest that desk-top wafer processing for small very-fast-turnaround ASIC chips could become a reality in the early 1990s.

WHAT DOES ALL THIS MEAN?

When one stands back and contemplates the significance of all this activity, some interesting trends emerge:

- A strong interest in Quick ASIC

- Unbundling of NRE

- A wide variety of technologies
- Less demand for PCBs

Each of these trends is significant, but together they mean that tomorrow's prototyping will look very different from today's.

Strong Interest in Quick ASIC

First and foremost, Quick ASIC is not a passing fad. Users of custom products will continue to demand quick turnaround and are willing to devote a significant share of their research and development budgets to getting a system design done quickly. At the outset, these users are willing to pay a premium for Quick ASIC but, as the market matures, we expect a sharp decline in NRE charges. We expect these charges ultimately to be less than what is currently charged today for conventional turnaround times. This price erosion is expected as early as 1987; by 1988, NRE charges could be 20 percent below today's rates.

Unbundled NRE

As Quick ASIC gains a significant share of the total ASIC market, users will want to see what they are paying for, which means that ASIC suppliers will be asked to itemize NRE charges and production charges. This is a natural outcome since some suppliers will concentrate on prototypes, while others will support production orders. From the user's point of view, this is also more acceptable, since often the funding of a ASIC project comes from two distinct sources: the engineering team controls the development funding and corporate production controls the production orders. This also implies that the prototype supplier and the foundry that does the manufacturing must form alliances to ensure proven designs flow smoothly from prototypes to production.

A Wide Variety of Technologies

DATAQUEST believes that we are entering a period where a variety of technologies will be used for attaining Quick ASIC. Our Semiconductor Equipment and Materials Service has noted a sharp increase in capital expenditures devoted to the development of fast-turnaround, small-production lots, and we expect some of this equipment to be used to supply fast prototypes. The key driving force is cost, which is directly related to throughput. The Quick ASIC suppliers that can produce prototype parts the fastest with the lowest capital investment will ultimately win out. What is certain is that this segment will get a great deal of attention from equipment makers, ASIC suppliers, and semiconductor users.

Less Demand for PCBs

Today, hundreds of PCB manufacturers make their livings supplying low-volume PCBs for breadboarding. These suppliers will experience a major change in their business as their customers start using gate arrays or PLDs instead of standard SSI/MSI logic. In the long term, the number of PCBs required to support the breadboarding will decline as more and more of the system integrates onto fewer ASICs. These PCB suppliers will also have to adjust to the proliferation of package configurations used in gate arrays and the very-short-turnaround times required.

Perhaps in the long term Quick ASIC will be the only way to get a custom chip, and the design engineers and their companies will be able to get a product out with a little less anxiety and stress.

Andrew M. Prophet

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RESEARCH NEWSLETTER

SIS Code: 1986-1987 Newsletters, March
1986-12

EPROM MARKET OVERVIEW--1985

SUMMARY

The worldwide market for MOS EPROMs closed with revenues of $878 million in 1985, down 26 percent from 1984 revenues of $1,179 million. In a year that saw the entire MOS memory market shrink by 39 percent in dollars, MOS EPROMs held up well in revenues, although profits for all participants were impacted drastically--especially in the second half of the year.

- Intel's EPROM revenues dropped only 2 percent while its market share increased 5 percent--from 17 percent to 22 percent of the worldwide total--reversing the company's loss of share in 1984.

- In September, AMD, Intel, and National Semiconductor jointly charged Japanese EPROM manufacturers with dumping. On March 10, the Department of Commerce's preliminary ruling assigned dumping penalties averaging 63 percent on Japanese suppliers.

- CMOS constituted 10 percent of the EPROM market in 1985.

- Total units grew 9 percent in 1985. Though the average density of devices shipped (bits/unit) increased 48 percent over 1984, average unit prices (AUP) at year-end 1985 were less than half the 1984 AUP.

THE MARKET--1985

Table 1 shows estimated EPROM revenues for the top nine suppliers for 1983 through 1985. Although the rankings changed very little despite intense competition, in several cases there was considerable change in market share. In most cases, this most closely tied to a vendor's presence at the high-density end of the product spectrum, where unit growth outstripped price declines to sustain the only growing markets.

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Table 1

ESTIMATED EPROM REVENUES
(Millions of Dollars)

Company	1983	1984	1985
Intel	$184	$ 202	$197
Fujitsu	99	158	118
AMD	75	155	117
Hitachi	124	145	113
Mitsubishi	83	155	66
Texas Instruments	83	128	65
NEC	64	70	55
Toshiba	18	38	55
National	39	45	22
Others	60	83	70
Total	$829	$1,179	$878

Source: DATAQUEST
March 1986

Table 2 shows the estimated market composition for 1985, giving units shipped, AUP, and revenue for each density.

Table 2

1985 EPROM MARKET--UNITS, AUP, AND REVENUE

Density	Units Shipped (M)	AUP ($)	Revenues ($M)
2K-8K	0.5	$ 6.20	$ 3
16K	28.0	$ 2.50	70
32K	38.5	$ 2.65	102
64K	101.8	$ 2.85	290
128K	56.7	$ 3.95	224
256K	21.9	$ 8.00	175
512K	0.4	$ 32.50	14
1Mb	S	$115.00	0
Total	247.8	$ 3.54	$878

Source: DATAQUEST
March 1986

Table 3 shows the quarterly revenue mix by density. Only the 256K market--dominated by Intel and AMD for the first half--and the nascent 512K market grew during the year. All other markets declined due to reduced demand or severe price attrition.

Table 3

EPROM--QUARTERLY MARKET MAKEUP BY DENSITY
(Millions of Dollars)

Density	1984	1985 1st Qtr.	1985 2nd Qtr.	1985 3rd Qtr.	1985 4th Qtr.	1985 Year
2K-8K	$ 6	$ 1	$ 1	$ 1	$ 0	$ 3
16K	115	19	18	17	16	70
32K	190	35	27	22	18	102
64K	450	100	70	65	55	290
128K	330	80	55	46	43	224
256K	87	44	52	38	41	175
512K	1	2	4	3	5	14
1Mb	0	0	0	0	0	0
Total	$1,179	$281	$227	$192	$178	$878

Table 4 gives some perspective as to what the EPROM market has undergone during the last two swings of the pendulum--the strength of 1984 and the cataclysmic slide of 1985--and, based on year-end 1985 pricing, the prospects for 1986.

Table 4

MOS EPROMS--AVERAGE UNIT PRICES, 1983-1985

Density	1983	1984	1985	4th Qtr. 1985
2K	$ 4.00	$ 5.00	$ 6.00	$ 6.00
8K	$ 3.50	$ 4.00	$ 6.20	$ 8.00
16K	$ 3.20	$ 3.35	$ 2.50	$ 2.30
32K	$ 4.20	$ 3.80	$ 2.65	$ 2.30
64K	$ 5.20	$ 5.15	$ 2.85	$ 2.25
128K	$ 18.40	$ 12.15	$ 3.95	$ 2.62
256K	$102.00	$ 41.80	$ 8.00	$ 4.75
512K	N/A	$108.00	$ 32.50	$ 22.15
1Mb	N/A	N/A	$115.00	$115.00
Unit Price--Overall	$ 4.72	$ 5.82	$ 3.54	$ 2.75
Price/Bit (Millicents)	10.7	9.8	4.0	2.7
Total Units (Millions)	180	227	248	66

N/A = Not Applicable

Source: DATAQUEST
March 1986

PRODUCT LINE PROFILES

16K EPROMs

The supplier base of 16Ks has eroded by about half its number in the past 24 months, as prices were depressed and manufacturers' processes were upgraded. Japanese manufacturers have almost completely withdrawn 16Ks for export sales, though some manufacturers continue to ship to their domestic market. The 1985 market totaled about $70 million for 28 million units, down 39 percent and 18 percent, respectively, from 1984 levels.

32K EPROMs

Shipments of 32K EPROMs totaled about $102 million (for 38.5 million units), down 46 percent in dollars and 23 percent in units from 1984. The NMOS 32K market is serviced by three parts: 2532s (Hitachi, SGS-Ates, and Texas Instruments) and the 2732 and 2732A. The 2732A was generally the most broadly supplied and the lowest priced. National Semiconductor continued to be the leading supplier of 32K EPROMs built using CMOS technology.

64K EPROMs

The market for 64K EPROMs was estimated to be $290 million in 1985, down 36 percent from 1984, even though units grew 17 percent, to 102 million pieces. Fujitsu, Hitachi, and Mitsubishi combined to supply about 60 percent of the units; AMD, Intel, and Texas Instruments supplied another 29 percent.

128K EPROMs

The 128K EPROM market was the least elastic of the EPROM markets during 1985. As prices from year-end 1984 dropped by 67 percent to year-end 1985 and units shipped grew 110 percent, the market declined 32 percent in revenue, to $224 million. Hitachi and Mitsubishi teamed up for 41 percent of the total market; Intel was the leading U.S. producer, shipping an estimated 8 million units.

256K EPROMs

In 1984, AMD and Intel had an estimated 82 percent of the 256K market, with Fujitsu having another 10 percent. But when the commodity-oriented Japanese production mills--Hitachi, NEC, and Toshiba--really started to deliver, prices plummeted. More than any other market, it was pricing of the 256K EPROMs that ultimately precipitated the dumping lawsuit by AMD, Intel, and National Semiconductor. The leading edge had consistently been the rather exclusive province of technology leaders Intel and, more recently, AMD.

Prices for 256Ks dropped from an average of $12.25 in the second quarter of 1985 to about $5.25 in the third quarter, with some business approaching $3.00. The dumping lawsuit, on top of a general restoration of supply/demand balance, combined to stabilize the 256K market significantly in the fourth quarter. Total 256Ks shipped during 1985 were about 22 million units, valued at $175 million.

Though the market slide has hesitated for a few months, intense competition will not let up as new suppliers Atmel, General Instrument, Seiko Epson, and VTI join the continued onslaught of leading Japanese suppliers--Fujitsu, Hitachi, Mitsubishi, NEC, and Toshiba--all of which are now in high-volume production.

512K EPROMs

For most of 1985, AMD and Intel were the only suppliers of 512K EPROMs. However, the market size ($2 million to $5 million per quarter) and slow growth rate did not afford much protection from the intense pricing that AMD and Intel eventually faced in all other densities. Shipments for the year totaled an estimated 440,000 units, with Intel having 60 percent, AMD 35 percent, and Hitachi plus Fujitsu, both of which began shipping in the fourth quarter, the remaining 5 percent. Prices at year end were sometimes in the $15 range.

1Mb EPROMs

AMD sampled its 1Mb EPROM beginning in the second quarter, but the device was never moved into production during the year. Only Hitachi, with its CMOS 128Kx8, also sampled during the year.

It is in the 1Mb density level that we will begin to see a real diversity of EPROMs offered: CMOS will be a full partner to NMOS devices; bytewide (x8) and wordwide (x16) architectures will be widely offered; page-addressed upgrades of Intel's 27513 will likely be second sourced. Full participation requires three pinouts: 28, 32, and 40 pins; plus the likely availability of four packages: CERDIP, plastic DIP for OTP, and PLCC and SOJ surface-mount packages.

EPROM TRENDS

Several trends in evidence during the past few years continued during 1985. Like all MOS memory markets, the product line is slowly becoming more varied as users offer several package options and special application parts.

Enough of the technical and manufacturing foundation is now in place to point to a strong increase in EPROMs' already broad range of applicability. This foundation includes not only significant reductions in cost and cost per bit, but very importantly, ease of use, inventoriability, adaptability to an automated high-volume production line environment, availability of a broader range of packages (including SMDs), and custom-type parts.

Already in the United States, the use of mask ROMs has been reduced drastically as EPROMs' steeper learning curve has eroded the price advantage that ROMs have had historically.

Several of the trends that are making EPROMs unusually competitive are described below.

Plastic Packages

Drastic swings in market pricing and product line profitability, plus technical difficulty in mastering the OTP package, again slowed adoption and use of plastic-packaged EPROMs. With high CERDIP prices in 1984, vendors had little incentive to move to plastic; with low CERDIP prices in 1985, users had little incentive to adapt what was viewed as an uncertain technology.

On top of all of this, manufacturers continued to have difficulty in achieving a speed sort comparable to CERDIP parts and guaranteeing long-term reliability.

Surface-Mount Packages

Intel announced PLCC surface-mount EPROMs in the third quarter of 1985. By mid-1986, its entire EPROM line, except 2732s, will be offered in a PLCC package.

Japanese suppliers have generally started with the SOJ package as their surface-mount device, although many plan a PLCC option as well. It appears that the strong consumer market customer base in Japan, which uses SOJ, has been a major impetus for Japanese makers to adopt that device first.

Design Rules

Sub-2um design rules are now commonplace in most manufacturers' high-density EPROMs, and the leading-edge design now in production is under 1.5um. During 1986 and 1987, it is likely that most EPROM manufacturers will take their most advanced process and upgrade their high-density products (128K and above). These new products should enable suppliers to both offer higher-performance parts and reduce overall manufacturing costs so they can begin to restore profitability to their EPROM product lines.

Page-Addressed EPROMs

Intel offered a page-addressed 512K EPROM in 1985, the 27513, which was organized as four pages of 16Kx8 each. This was intended to ease upgrades for 128K users. However, no other vendor followed suit as a second source.

Intel plans to extend this architecture to the 1Mb family of devices, which was announced in the first week of March 1986. At higher densities, the rationale for this feature becomes more compelling. Atmel and General Instrument already have announced that they will offer a similar feature.

Advances in Programming Algorithms and Throughput

As EPROMs migrated to higher densities, programming time became an increasing concern. Using the programming algorithms in place at the 128K density, 256Ks would have taken about 30 minutes each.

This was reduced to six minutes through development of the Intelligent Programming Algorithm, which has subsequently been adopted by others in form or substance. (The Intelligent Programming Algorithm is copyrighted by Intel Corporation.)

Recently, Intel announced a further advancement, Quick Pulse Programming, that allows another, significant reduction in programming time--down to only four seconds for a 256K EPROM.

New EPROM Suppliers

The past year has brought several new suppliers to the EPROM market, which historically has featured a narrow supplier base. Several of these manufacturers offer outstanding new technical approaches to the market.

Atmel

Atmel is a group of ex-Seeq employees who spun out to develop EPROM, EEPROM, and EPLD products. The company has an extensive technology licensing and product development fab arrangement with General Instrument in Chandler, Arizona. OTPs will be available in all densities. Atmel's EPROM products include:

Density	Technology	Speed	Availability
256K	NMOS or CMOS	150ns	Now
512K	CMOS	150ns	Q2, 1986
1Mb	CMOS	150ns	Q4, 1986

Cypress Semiconductor

Cypress emphasizes a unique four-transistor-per-cell approach to produce high-speed bipolar PROM replacements using "EPROM" technology. Its (E)PROM products include:

Density	Speed	Availability
4K	30ns	Now
8K	30ns	Now
16K	25ns	Now

General Instrument

Through its licensing arrangement with Atmel, General Instrument has upgraded its EEPROM product line, and has begun offering a family of EPROMs and OTPs, to complement its existing position in the ROM market. OTPs will be available in all densities. General Instrument's EPROM family includes:

Density	Technology	Speed	Availability
256K	NMOS and CMOS	150ns	Now
512K	CMOS	150ns	Q2, 1986
1Mb	CMOS	150ns	Q2, 1986

Seiko Epson/SMOS Systems

Seiko Epson and its U.S. subsidiary, SMOS Systems, have offered 64K and 256K CMOS EPROMs and NMOS 128Ks since late in 1985.

Sharp

Sharp obtained license to EPROM technology via WaferScale Integration, in exchange for foundry capacity. The original agreement calls for Sharp to produce commodity EPROMs and WSI to produce high-performance devices.

VLSI Technology

VLSI Technology initially obtained CMOS EPROM technology through a licensing arrangement with National Semiconductor. The company began shipping a full line of CMOS EPROMs in the second half of 1985. Its EPROM products include:

Density	Speed	Availability
64K	150ns	Now
128K	150ns	Now
256K	150ns	Now
512K	150ns	Now

WaferScale Integration (WSI)

WSI offers a 64K high-speed (70ns) CMOS EPROM. It has a technology exchange and foundry arrangement with Sharp.

DATA ISSUES

The data put forth here summarize the more detailed market data available to DATAQUEST clients through other means (described below), and are comparable to those published, in aggregate, by other industry sources.

Reconciliation with WTSP Data

Data published here are consistent with trade statistics gathered through the WTSP, if adjustments are made to the WTSP "Other MOS Memory" totals to account for EEPROMs and other included categories.

Availability of Detailed Data

Detailed quarterly shipment data, including estimated shipments by vendor for each product, are now available on the DATAQUEST On-Line Service. Hard copy is being readied for publication and will be mailed to notebook holders soon. When available, it can be found in the Semiconductor Industry Service Products and Markets binder, behind the Memory tab, under "MOS EPROMs--Company Shipments."

OUTLOOK

The outlook for EPROMs, as a technology, has never been brighter. It is easily imagined that costs per bit will be reduced fivefold in the next five years, even from the depressed 1985 levels. This, on top of significant improvements in ease of use, will mean vast improvements in "total cost of utilization" available to systems users.

The outlook for the EPROM market and suppliers to the market is one of continued intense competition and readjustment to a major Japanese presence. If U.S. makers can employ their tremendous technical skills, applications orientation, and product line diversification, and can improve their high-volume manufacturing skills through their own efforts or through alliances, they can offset the Japanese advantages of having larger resource bases, captive markets, and finely tuned, high-volume manufacturing systems.

The final resolution of the dumping charges by AMD, Intel, and National injects considerable uncertainty. At the very least, it has stabilized the market by making Japanese suppliers wary of being price leaders.

Lane Mason

SIS Code: 1986-1987 Newsletters: April
1986-17

PRELIMINARY FIRST QUARTER 1986 MICROCOMPONENT UPDATE

Microcomponent growth in first quarter 1986 was up 3 percent from the previous quarter. Microdevices followed the flow of the semiconductor industry with a high book-to-bill ratio in January and February, reflecting a healthy year ahead. Shipments were ahead of bookings during the first quarter. For all microcomponents:

- January was a dynamite month. We believe that this was an inventory-building period.
- February was a relatively flat month.
- March revealed the hiccup the industry needed to push it into high growth for the rest of the year.
- ASPs are increasing; however, shipments appear to be flat.

In our quarterly microcomponent forecast shown in Table 1, we project that MPUs will grow faster during the first half of 1986 because of many new product introductions expected later in the year. Microcontrollers will grow at about the same rate as the rest of the industry.

Table 1

QUARTERLY MICROCOMPONENTS FORECAST
(Millions of Dollars)

	1986				
	Q1	Q2	Q3	Q4	Year
MCU	$296	$319	$345	$391	$1,351
MPU	91	120	147	172	530
MPR	348	353	365	408	1,474
Total	$735	$792	$857	$971	$3,355

Source: DATAQUEST
April 1986

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Four or five product types dominated the 8-bit and 16-bit MPU and 8-bit MCU markets during the first quarter. In the 8-bit MPU market, the Z80, 8085, 6802, 6809, and 8088 shipped 84 percent of the market. In the 16-bit MPU market, the 8086, 68000, 80286, 80186, and Z8000 shipped 82 percent of the market. In the 8-bit MCU market, the 8049, 6805, 8048, and 8051 shipped 55 percent of the market.

We are currently collecting unit and revenue shipment data by company and product type to present in a detailed first quarter shipments report.

Janet Rey-Oncel

May Newsletters

The following is a list of the newsletters in this section:

(continued)

May Newsletters

(continued)

May Newsletters

Dataquest
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RESEARCH
NEWSLETTER

SIS Code: 1986-1987 Newsletters: May
1986-23

BOARD COMPUTER INDUSTRY SEGMENT SUMMARY

SUMMARY

The board computer market is alive and growing, although at a slower rate than expected. As silicon technology shrinks the size of computer systems, the board computer industry is playing an increasingly important role in technical applications by replacing older minicomputers. Additionally, new applications and market segments are opening up as vendors introduce new products in the 32-bit product segment.

The board computer market developed out of the small niche between full systems and semiconductors. A board computer is not considered a complete computer system with a display and mass storage peripherals, but rather, a ported system that may include a CPU, memory, and an I/O module.

We forecast that this segment will develop into a $1.3 billion industry by 1990, up from $574 million in 1985. The market is fueled by continually increasing performance of VLSI electronics, shrinking computer sizes, declining average selling prices, and expanding market opportunities.

From an applications perspective, industrial automation, real time, medical, and laboratory automation continue to be the largest applications, totaling 82 percent of the market revenues.

Vendors supporting various bus structures are continuing to wage war, first at the bus level and secondly at the product level. Multibus and Q-bus together captured 76 percent of the market, with VMEbus placing third at 11 percent.

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MARKET SIZE AND FORECAST

Size

Tables 1 through 4 and Figures 1 through 4 present our estimates of factory revenues and unit shipments for the board computer industry for 1980 through 1990. The board computer industry grew 11 percent from 1984 to 1985. This was a slight increase over the previous year's growth of 4 percent. It is still significantly lower than the computer industry's normal growth rate of 20 to 25 percent. The growth was a result of a slight increase in capital spending over previous years and the sudden unavailability of older, traditional minicomputers, which were restricted from being sold because of FCC radio frequency emission legislation. The older, traditional minicomputers were replaced by board computers with equivalent or greater functionality and performance. Additionally, several applications are using board computers that previously used minicomputers.

In addition, advancements in silicon technology have reduced component costs. Many vendors reduced prices to stimulate demand and in response to increasing competitive pressure. This has slowed the growth of revenues somewhat.

Forecast

We expect the industry to grow slowly, stimulated by new market opportunities created by 32-bit architectures and continued recovery in capital spending in the technical markets. The board computer industry is sensitive to the state of the economy in much the same way as the semiconductor industry is. An expected economic recovery will fuel the growth of the board computer segment.

The 8-bit segment revenues are forecast to peak in 1986 and then decline gradually. The 16-bit segment represents the main line of the market; the 32-bit segment is expected to show strong growth over the forecast period. We expect a flood of 32-bit products based on the 68020 and 80386 to emerge in 1986, which will stimulate demand and a decline in prices.

Bus Wars

Intel and Motorola will continue to wage advertising wars, vying for design wins with their respective Multibus II and VMEbus architectures, although almost no CPU boards were shipped on either bus in 1985. We expect both of these buses to survive and succeed in a neck-to-neck battle. The other high-speed 32-bit buses such as Nubus, Future bus, and FASTbus still lack significant vendor support, and we expect this situation to continue, since most of the industry is focusing on relatively low-speed applications. We expect Digital to announce board computer products supporting the newly announced Q-Bus replacement--the VAXBI bus--later in the year. However, we do not anticipate that the

VAXBI will significantly affect the industry until 1987. This bus is currently offered only on expensive computer systems costing more than $130,000.

Table 1

ESTIMATED WORLDWIDE FACTORY REVENUES
HISTORY FOR BOARD COMPUTERS
(Millions of Dollars)

Board Size	1980	1981	1982	1983	1984	1985	CAGR 1980-1985
8-Bit	$115	$150	$158	$186	$190	$205	12.3%
16-Bit	141	214	242	311	325	365	21.0%
32-Bit	0	0	0	0	1	4	N/A
Total CPU Board Revenues	$256	$364	$400	$497	$516	$574	17.5%

Table 2

ESTIMATED WORLDWIDE FACTORY REVENUES
FORECAST FOR BOARD COMPUTERS
(Million of Dollars)

Board Size	1986	1987	1988	1989	1990	CAGR 1986-1990
8-Bit	$210	$205	$200	$ 185	$ 170	(5.1%)
16-Bit	440	541	666	819	983	22.3%
32-Bit	12	30	65	100	145	86.4%
Total CPU Board Revenues	$662	$776	$931	$1,104	$1,298	18.3%

Source: DATAQUEST
May 1986

Table 3

ESTIMATED WORLDWIDE UNIT SHIPMENTS
HISTORY FOR BOARD COMPUTERS
(Thousands of Units)

Board Size	1980	1981	1982	1983	1984	1985	CAGR 1980-1985
8-Bit	167	233	274	365	420	500	24.5%
16-Bit	64	174	222	309	380	474	49.3%
32-Bit	0	0	0	0	0	1	N/A
Total CPU Board Units	231	407	496	674	800	975	33.4%

Table 4

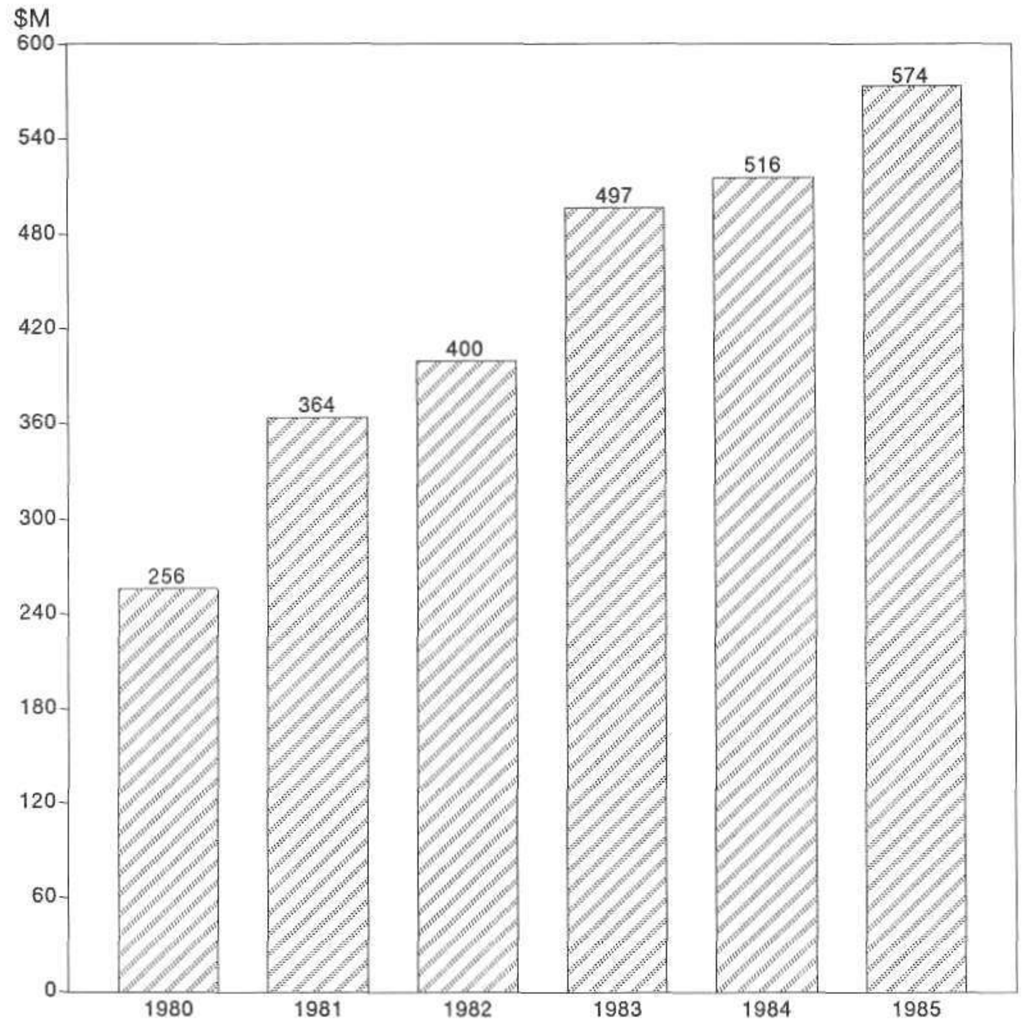
ESTIMATED WORLDWIDE UNIT SHIPMENTS
FORECAST FOR BOARD COMPUTERS
(Thousands of Units)

Board Size	1986	1987	1988	1989	1990	CAGR 1986-1990
8-Bit	580	700	800	850	875	10.8%
16-Bit	625	800	975	1,210	1,550	25.5%
32-Bit	3	10	28	50	77	120.6%
Total CPU Board Units	1,208	1,510	1,803	2,110	2,502	20.0%

Source: DATAQUEST
May 1986

Figure 1

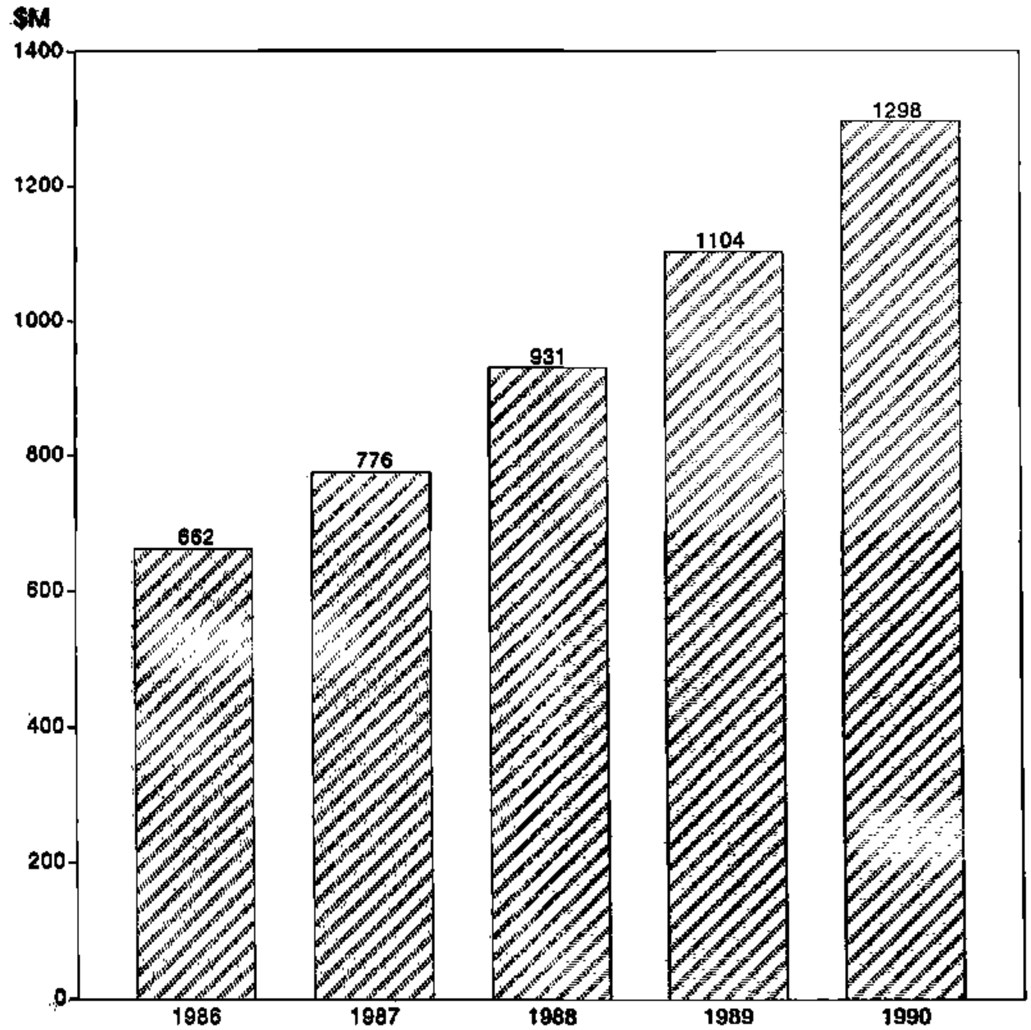
**ESTIMATED WORLDWIDE FACTORY REVENUES
HISTORY FOR BOARD COMPUTERS
1980-1985**



Source: DATAQUEST
May 1986

Figure 2

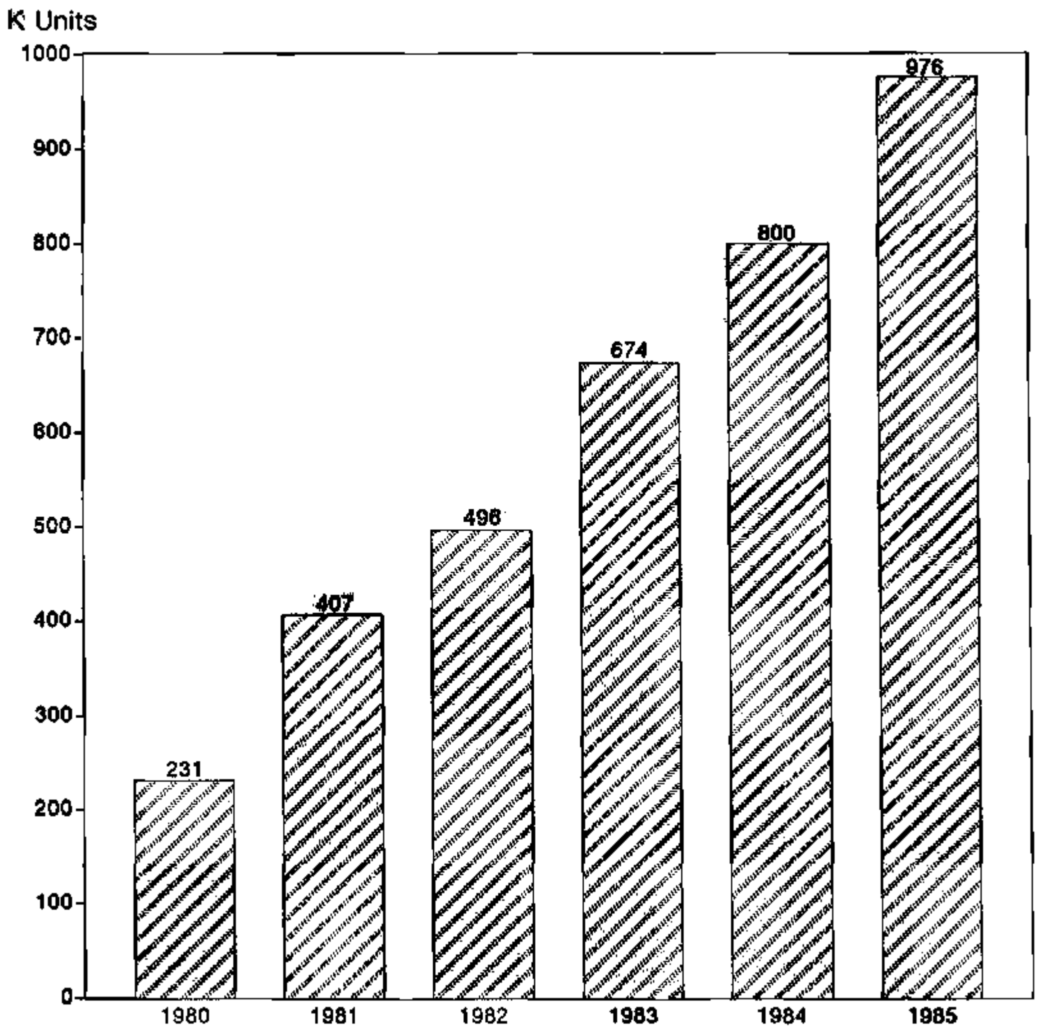
ESTIMATED WORLDWIDE FACTORY REVENUES
FORECAST FOR BOARD COMPUTERS
1986-1990



Source: DATAQUEST
May 1986

Figure 3

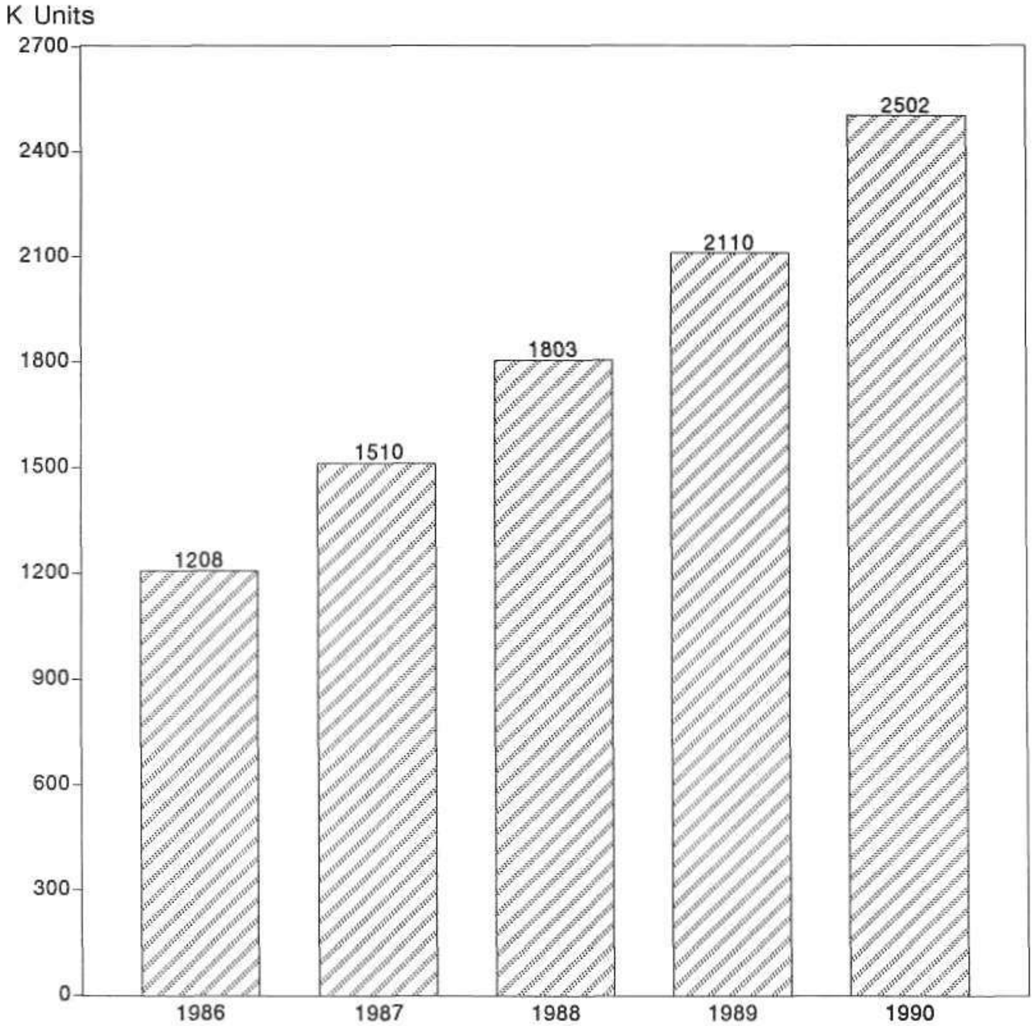
ESTIMATED WORLDWIDE UNIT SHIPMENTS
HISTORY FOR BOARD COMPUTERS
1980-1985



Source: DATAQUEST
May 1986

Figure 4

**ESTIMATED WORLDWIDE UNIT SHIPMENTS
FORECAST FOR BOARD COMPUTERS
1986-1990**



Source: DATAQUEST
May 1986

Figure 5 shows percentages of worldwide 1985 factory revenues segmented by bus structure. Intel and Digital continue to fight tooth and nail for the number one position with Motorola's VMEbus. The VMEbus gained significantly over its 1984 position.

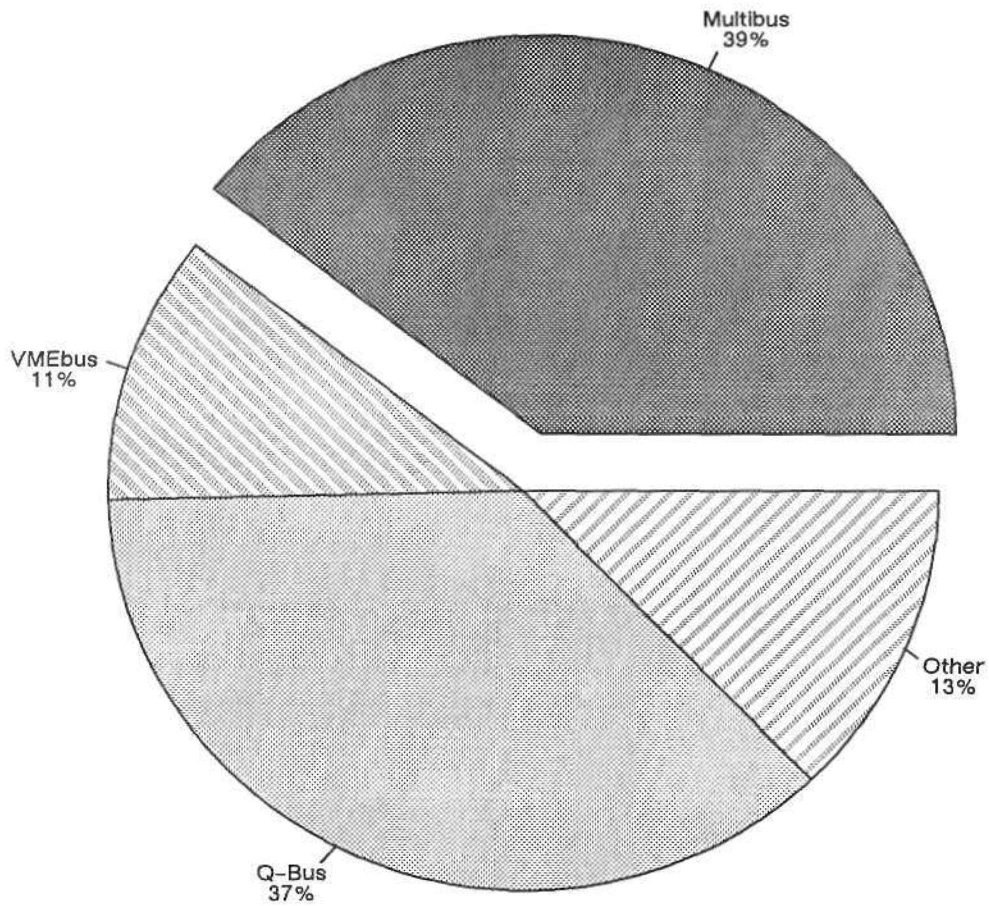
Applications

The board computer market is dominated by the industrial automation application, which has had restricted levels of capital investment spending for the last three years. Table 5 presents our estimates of percentages of revenue by application for 1980 through 1989. Figure 6 illustrates the 1985 board computer market revenue shares by application.

We anticipate that the applications percentages will not change much, with the exception of an increase in communications at the expense of the laboratory and medical markets.

Figure 5

ESTIMATED WORLDWIDE 1985 FACTORY REVENUES BY BUS STRUCTURE



Source: DATAQUEST
May 1986

Table 5

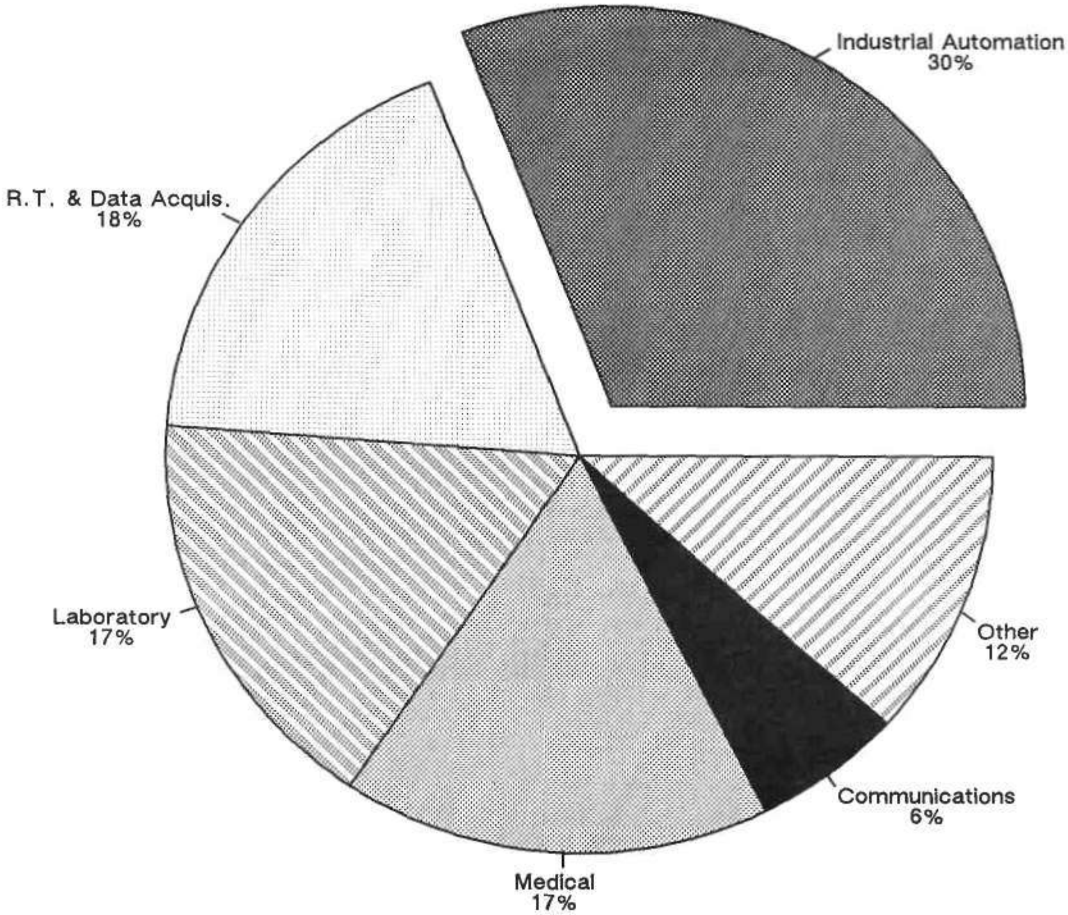
ESTIMATED BOARD COMPUTER MARKET BY APPLICATION
1980-1989
(Percentage of Revenue)

Application	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Design Automation	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Industrial Automation	21	21	21	24	26	30	33	33	35	35
Scientific	1	1	1	1	1	1	1	1	1	1
Earth Resources	1	1	1	1	1	1	1	1	1	1
Real-Time Data Acquisition and Control	16	16	17	17	17	18	18	18	20	20
Graphics	1	1	1	1	1	1	1	1	1	1
Communications	2	2	2	2	4	6	9	14	15	16
Software Development	1	1	1	1	1	1	1	1	1	1
Computer-Aided Publishing	0	0	0	0	0	0	0	0	0	0
Laboratory	26	26	25	24	22	17	15	13	10	9
Medical	25	25	25	23	20	17	13	10	8	8
Other	5	5	5	5	6	7	7	7	7	7
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Source: DATAQUEST
March 1986

Figure 6

APPLICATIONS AS PERCENTAGE OF REVENUE
1985



Source: DATAQUEST
May 1986

DATAQUEST CONCLUSIONS

The board computer was hit as hard as, if not harder than, the rest of the technical computer industry. Competition continues to remain tough with more than 100 vendors offering CPU boards. But there are few barriers to entering the market and the cost of entering remains low. Considerable forces are building to fuel the growth of the entire board computer industry as the computer industry evolves and scales downward in system size and price.

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Janet Rey-Oncel
Brad Smith

Dataquest
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RESEARCH NEWSLETTER

SIS Code: 1986-1987 Newsletters: May
1986-22

ASIC: CROSSING THE APPLICATIONS THRESHOLD

"Adolescence is the awkward age when a child is too old to do something cute and perhaps too young to do something sensible."

--E. C. McKenzie

AT THE THRESHOLD

It almost seems that the application-specific integrated circuit (ASIC) industry has crossed the threshold from youth to adolescence. Like the child who has grown and matured rapidly, who has seen his potential but is not sure how to achieve it, so too is the ASIC industry. Standing at the threshold, with great optimism, ASIC suppliers visualize end-use markets as opportunities and challenges. The ASIC industry knows it has a way to go, and believes it has the maturity, but it is not exactly sure what path to choose.

This newsletter summarizes a recent analysis of end-use ASIC applications done by our Semiconductor Application Markets (SAM) service and the Semiconductor Industry Service (SIS). Our analysis shows three important points:

- ASICs have diffused into most end-use applications but still have a way to go.
- Design starts are fueling the growth of the ASIC market.
- ASIC suppliers are going to face a number of challenges and opportunities.

We take a closer look at some of the more common applications for programmable logic devices (PLDs), gate arrays, and cell-based designs (CBDs), and we conclude with observations that indicate the strategic direction for both ASIC users and suppliers.

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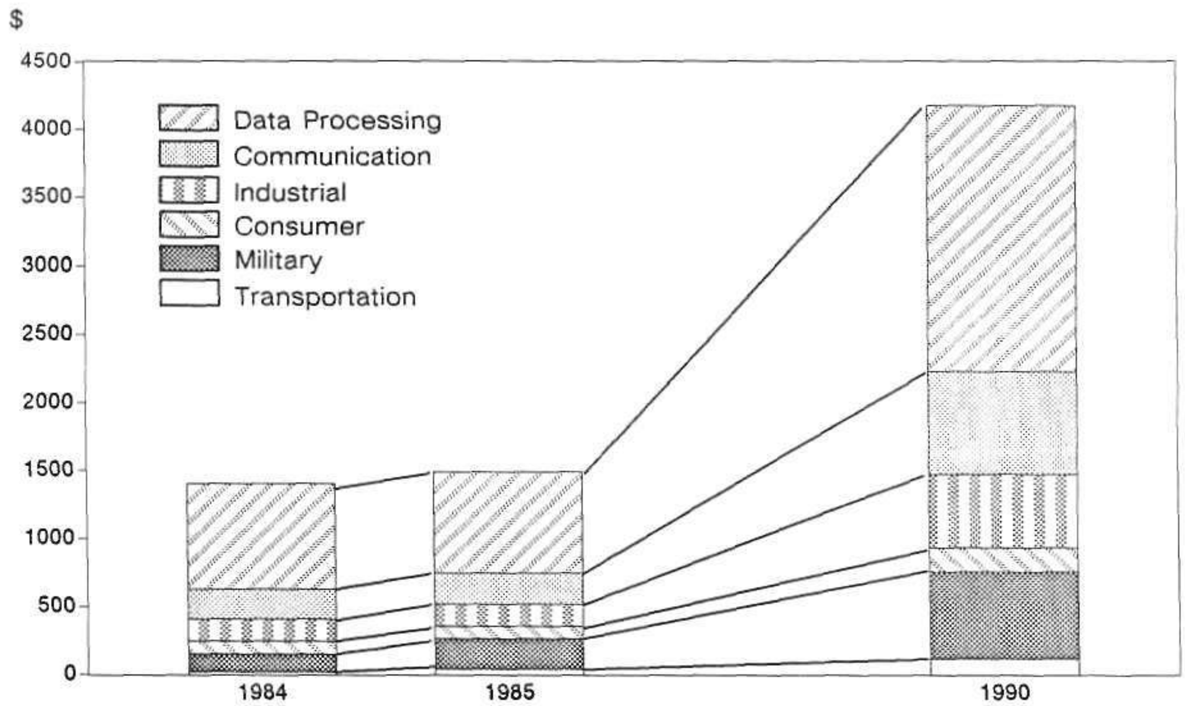
As the youthful ASIC market captures a larger market share, we expect suppliers and users to develop new relationships. Today, only 17 percent of all worldwide integrated circuit (IC) revenue is ASIC, but by 1990 it will exceed 25 percent. Furthermore, as Figure 1 shows, all North American end-use markets are expected to use ASIC in one form or another. This means that suppliers will have to learn how to service the unique characteristics of each application. Users, in turn, will have to learn which design methodology is the most appropriate for their needs. The following sections expand on these issues and provide supporting data.

Figure 1

ESTIMATED NORTH AMERICAN ASIC END-USE CONSUMPTION
(Millions of Dollars)



Source: DATAQUEST
June 1986

ASIC PENETRATION: A LONG WAY TO GO

DATAQUEST has just completed a major survey of 200 of the largest electronic businesses in North America. These companies have more than 500 semiconductor procurement locations and represent a diverse group of buyers, material managers, purchasing directors, and corporate contract managers. While profiles of this group do not include all electronic businesses, which number in the thousands, we believe they represent at least 55 percent of the total dollars invested in ICs. From the ASIC point of view, these companies represent the largest and most influential body of procurement management to be found in North America.

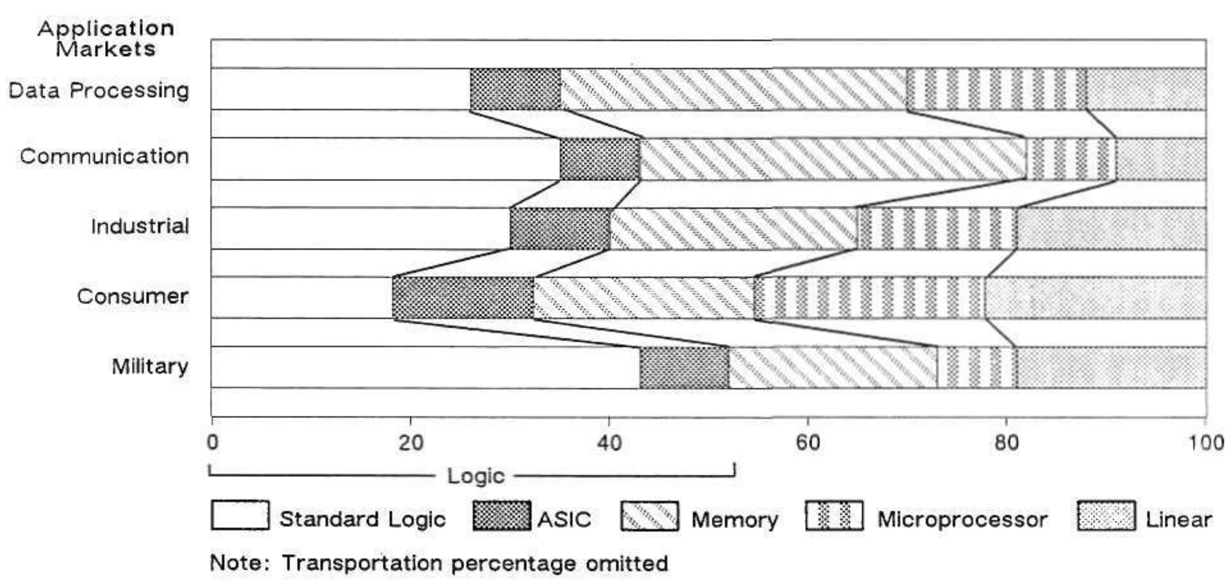
Perhaps the most startling finding is that ASIC penetration has yet to mature. This is because most users devote a major portion of their procurement budget to logic products and because only a fraction of the logic budget is currently devoted to ASIC. Figure 2 shows the end-use distribution of IC dollars subdivided into the five major product categories.

It is interesting to note that logic, which includes ASIC and standard logic, makes up a major portion of IC procurement in all the end-use segments. While ASIC is not currently consuming a major portion of logic, it does suggest its large potential. But the most important finding shows that there is a very large group of users that is contemplating using ASIC. Of all the system manufacturers that were polled, 57 percent said they were seriously considering ASIC, 33 percent said they were not, and 10 percent were undecided.

A corollary to the above finding is how ASIC procurement is distributed throughout the United States. Table 1 and Figure 3 show that ASIC purchases are concentrated in the Pacific area, followed by the Northeast and the Midwest. These findings reinforce our previous findings that most U.S. design centers are concentrated on the coasts and in the Midwest.

Figure 2

IC PROCUREMENT--1985
(Percent of Total)



Source: DATAQUEST
May 1986

Table 1

EXPECTED ASIC DESIGNS
(Percent of Respondents by Region)

	Atlantic	Midwest	Northeast	Mountain	Pacific	South	Total
Gate Array	9.0%	13.4%	20.9%	7.5%	40.3%	9.0%	100.0%
Standard Cell	8.7%	13.0%	19.6%	6.5%	34.8%	17.4%	100.0%
PLD	6.3%	12.5%	25.0%	12.5%	25.0%	18.8%	100.0%
Full Custom	8.3%	25.0%	18.8%	2.1%	31.3%	14.6%	100.0%

Source: DATAQUEST
May 1986

Figure 3

ASIC PROCUREMENT SURVEY AUDIENCE

Source: DATAQUEST
May 1986

DESIGN STARTS--FUEL FOR ASIC GROWTH

There is another way to look at ASIC growth--by examining the estimated design activity from the user's point of view. Table 2 measures the estimated 1986 North American design activity. Respondents were asked how many designs they were planning and what percentage was planned per each design method. For example, for users who plan to do greater than 76 designs, the percentage that will be done using gate arrays is expected to be 60 percent. The other designs are expected to be done using CBD or full-custom design methods. The data shown in Table 2 suggest that regardless of the number of designs per year, most users expect to buy more gate arrays than any of the other design tools.

Table 2

ESTIMATED 1986 NORTH AMERICAN DESIGN STARTS
(Percent of Total)

Number of Designs per Year	Gate Array	PLD	CBD	Full Custom	Total
All Ranges	47.4%	5.1%	23.1%	24.4%	100.0%
<25	47.0%	5.9%	22.4%	24.7%	100.0%
26-50	43.3%	2.5%	30.0%	24.2%	100.0%
51-75	50.0%	-	50.0%	-	100.0%
>76	60.0%	-	7.0%	32.0%	100.0%

Source: DATAQUEST
May 1986

We believe that this preference for gate arrays can be traced to two areas. It is fueled first by very user-friendly electronic design automation (EDA) and second by the proliferation of low-cost workstations. Most design centers now offer easy access to EDA, which, in turn, can interface with ASIC suppliers.

While Table 1 shows a small percentage of design starts for PLDs, we believe that the data do not truly represent their use. PLDs are purchased like commodity ICs and the number of designs done are usually not known by the buyer. Therefore, one cannot infer the true number of PLD designs from the table. Furthermore, it does not reflect the long-term potential of the PLD market. DATAQUEST believes that PLDs will become a very significant factor in applications that require low gate count, i.e., below 3,000 gates on chip.

The CBD segment shows significantly less starts than gate arrays, but each CBD start will generate three to five times the production revenue of a gate array. Thus, what seems like a low number of design starts does not imply less production revenue in the future. Also, remember that CBD EDA tools are not as mature as those found in gate arrays. As more sophisticated EDA tools emerge, we expect the gap in design starts to narrow. A factor that could fuel CBD growth is the full-custom category. The percentage of CBDs versus full-custom suggests that by the end of the decade, full-custom designs will be replaced by CBDs. This is because they are less costly to design and can be done in a fraction of the time. Therefore, we believe that CBDs have a very significant growth potential as better EDA tools emerge.

OPPORTUNITIES AND CHALLENGES

Table 3 shows some very interesting insights into what could be both a challenge and an opportunity in disguise. This table shows the number of respondents classified by the six end-use categories and is further subdivided into ASIC users and nonusers. Note that industrial users and nonusers make up the largest segment. DATAQUEST believes that industrial applications are a good opportunity for suppliers that position themselves properly.

Table 3

ASIC USERS VERSUS NONUSERS
(Percent of Total)

End Use	Users	Nonusers
Data Processing	27%	22%
Communications	16	16
Industrial	35	45
Consumer	5	2
Military	16	15
Transportation	1	0
Total	100%	100%

Source: DATAQUEST
May 1986

At the same time, the industrial segment provides most of the challenge. Industrial users are a large group, but they often buy low production quantities and are evenly distributed throughout the geographical regions. Thus, the challenge to the supplier is how to promote, educate, service, and capture designs from the user base. It appears that a well-positioned gate array or PLD supplier may have a competitive advantage in this market.

The findings are much different for the consumer segment. The number of North American buying locations is very limited, but they tend to consume very high volumes per design. It should be noted that most consumer procurement is off-shore and thus is not reported in the table. The ASIC users in the consumer segment prefer CBDs or full-custom, largely because they offer the lowest unit cost.

A CLOSER LOOK

The following discussion examines application trends for three growing markets: PLDs, CBDs, and gate arrays.

PLDs--Application Markets

DATAQUEST estimates that worldwide consumption of PLDs in 1985 was $241.9 million, with more than 97 percent consumed in bipolar technology. We are estimating that worldwide consumption will be $1,016.7 million in 1990 (a CAGR of 28.4 percent between 1985 and 1990), with CMOS products capturing 52 percent of the sales.

As with most ASIC products in North America, the data processing segment is the largest application market for PLDs. As noted in Table 4, data processing applications are expected to consume 77 percent of all PLDs shipped in 1986.

Table 4

ESTIMATED NORTH AMERICAN PLD MARKET
BY APPLICATION MARKET

End Use	1984	1985	1986	1990
Data Processing	82%	76%	77%	73%
Communications	7	7	7	8
Industrial	8	8	8	9
Consumer	0	1	1	2
Military	3	8	7	7
Transportation	0	0	0	1
Total	100%	100%	100%	100%

Source: DATAQUEST
May 1986

Among the more common applications mentioned for PLDs are the following:

- Replacement of control logic in computers
- Peripheral controllers
- CRT display systems
- I/O port decoders

Speed has always been a critical issue for PLDs because of their use in control path (decoding), data path (arithmetic logic units, storage applications), and interface applications. As CMOS technology advances and propagation delay times become closer to bipolar (25 to 35ns), we expect fundamental changes in the PLD market.

For those data processing applications that constantly push for greater speeds, users will turn to ECL PLDs, which should reach speeds of 6 to 15ns. CMOS will find applications that require greater functionality and lower power, where speed is of secondary importance.

The primary reason cited for CMOS PLD applications has been the replacement of "glue logic," thus offering roughly a four-to-one savings in component count. The data processing segment has been the first and most active market in terms of pushing for reduced component count and power savings.

CBDs--Application Markets

A closer look at applications for CBDs shows that these are young markets with bright futures.

Data Processing

As shown in Table 5, during the 1984 and 1985 time frame, the data processing industry was by far the largest market for cell-based ICs. In the past, the emphasis on replacing TTL logic functions gave the first generation of the cell-based suppliers a window of opportunity within data processing applications. Most cell-based IC manufacturers believe that although the data processing application will continue to dominate the market, it will begin tapering off between now and the end of the decade because of the pervasiveness of other segments.

Table 5

ESTIMATED NORTH AMERICAN CELL-BASED DESIGN MARKET
BY APPLICATION MARKET

End Use	1984	1985	1986	1990
Data Processing	63%	60%	59%	47%
Communication	16	16	17	22
Industrial	8	8	8	11
Consumer	2	3	3	5
Military	7	8	8	8
Transportation	4	5	5	7
Total	100%	100%	100%	100%

Source: DATAQUEST
May 1986

Communication

There is a tremendous optimism about this market in the long term. We believe that because of expected high growth in communication equipment markets themselves and because of general opportunities for semiconductors within this sector, cell-based technologies will experience positive growth within the communication arena. Most applications come within telephony, modem, and PBX applications. Incorporating analog functions will also provide communication market opportunities because of filter and data conversion needs within the telecom market. However, there seems to be little use of the technology in central office applications.

Industrial

We believe that industrial applications also provide opportunity for all sectors of the ASIC market, including cell-based products. Incorporating solid-state electronics in industrial applications traditionally has occurred slowly. Today, the emphasis is on replacing traditionally mechanical and discrete semiconductor functions.

Frequently cited applications are process and numerical control, robotics, and factory automation. The MAP program has provided clarity and emphasis on standards and communication protocol within the factory; thus, many semiconductor products are seeing a "more quantifiable opportunity" within the traditionally nebulous industrial market.

Consumer

To date, our estimates for the consumer marketplace have been fairly pessimistic. U.S.-based production of consumer electronic equipment has fallen dramatically, and we believe that this trend will continue. The

Japanese consumer marketplace has centered on gate array technology. None of the manufacturers we spoke to were placing major emphasis on the consumer sector.

Our belief in modest growth in this sector lies primarily in changing the design methodology. Consumer products will utilize semicustom solutions in early production volumes of new equipment. If the product is successful, then a full-custom design will be used.

Military

DATAQUEST is optimistic about short-term prospects in the military market. We are, however, cautiously optimistic about the military markets' long-term opportunity because of political emphasis on cutting both the budget deficit and defense spending, coupled with a changing presidential administration in the near future.

The military market is a relatively small part of CBD consumption; possibly even lower than our current projections of 7 percent. Many manufacturers, however, are implementing military programs and product lines and are optimistic about stronger growth throughout the decade. Some manufacturers believe that the military will account for as much as 10 to 15 percent of their cell-based business within the next couple of years. Design-to-production cycles are lengthy, but once into production, military products tend to remain stable and experience long life cycles.

Transportation

The automotive applications were perhaps the most eagerly discussed by the manufacturers with which we spoke. Major applications for cell-based products can be found in the dashboard, engine control, and safety-convenience features. CBDs not only offer cost advantages in large volumes, but can handle high voltage requirements and expand overall functionality.

One possible cloud on the horizon stems from the automobile manufacturers' general refocusing to reduce their semiconductor supplier base. DATAQUEST agrees with ASIC vendor observations that these reductions might impact the ASIC supplier base in particular. Nevertheless, a willingness to maintain historical alliances will probably prevail unless a rival ASIC vendor has substantial advances in technology, cost, and quality "to bring to the party."

Gate Array--Application Markets

Many of the company representatives we spoke with earn the majority of their gate array revenue from the data processing segment. As shown in Table 6, we believe that this market sector withstood 1985 fairly well, but lost some market share to the military segment.

Table 6

ESTIMATED NORTH AMERICAN GATE ARRAY MARKET
BY APPLICATION MARKET

End Use	1984	1985	1986	1989
Data Processing	53%	47%	48%	41%
Communication	18	16	16	18
Industrial	12	12	12	15
Consumer	2	2	2	3
Military	15	22	21	22
Transportation	0	1	1	1
Total	100%	100%	100%	100%

Source: DATAQUEST
May 1986

Telecommunications applications also represent a sizable part of the market today. We believe that telecommunications combined with industrial applications represent opportunities for gate array manufacturers. Here again, the small volumes typically associated with industrial applications makes gate arrays an attractive solution.

We have seen little activity in the consumer and transportation segments. We know of only one manufacturer that has gate array design revenue from the auto market, and evidence of any future growth in this market is not anticipated.

WILL THE ADOLESCENT REACH ADULTHOOD?

The answer is an emphatic yes, but not without a maturing process. When DATAQUEST contemplates the issues discussed in this newsletter, the following conclusions become apparent.

ASIC Has a Long Way to Go

There are major revenue opportunities in all ASIC market sectors. In effect, ASIC suppliers have not saturated any end-use markets. The fundamental question is: Will the suppliers see the opportunity and will they act on it? Each of these applications markets is very different--each places different demands on the supplier and each requires a deeper level of understanding of the application. For some of the nimble suppliers the answer is a definite yes. This means that they must develop in-house expertise in application markets and form alliances that foster and develop that expertise. Such changes can ripple through suppliers and affect business strategies. Thus the suppliers will require a marketing organization that understands the characteristics of the end market, an engineering organization that understands the technical requirements, and a top management organization that understands the strategic factors that influence the end market. Therefore, the maturing process involves understanding what the customer really wants.

Complex Procurement and Fewer Suppliers

In reviewing the responses to our survey questions, one gets a clear message that many procurement managers are perplexed and overwhelmed by the rapid change in ASIC design methodology. On the one hand, they wish to narrow the base of suppliers and shorten the development schedule, while on the other hand they must seek out the very latest in technology, which may widen the vendor base. To make matters more complex, using ASIC requires an understanding of the caliber of each design methodology. Not only is the semiconductor technology critical, but the EDA tools are just as important. DATAQUEST believes that this complexity will force users to seek out suppliers that understand their end market and that are willing to develop close working relationships. Their commitment will narrow the supplier base, since most users will be willing to work closely with only a few suppliers.

ASIC Suppliers Will Concentrate on Certain End Markets

It also seems inevitable that many of the smaller ASIC suppliers that cannot afford to be broad-line suppliers must focus on certain applications. They will tailor their process technology, EDA tools, and design centers toward those end-use applications that best match their strengths. For example, some suppliers will focus on data processing while others may aim at the communication or industrial sectors.

So, like the adolescent who ultimately does something sensible, ASIC companies will develop those important characteristics that will sustain them through adulthood. Each will draw upon its own natural attributes and develop its own unique personality.

Andy Prophet
Anthea Stratigos
John Brew

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RESEARCH NEWSLETTER

SIS Code: 1986-1987 Newsletters: May
1986-21

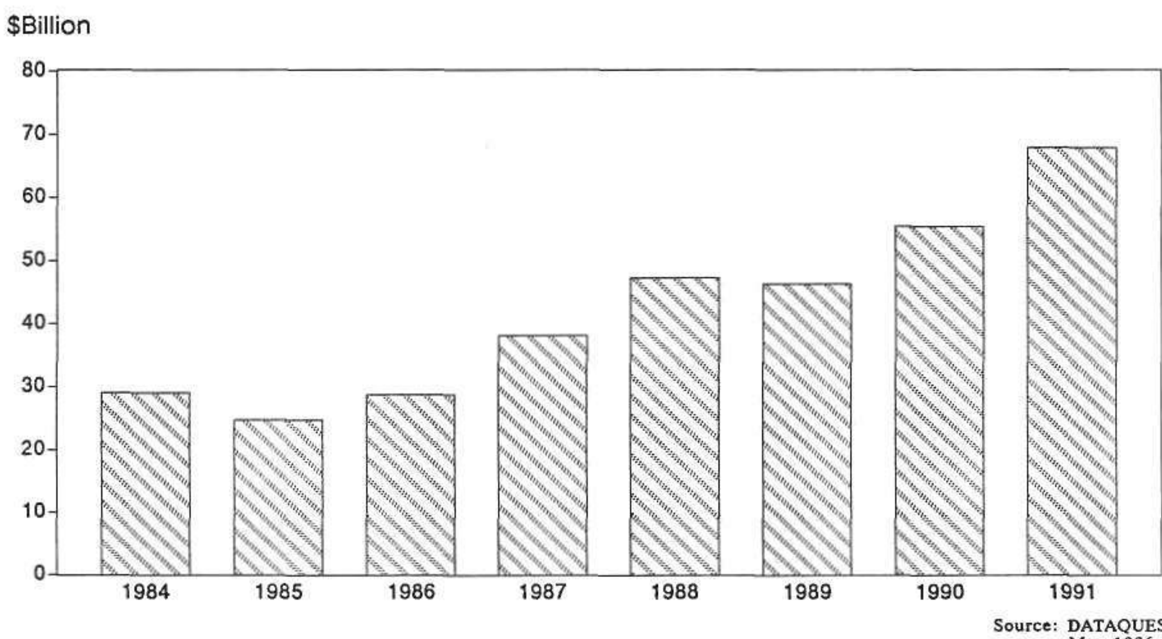
DATAQUEST VIEWS THE FUTURE: SEMICONDUCTOR CONSUMPTION THROUGH 1991

SUMMARY

DATAQUEST believes that worldwide semiconductor consumption will grow at a 18.3 percent CAGR between 1985 and 1991. At this rate, our industry will be valued at $67.9 billion by 1991 (see Figure 1). In arriving at this value, we have made certain assumptions regarding semiconductor usage in equipment, U.S. economic conditions, industrial cycles, and growth characteristics of regions and products.

Figure 1

WORLDWIDE SEMICONDUCTOR CONSUMPTION (1984-1991)



Source: DATAQUEST
May 1986

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END-MARKET ASSUMPTIONS

In looking to the future, DATAQUEST notes several variables that are significant to the semiconductor market. Key among these variables is the more pervasive usage of semiconductors in end equipment. Rapidly declining costs are one of the spurs driving increased usage, as is the added functionality of integrated circuits. We identify value moving from a board and system level to a chip level. As a result, the semiconductor content of systems is increasing. New applications are also emerging with high concentrations of electronics. Some examples of developing markets include digital televisions, compact disk players, personal facsimile equipment, and smart cards. Because of the increasing ratios of semiconductors to systems, we believe that semiconductor growth can outpace equipment growth. Over the last decade, the semiconductor industry has grown, on the average, four percentage points above the end-equipment industry. Thus, our semiconductor forecast corresponds to a worldwide equipment growth rate of approximately 13.8 percent.

U.S. ECONOMIC HIGHLIGHTS

The U.S. economy is of importance to world consumption for several reasons. U.S. suppliers of semiconductors and equipment have a world presence and what impacts them impacts the world. And, from a usage standpoint, the U.S. market is the largest consumer of electronics and consumer electronic goods. For these reasons, we believe that it is critical to take the condition of the U.S. economy into consideration.

The U.S. economy appears to be reviving, with seasonally adjusted real GNP growth of 4.2 percent in the first quarter of 1986. This growth is expected to continue at a strong pace through 1986, leading to an annualized real GNP of 3.2 percent. Positive long-range factors indicate that the economy will remain healthy until perhaps 1989. Lower interest rates, declining oil prices, and a devaluated dollar are expected to power a growth surge. Manufacturing output and employment are already rising. The duration of economic growth is determined in part by the state of inflation. If oil prices stay down, inflation rates may be kept under check. However, inflationary pressures are expected to build by 1988. While it is unlikely that a recession will occur in an election year, one could occur in 1989.

FORECAST CONSIDERATIONS

DATAQUEST believes that a recession in the semiconductor industry will occur in 1989. However, it is conceivable that the state of the economy could change the timing of the recession. In consideration of this possibility, we have viewed three alternative scenarios. The best-case analysis assumed a delayed recession that registered a 10 percent growth in 1988 and a 5 percent decline of 1989. Our worst-case analysis considered a harsh drop in 1989 of 20 percent followed by a mild 10 percent growth in 1990. The scenario for which we tailored our forecast sees a modest decline of 2.1 percent in 1989 followed by a vigorous upturn of 20 percent in 1990.

INDUSTRY CYCLES

Economic history illustrates little correlation between GNP growth and semiconductor growth. Greater correlation may be noted with the pattern of capital spending for semiconductor manufacturing equipment. Capital spending follows a four-year cycle in which investment is made, equipment/facilities come onstream, and production is boosted, which leads to overcapacity and falling prices. The end result of this cycle is reduced investments and rising prices from undercapacity. Hence, the cycle starts again. Thus, the boom and bust cycle in the semiconductor industry is partly created by the industry itself.

DATAQUEST notes that there is still excess capacity from the last cycle of capital spending. In 1986, world capital spending is expected to be flat to down relative to 1985. Through this year and 1987, however, we expect much of the excess capacity to become engaged or taken out of production. As a result, DATAQUEST forecasts capital spending will grow 46 percent in 1987, in line with vigorous semiconductor demand. We expect 1988 capital spending to increase by 24 percent, follow by a sluggish 1989 with 3 percent growth.

It is conceivable, however, that semiconductor demand from new markets could override general economic conditions. We saw this occur in 1982 with the video game boom. Demand for personal computers also added strength and perhaps confusion to the boom year of 1984. We believe that if new markets develop, they will probably fit into the 1988 time frame.

IMPACT OF U.S. TRADE BARRIERS

The impact of recent legislation to protect the U.S. memory market against Japanese dumping is likely to have some negative impact for U.S. end-equipment manufacturers. Japanese manufacturers of memory circuits are apt to sell their products elsewhere. This will hurt the U.S. computer manufacturers that depend on Japanese memory parts. While large manufacturers can purchase components in other markets, small manufacturers may find themselves less able to compete, as prices for memories go up dramatically and become difficult to acquire. Purchases abroad by large computer manufacturers will also undoubtedly hurry the regional market shift to Asia/Pacific markets.

REGIONAL AND PRODUCT TRENDS

As noted earlier, DATAQUEST expects to see the fastest growth coming from the Asia/Pacific markets. The Taiwanese and Korean markets will likely consume more of their own products as their own consumer and telecommunication markets develop. Large U.S. manufacturers will also undoubtedly buy more of their components abroad as a long-range trend.

All semiconductor products will strengthen in 1986. The strongest growth can be expected in the MOS digital area. Among the MOS technologies, we expect CMOS to grow dramatically because of its attractive speed/power ratio. DATAQUEST forecasts that CMOS will grow at the compound annual rate of 40.2 percent between 1985 and 1991. We also believe that CMOS will account for more than 85.0 percent of the market by 1996. Please refer to Table 1 for more complete data on this industry.

DATAQUEST CONCLUSIONS

End-market growth and favorable economic conditions point to strong semiconductor growth throughout 1988. However, we believe that the worldwide market will experience a recession in 1989, which will mean a market decline of 2.1 percent. In the U.S. market, the 1989 recession will be more pronounced, at a negative 6.9 percent. Other geographic regions will experience less severe declines. Over the six-year span between 1985 and 1991, we expect the world to register a compound annual growth rate of 18.3 percent.

DATAQUEST is currently publishing its Consumption and Shipment Forecast. For detail on regional and product consumption, history, or forecasts, please refer to this service section located in the Semiconductor Industry Service "Industry and Technology" binders.

Barbara A. Van
Howard Z. Bogert
Gene Norrett

Table 1

WORLDWIDE SEMICONDUCTOR CONSUMPTION FORECAST
(Millions of Dollars)

	1984	1985	1986	1987	1988	1989	1990	1991	CAGR (1985-91)
Total Semiconductor	29067	24735	28821	38163	47346	46357	55458	67908	18.3%
Total Integrated Circuit	22753	18875	21941	30498	38670	37848	46108	57264	20.3%
Bipolar Digital (Technology)	4812	3784	4084	5109	6011	5747	6453	7523	12.1%
TTL	4067	3043							
ECL	607	607							
Other Bipolar Digital	138	134							
Bipolar Digital (Function)	4812	3784	4084	5109	6011	5747	6453	7523	12.1%
Bipolar Digital Memory	719	595	642	744	833	820	862	912	7.4%
Bipolar Digital Logic	4093	3189	3442	4365	5178	4927	5591	6611	12.9%
MOS (Technology)	13014	10324	12182	18207	24046	23626	29866	38398	24.5%
NMOS	8850	6390	6829	8999	10253	8197	8893	9539	6.9%
PMOS	281	146	116	105	87	72	67	61	-13.5%
CMOS	3883	3788	5240	9103	13706	15357	20906	28798	40.2%
MOS (Function)	13014	10324	12182	18207	24046	23626	29866	38398	24.5%
MOS Memory	6261	4008	4583	7348	10033	8935	11089	14055	23.3%
MOS Micro Device	3261	2751	3355	5055	6734	6939	8965	11761	27.4%
MOS Logic	3492	3565	4244	5804	7279	7752	9812	12582	23.4%
Linear	4927	4767	5675	7182	8613	8475	9789	11343	15.5%
Total Discrete	5054	4676	5401	5924	6625	6497	7009	7895	9.1%
Transistor	2528	2280	2619	2909	3272	3339	3656	4155	10.5%
Small Signal Transistor	1285	1109	1313	1458	1574	1624	1765	2017	10.5%
Power Transistor	1243	1171	1306	1451	1698	1715	1891	2138	10.6%
Diode	1792	1621	1909	2072	2278	2159	2308	2572	8.0%
Small Signal Diode	537	486	545	567	626	572	622	689	6.0%
Power Diode	992	892	1089	1215	1313	1262	1367	1550	9.6%
Zener Diode	263	243	275	290	339	325	319	333	5.4%
Thyristor	438	445	507	539	606	536	519	542	3.3%
Other Discrete	296	330	366	404	469	463	526	626	11.3%
Total Optoelectronic	1280	1184	1479	1741	2051	2012	2341	2749	15.1%
LED Lamps	277	249	309	346	392	360	433	509	12.7%
LED Displays	453	421	509	582	676	642	737	846	12.3%
Optical Couplers	189	173	218	256	305	323	379	451	17.3%
Other Optoelectronics	361	341	441	557	678	687	792	943	18.5%

Source: DATAQUEST
May 1986

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RESEARCH NEWSLETTER

SIS Code: 1986-1987, Newsletters: May 1986-20

GRAPHICS-SPECIFIC ICs--REVOLUTION IN THE GRAPHICS INDUSTRY

EXECUTIVE SUMMARY

Graphics-specific integrated circuits (GSICs) are finding their way into a substantial number of graphics terminals, controllers, and add-on boards. This has caused a faster price/performance increase than ever before in the graphics industry. The result has been a large increase in the number of new, first-time users for personal computer-based graphics systems. DATAQUEST forecasts that by the end of 1985 the number of PC-based graphics systems installed will equal almost two times the installed base of bit-mapped graphics terminals and standalone workstations. This is remarkable when one considers that in 1983 the installed base of conventional graphics terminals was 1.3 times the installed base of PC-based graphics. We believe that the role of GSICs in sustaining this expansion will continue and increase both in the low-end or PC-based arena and in the higher-performance graphics terminal segments.

This is the first in a series of newsletters that address the impact and nature of merchant ICs for graphics. In this newsletter we will present a background of GSICs and review the application of such graphics-specific ICs to various graphics functions that make up a complete graphics system. Future newsletters will address captive or proprietary GSIC products available or in development, and will look at the performance levels of both merchant and captive GSIC products.

DEFINITIONS

DATAQUEST defines an ASIC as a semiconductor product that is designed for a single customer. ASICs include both custom and semicustom products; custom products are either standard cell or full-custom designs, while semicustom products are either gate arrays or field-programmable devices. GIS defines a graphics-specific IC as a close cousin of an ASIC, but one that is usable only as a component in a graphics device or system. We consider a GSIC to be a merchant device if

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it is available to more than one customer, and we call it a captive or proprietary device if it is designed by and for one customer. Compared to the ASIC definition, only the captive GSIC is truly an ASIC, and since these captive devices are a minority in the market, we believe that it is necessary to create the GSIC designation. Our definiton of a GSIC excludes from consideration general-purpose devices such as digital signal processors (DSPs), digital to analog converters (DACs), floating point or array processors, and bit-slice microprocessors (e.g., an AMD 29116). These excluded devices frequently are present in graphics systems, but are general purpose in nature and can also be used in a variety of other, non-graphics systems. In addition, they follow the more general semiconductor market in terms of price, performance, and technology and so do not necessarily respond to the narrower demands of the graphics market.

BACKGROUND

One of the first merchant GSIC products for graphics was the NEC7220 Graphic Display Controller. Although it was not a high-performance device, it replaced a PCB in function and at a much lower cost ($175 versus $500). In addition, it made the use of small form-factor boards for an entire graphics system a reality. This in turn made add-on boards for personal computers a new graphics market segment that is growing at 100 percent per year. The first proprietary GSICs appeared in graphics products in late 1983. Most of these are semicustom gate array and are used in such products as the Ramtek 2020 and the Raster Technologies One/60. Silicon Graphics' Geometry Engine, however, which is used in all of its products, is full-custom VLSI. Other, newer merchant and captive GSIC products are now on the market and are expected to have a similar impact in various graphics segments. They are also expected to obsolete current GSIC designs used by graphics companies in those segments.

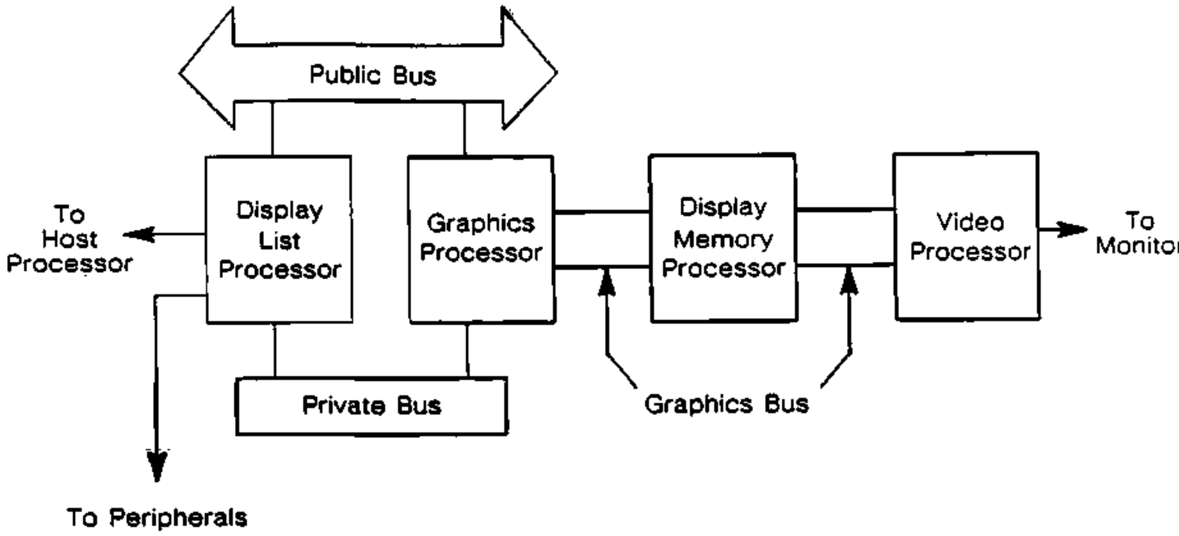
TECHNOLOGY OVERVIEW

Graphics Architecture

Figure 1 presents a generic graphics architecture in block diagram format. This figure serves as a basis for the following discussion about uses of an ASIC or a GSIC in a graphics terminal or controller. A graphics controller can be thought of as four logical processors, which in the past corresponded to one or more physical printed circuit boards. The advent of GSICs has reduced this one-to-one correspondence to some extent today, and we expect fewer boards per logical process in the future. The functions carried out in each of these processors are summarized below.

Figure 1

GENERIC GRAPHICS ARCHITECTURE



<u>Display List Processor</u>

This is the first step in the graphics pipeline. The functions normally carried out here are:

- System memory and control
- Graphics display list memory and control
- Control of the interface between the host processor and the graphics system
- Management of the input and output peripherals attached directly to the graphics system
- Other device emulation
- Running system start-up and diagnostic procedures

The display list processor can be thought of as the front end to the basic function of a graphics system; its purpose is to create and display graphics or geometric entities. This front end off-loads some host computer activities while it speeds up user response times. It can also be used to make the system emulate other graphics devices at a small fraction of the performance penalty associated with carrying out such emulation in the host central processor. It should be noted that not all graphics controllers or terminals use display lists, and on many products they are optional. In the concept design and imaging application areas, display list processors have become quite popular, but in the data conversion and personal computing application areas, they have yet to gain a foothold. When offered, these functions generally require the use of a 16- or 32-bit microprocessor as a monitor for the display list function, especially very large display lists on the order of 2Mb to 4Mb, which have become popular. In addition, the host interface communications may entail one or more combinations of DMA, serial, or Local Area Network (Ethernet, MAP, X.25) protocol, further increasing the computational load on the display list processor. Control of a keyboard, mouse, light pen, data tablet, or even a local hard copy and disk storage device, is also carried out by this processor. In fact, many display list processors already utilize VLSI components for serial I/O, LAN, and peripheral controllers, as well as incorporating the latest high-density DRAMs. In the future, GSICs that incorporate graphics standards such as the computer graphics interface (CGI) portion of GKS will probably find a home in the display list processor part of a graphics system.

Graphics Processor

The second step is the graphics processor. A wide variety of functions can take place here, some of which are very dependent on the application and thus may not be used at all in certain graphics systems. The typical functions are:

- Transformation of display list data from world or application program coordinates to the two-dimensional display coordinate system, in preparation for transfer to the graphics image, or pixel, memory
- Generation of characters and/or vectors (including lines, circles, and arcs) and/or polygons based on display list data
- Bit block transfers (BITBLT) and raster operations (raster ops) such as rapid moves of groups of pixels
- Support for picking of graphics entities by the user
- Execution of simple two-dimensional clipping, rotation, and translation calculations on displayed graphical data
- Execution of more complex three-dimensional transformations on graphics entities based on interactive user input
- Control of hardware pan, zoom, scroll, and roam
- Control of local windowing of independent processes
- Calculation of algorithms for rendering of solid objects

This step is the first in the actual display process since it takes in application-generated data and transforms it into a displayable format corresponding to the layout of the display or pixel memory. This is also the location for rendering operations that are used to depict graphics entities as hidden line/hidden surface objects that enhance the realism of the viewed objects in terms of their surface texture and three-dimensional nature. The combination of rendering with three-dimensional transformations is also addressed in this logical process and is used in such areas as vehicle simulation, video effects, solid modeling, and mechanisms/kinematics. The complexity of this process is much greater than in any of the other functions, since it involves the generation of shaded images made up of large numbers of polygons, as well as the calculation of light sources and reflectivity values for all the objects displayed. Three-dimensional transformations of these objects further add to the computational complexity of the task.

In imaging application areas, this step in the block diagram would be called the image processor, and image enhancement and modification calculations would replace some of the vector and geometry-related operations carried out in a graphics environment. Actually this step could be skipped altogether in imaging applications since another input to the display and pixel memory step can come from direct video inputs that bypass both the display list and graphics/imaging processors and go directly into the raster image memory.

Display Memory Processor

The third step is the display memory processor. The functions carried out here are:

- Control and synchronization of the high-speed display, or pixel, memory with the graphics processor and the video processor
- Management of display memory buffering, when offered
- Management of the Z-buffer memory, when offered
- Read back of memory locations to the graphics processor
- Control of memory mapping for some imaging applications

In traditional graphics terminals this processor is usually called a frame buffer. It is the core of the graphics process and is memory intensive, especially in the imaging areas where the number of memory bits assigned to each displayed pixel on the graphics monitor can run between 24 and 48 bits. Another area of complexity is that of memory buffering; the typical display memory for all but the imaging applications is either single or double buffered, meaning that the equivalent of one or two planes of display memory are stored for every plane of viewable memory on the monitor. In imaging applications, two, four, or more buffers may be used. Z-buffer management refers to separate memory used in the display of hidden line or hidden surface objects.

Video Processor

The fourth step is the video processor. The functions carried out here are:

- Management of the color palette or look-up table that maps color assignments from the display memory to viewable pixel locations on the monitor
- Control and synchronization of the video circuitry that drives the monitor
- Control of the memory interface from the memory processor or frame buffer
- Management of hardware cursors and light pens

Not all systems offer look-up tables, but when offered these may be programmable or fixed. Look-up tables vary in complexity depending on the number of simultaneously displayable colors desired, the number of colors available to choose from for display, and the bandwidth of the monitor on the system. Video circuitry control and the memory interface control are necessary elements in all graphics systems. There is little difference among the various graphics applications regarding the video processor functions, although imaging applications generally have more complex look-up tables.

VLSI Application Areas

Table 1 presents a list of representative suppliers that offer GSIC products. The table also indicates what functional step of Figure 1 is addressed by each product.

As this table indicates, most of the merchant GSICs are aimed at the graphics processor step. Not all of the products are complete graphics processors, but many of them address specific functions such as rendering (Weitek's Tiling Engine), bit block transfers, raster ops (Pacific Mountain Research's BLT Chip), or two-dimensional polygon and vector generation (XTAR's GMP). In general, these products reduce the cost of a given level of performance, but do not increase the performance. For example, the Weitek product offers rendering speeds that are attained or exceeded in most current three-dimensional terminal offerings but at a fraction of the cost. In addition, soon to be announced terminal products will exceed the tiling engine performance by a factor of 10 or more but at a price at least ten times that of the board-level version of the tiling engine (the WTE7100). These newer terminal products will utilize captive GSIC products to accomplish the complex graphic/imaging display functions, which will advance the performance at a constant price in the high end of the graphics marketplace. So, despite the performance difference, merchant GSICs are available at a competitive level of price/performance.

Table 1

REPRESENTATIVE SUPPLIERS AND GRAPHICS SPECIFIC ICs

Company	Product	Functional Area*	Unit Price
Chips and Technologies	Enhanced Graphics CHIPSet	G.P.	$85.40, (Quantity 100)
Hitachi	HD63484	G.P.	$46.80 (Quantity 1,000)
Intel	82716VSDD	V.P.	$20.00 (Quantity 1,000)
Motorola	6845	G.P.	$5.00 (Quantity 1,000)
	68490	G.P.	N/A
National Semiconductor	DP8500	G.P.	N/A
	DP8512/15/16	V.P.	N/A
NEC	uPD7220A	G.P.	$130.00 (Quantity 100)
	uPD4126C	D.M VRAM	N/A
Pacific Mountain Research	PMR96016	G.P.-Raster Operations	$39.80 (Quantity 100)
Texas Instruments	TMS34061	V.P.	$35.50 (Quantity 100)
	TMS34070	V.P. Look-up Table	$24.00 (Quantity 100)
	TMS4161EV4	D.M.P.VRAM	$24.00 (Quantity 100)
Weitek	Tiling Engine	G.P. Solid Rendering	N/M*
XTAR	X1001/1002-GMP	G.P.	$325 (Quantity 100)

N/A = Not Available
N/M = Not Meaningful
G.P. = Graphics Processor
D.M.P. = Display Memory Processor
V.P. = Video Processor

*The Weitek chip set is only available in a board-level product incorporating other Weitek components.

Source: DATAQUEST
May 1986

The video processor and display memory areas are the others to be addressed by the merchant suppliers. The memory area is, of course, a natural one for the large merchant houses, but the video control area is a new one for them. Consistent with the products for the graphics processor step, these products offer lower-priced solutions at a level of performance equivalent to previous or current terminal offerings. One difference is that these products are appealing to both high- and low-end graphics systems vendors and are not likely to be addressed by captive design efforts.

ANALYSIS

Many functions in a graphics system lend themselves to VLSI implementations. The functional areas discussed in the previous section usually are separate circuit boards in traditional graphics systems and, in many cases, such as in the display memory area, are multiple boards. The attractiveness of VLSI is twofold to a graphics vendor: on the one hand, VLSI can significantly reduce both board count and complexity with the benefit of lower cost, lower power consumption, simpler board design, and better manufacturability and servicability; on the other hand, a vendor could maintain a given board count and increase performance per board.

A simple example of this would be the use of 256K DRAMs in place of 64K DRAMs on a memory board to either cut real estate requirements by a factor of four or increase the number of bits/board by a factor of four. A vendor's choice here is dictated by the market segment for the particular graphics product in question. The business graphics and process control segments, which are less performance sensitive than others, will rapidly move to merchant GSICs for all the functional areas of Figure 1, while performance-sensitive segments such as CAD/CAM, simulation, and imaging will move to merchant solutions only in the video processor and memory areas and rely on their own captive GSIC designs in the other areas. Of course, the high-performance vendors will continue to utilize other non-graphics VLSI products such as bit-slice, array processor, and signal processor devices and remain customers of the merchant suppliers.

The move to more and more GSIC devices in the graphics industry not only affects the user base because of better price/performance, but also has a dramatic effect on the vendors of graphics systems. These vendors will no longer be able to add significant value to graphics systems in areas where commodity GSICs exist; they will have to look to other, non-GSIC parts of the overall system to add value or accept steadily decreasing prices for their products. We have already seen the effect of these advances. In the personal computer graphics board market segment, virtually all of the products utilize either the NEC, Motorola, or Hitachi chip and produce screen resolution and performance equivalent to the traditional business graphics and process control terminals. More important in DATAQUEST's view is that the price of a PC XT plus graphics board and monitor is equal to the traditional terminal price exclusive of any CPU resources, and the PC solution can include both Digital Equipment's VT-100 and Tektronix's graphics emulation. This will result, we believe, in loss of business for the traditional, low-end terminal suppliers unless they can compete on a price basis with the PC board suppliers.

Moreover, as the graphics market matures, price/performance is becoming the crucial measure of a graphics system, and such price/performance is being measured in the context of an application solution. And, with the growing number of merchant and captive GSICs available, it is possible to produce low-cost products that are oriented to very specific application areas. Users will no longer pay a higher price for higher performance unless it can be used in their particular graphics application. For example, in a two-dimensional drafting application, the crucial performance metric is the two-dimensional vector drawing performance features of a given system. Offering advanced solid modeling features in such a system will not fetch a higher price than a simpler and less costly two-dimensional system that uses merchant GSICs to attain acceptable vector drawing rates. In addition, vendors that choose not to use GSICs when all or some of their competition do, will be at a significant cost disadvatage. This disadvantage could be as much as a factor of ten if one considers the cost of one GSIC chip versus a circuit board implementation using only discrete components.

For low-performance application areas, these off-the-shelf GSICs are providing acceptable performance for the users at lower prices than ever before and putting pressure on the traditional low-end terminal vendors to use the most current VLSI products or perish. In high-performance applications, graphics systems vendors with the most advanced captive GSIC design capability will be at a significant advantage not only from a technical but also from a business point of view.

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RESEARCH NEWSLETTER

SIS Code: 1986-1987 Newsletters: May
1986-19

MARKET DEVELOPMENT FOR MOS 32-BIT MICROPROCESSORS

OVERVIEW

During the last two years, 32-bit microprocessor activity has increased tremendously. Production quantities from 32-bit MPU semiconductor suppliers began to appear on the market, and by the beginning of 1986 the merchant market supplier base grew to thirteen. Within this supplier base, five of the thirteen companies delivered volume production or sample quantities to customers in 1985, and six more had promised sample quantities in 1986 or 1987.

Despite the early entry of a few 32-bit microprocessors, high levels of volume production are not expected until the 1990s. The 32-bit market is still in its infancy. Initial use has been limited to a small number of high-end applications, such as engineering and scientific workstations or high-performing multiprocessor systems. However, DATAQUEST believes that office automation, comprising multiuser systems, advanced personal computers, and network servers will become the largest 32-bit market segment in the next five years.

We estimate that the market for 32-bit MPUs (the CPU only) will be $36 million during 1986, growing slowly to $321 million in 1991, with an annual compounded rate through 1991 of 55 percent in dollars. We believe that 32-bit shipments will not significantly affect the overall microprocessor market until the mid-1990s. We think that the major reason why 32-bit MPUs are growing slowly is because <u>today</u>, they are not seen as practical, cost-effective solutions for most applications.

Table 1 shows DATAQUEST's forecast for 32-bit microprocessor unit shipments, ASPs, and revenue from 1984 through 1991.

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Table 1

32-BIT MICROPROCESSOR UNIT SHIPMENT AND REVENUE FORECAST

	1985	1986	1987	1988	1989	1990	1991
Units (K)	100	290	710	1,410	2,610	4,700	8,520
ASPs ($)	175	125	82	63	51	41.5	37.7
Revenue ($M)	17	36	58	90	134	195	321

Source: DATAQUEST
May 1986

MARKET APPLICATIONS

Engineering and scientific computers have been among the first applications to implement 32-bit MPU technology. Desktop workstations are already widely used to design and simulate everything from complex chips and software to automobiles and aircraft. Scientific systems are used for data collection and processing for a variety of purposes, such as weather prediction, medical research, and oil exploration. Markets for equipment used in computer-aided engineering (CAE), computer-aided design (CAD), and computer-aided software engineering (CASE) are among the fastest growing in the computer industry.

One trend we have noted in the engineering market is a shift away from shared superminicomputers, such as Digital's VAX, and toward individual workstations for each engineer. Until now, large systems have been necessary for a number of computation-intensive tasks that no existing workstation could adequately perform. The new 32-bit MPUs will offer the power of a minicomputer in inexpensive systems, which we believe will aid in workstation acceptance.

In industrial and factory automation applications, 32-bit MPUs will be used in process-control systems, sophisticated robots and cluster controllers (which manage robot groups), and computer-aided testing equipment. These applications demand real-time response (that is, events must be dealt with as they arise, with no significant delay) and high reliability, high performance, fast response time, software protection, and special operating systems. These demands can be met with 32-bit MPUs.

The 32-bit MPU is well-suited for use in a variety of high-end telecommunications equipment, including central office switches and private branch exchanges (PBXs), as well as local area computer networks and signal processing applications. Existing phone cabling is increasingly being used for a variety of communications purposes, including local computer networking and combined voice, data, and video networks. The switching systems that control such functions demand high performance, large memory addressability (since the systems use lengthy "lookup tables" to identify and track parties on the network), and fast context switching for routing a multitude of concurrent signals.

Switches such as PBXs are being equipped with a growing number of intelligent functions, including automatic route optimization, phone mail, and even environment and security control in buildings. These functions require sophisticated application processors with the features of a 32-bit MPU. Among other communications management systems that will use 32-bit MPUs are network servers, which manage many functions on local area networks.

Ultimately, office automation is expected to become the largest of the 32-bit market segments. High-end MPUs will form the basis of multiuser systems, advanced personal computers, and network servers.

Though a home and consumer segment will eventually emerge, 32-bit chips provide more processing power than most current applications can exploit. A few exceptions may develop in automotive applications, such as engine control and navigational systems.

MARKET POTENTIAL

Most minicomputers, superminicomputers, and mainframes are 32-bit machines, and 32-bit processing is seen as adequate for all but the most demanding computer applications. It is therefore likely that 32-bit microprocessors will become the standards of high-end systems for years to come.

The 32-bit processor will also play a major role in mini- and superminicomputer replacement. These midsize computers are pervasive in government, business, and large organizations, and are used by work groups or entire small to medium-size companies. The midsize system industry is expected to grow faster than the total computer industry. With the coming of the 32-bit MPU, $10,000 to $20,000 systems will match the performance of large minis and superminis costing hundreds of thousands of dollars, opening an enormous new market opportunity for computer suppliers.

In addition, we expect 32-bit MPUs to foster a number of entirely new applications including machine vision, computer voice recognition, advanced robots, and artificial intelligence (AI) systems capable of making humanlike judgments. "User friendliness" will take on new dimensions as the increasing intelligence of machines allows them to process spoken and natural language commands. Table 2 shows DATAQUEST's application forecast for 1985 and 1990.

Table 2

32-BIT MICROPROCESSOR APPLICATION FORECAST
(Thousands of Units Shipped)

	1985		1990		
Application	Shipments	Percent of Total	Shipments	Percent of Total	CAGR
Engineering/Scientific Workstations	73.6	80%	423.0	9%	41.9%
Industrial Factory Automation--Robotics	7.4	8	235.0	5	9.7%
Telecom Central Office Switching/PBX	3.7	4	188.0	4	119.4%
Office Automation--Multiuser/PC/Network Servers	0.9	1	3,572.0	76	424.5%
Others Military Parallel	6.4	7	282.0	6	113.2%
Total	92.0	100%	4,700.0	100%	119.6%

Source: DATAQUEST
May 1986

MARKET LEADERS AND FOLLOWERS

Market development requires collective development efforts of all suppliers. Among the eight that have sampled product, only four are in volume production. Six of the 16 manufacturers developing product are Japanese manufacturers. Typically the Japanese wait until the market is fully developed before jumping in, but this time the Japanese have taken a strong position. Three reasons that account for their strong position are: the Japanese have enormous amounts of capital available for research and development because of their vertical infrastructure; developed expertise in process technology is required to establish leverage in second-source negotiations with U.S. suppliers; and the need for 32-bit microprocessor technology is as important to Japanese industry as it is to U.S. industry. In Table 3, DATAQUEST depicts the current availability and status of the 32-bit MPU suppliers.

All 32-bit MPU manufacturers have different approaches. However, because of National Semiconductor and Motorola's early entry into the marketplace, these two manufacturers have captured more than 85 percent of market share. Figures 1 and 2 show DATAQUEST's estimates of the 32-bit microprocessor market share by manufacturer for 1985 and 1986, respectively.

Table 3

32-BIT MICROPROCESSOR AVAILABILITY

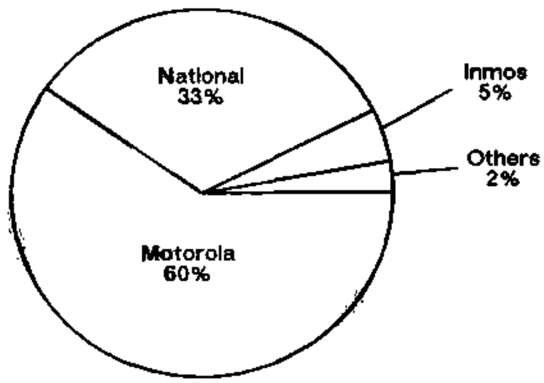
Manufacturer	Device	Process	Sample	Production
AT&T	WE 32200	CMOS	Q3/1986	Q1/1987
	WE 32100	CMOS	Q2/1985	Q4/1985
	WE 32000	CMOS	Q1/1981	Q1/1981
Fairchild	CLIPPER	CMOS	Q2/1986	Q3/1986
Inmos	T414	CMOS	Q4/1984	Q1/1986
Intel	80386	CMOS	Q4/1985	Q3/1986
Matsushita	Proprietary	CMOS	Q3/1986	Q1/1987
Mitsubishi	Proprietary	N/A	N/A	N/A
Motorola	68020	CMOS	Q2/1984	Q1/1985
National	32332	NMOS	Q4/1985	Q2/1986
	32032	NMOS	Q4/1983	Q2/1984
NCR	NCR32	NMOS	Q1/1983	N/A
NEC	V70	CMOS	Q4/1986	Q1/1987
Sony	V70	N/A	N/A	N/A
Toshiba	Proprietary	N/A	N/A	N/A
Thomson	68020	CMOS	N/A	N/A
Oki	Proprietary	N/A	N/A	N/A
TI	32032	NMOS	Q2/1984	Q1/1986
Zilog	Z80,000	NMOS	Q1/1986	N/A
	WE 32100	CMOS	N/A	N/A

N/A = Not Available

Source: DATAQUEST
May 1986

Figure 1

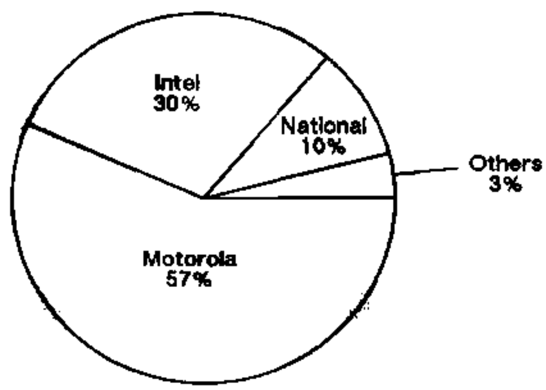
32-BIT MICROPROCESSOR MARKET SHARE
1985



Source: DATAQUEST
May 1986

Figure 2

ESTIMATED 32-BIT MICROPROCESSOR MARKET SHARE
1986



Source: DATAQUEST
May 1986

EXPECTATIONS FROM SUPPLIERS

CMOS

We foresee that suppliers of CMOS devices will have an advantage. Most of the current 32-bit MPU entrants are already using CMOS, and performance upgrades and increased function density will only be possible with CMOS technology. The CMOS process, which is necessary for further enhancements and generations, is not always implemented immediately; National and Zilog are both currently using NMOS processing on their MPUs. However, if these vendors are to remain competitive in the overall sense, they will need to shift to a total CMOS technology.

Faster Parts

The acceptable clock frequency for an MPU in the past has been between 5 and 12 MHz. Today's advanced MPU speeds are capable of 22 to 33 MHz, and by the end of 1986 we expect several 32-bit devices to be sampling these high-speed versions of its architecture. By 1990, we believe that 50 MHz will be possible in design fabrication; however, production quantities will not be available. We believe that clock frequencies will plateau at 33 MHz due to the heat dissipation problems on board-level products.

Price Competition

During the next two years, prices are expected to decrease 50 percent from their current levels. Most 32-bit MPUs will likely be priced at less than $100 in a few years, while their 1990 prices could be close to that of today's 16-bit microprocessors. Cost-to-performance ratios in the future are expected to be excellent, since MPUs tend to offer constant performance at a decreasing price.

We believe that the 32-bit MPU ASP will be affected by factors such as new product introductions, processor clock rates, manufacturing volume, and package complexity. The package type and pin count will have a definite effect, as a nonmultiplexed bus requires more pins. If vendors are targeting a higher-performance market area with a more complex design, they will surely be at the higher end of the ASP curve. Fairchild and Inmos are examples of this trend; their ASPs are in the $300 to $400 range. AT&T, Intel, and Motorola most likely fall in the middle between $100 and $300, while National and TI are on the lower end with quoted prices well under $100 in late 1985.

Architectural Comparisons

Technical feature content becomes very important when the performance of the 32-bit microprocessor weighs heavily in the decision to select a particular product and architecture. Throughput as measured in millions of instructions per second (MIPS) is one yardstick. However, this is not always truly indicative of efficiency, since different applications stress different aspects of the design.

One architectural issue growing in the 32-bit area is whether the microprocessor should use a Complex Instruction Set Computer (CISC) or a Reduced Instruction Set Computer (RISC). RISC creates a much faster, more efficient computing engine than CISC. Today most of the current product offerings are general-purpose microprocessors or CISC. Only two 32-bit devices on the merchant market use RISC-like architectures: Fairchild's CLIPPER and Inmos' T414. The speed and performance enhancements offered by these two devices offer something different to the 32-bit area, indicating that the 32-bit world will be completely different from other microprocessor markets.

The 32-bit device manufacturers are offering many performance enhancements to address the high-performance needs of the users. Pipelining, memory management, dynamic bus sizing, and cache are all performance enhancements implemented by most of the general-purpose 32-bit microprocessors. On-chip or off-chip strategies differ from processor to processor.

Memory management has typically been offered as a separate component; however, Intel and Zilog believe that an on-chip MMU solution is best and that one less VLSI device will reduce the board cost. On-chip cache is generally accepted as a performance enhancer by most users except for Inmos, Intel, and National. The downside to on-chip MMU and cache is that manufacturing and testing the microprocessor becomes more complicated with the added circuitry.

Development Support

The 32-bit microprocessor and its support components pose a very complex design task, for both the hardware interface and the software involved. Manufacturers of 32-bit microprocessors must invest at least $100 million to market a complete 32-bit family. The complete family must be on the market for users to fully design in products. Only National Semiconductor has the complete 32032 family on the market. But, putting just any family of processors on the market is not acceptable. Getting a family of very high-performance 32-bit microprocessors into the market for minicomputer manufacturers to work with is what is needed. In order for Pyramid-type computers to become major users of 32-bit MPUs, the chips need to perform three to four times faster than Motorola's 68020.

DATAQUEST believes that 30 to 40 percent of the potential 32-bit market will consist of independent software by the year 1990. The linking factor will be a C-like language, despite the extended processor architecture approach of upward compatibility.

Peripheral Chips

Support devices in a particular 32-bit microprocessor family are important for high-performance applications. The floating-point or math accelerator unit is vital to users and to the growth of the 32-bit market. This is due to the nature of the applications (technical workstations, graphics, robotics, and other complex mathematical systems) where 60 to 70 percent of all 32-bit designs require floating-point calculations. Table 4 lists the current critical peripheral chips on the market.

Table 4

CRITICAL 32-BIT PERIPHERAL CHIPS

Company	CPU	FPU	MMU	DMA	Others
AT&T	32100	32106	32101	32104	32103 (DRAM) 32105 (SIO) 32102 (Clock Modular)
Fairchild	CLIPPER	On-Chip	CAMMU MMU		
Inmos	Transputer T424	F424 On-Chip			6412 (Graphics) M212 (DKS)
Intel	80386	80387 80287	On-Chip	82258	82384 (Clock) 82387 (Clock) 82586 (Graphics) 82586 (LAN) 82588 (LAN)
Mostek			68451		
Motorola	68020	68881	68851	68442	68461 (MMC) 68605 (XPC)
National	32032 32332	32081	32082 On-Chip	32203	32201 (Clock) 32202 (I/O) 32382 (MMU Planned) 32381 (FPU Planned) 32310 (Weitek Interface Chip)
Signetics			68920		
TI	32032	32081	32082		32201 (TCU) 32202 (ICU)
Weitek		Chip Set (1164, 1165)			Intel (80883 Interface) National (Chip Set)
Zilog	Z80,000	Z8070	On-Chip	Z8016	Z8581 (Clock)

Source: DATAQUEST
May 1986

DATAQUEST ANALYSIS

We expect the leading 32-bit architectures to develop during the next several years. In the past, four or five architectures constituted more than 80 percent of the market for 8-bit and 16-bit microprocessors. We expect the 32-bit microprocessor market to develop in the same way. Suppliers such as Intel, Motorola, and National will probably be leaders, since their architectures are upward-downward compatible. This compatibility factor prompts many users to consider the benefits of offering end products in a low-, middle-, and high-range performance/ feature format.

We believe that many suppliers will become niche product manufacturers as various applications open up; the Fairchild CLIPPER and Inmos Transputer are currently in this category. Even Zilog's Z80,000 is considered a specialized device. It has many of the attributes of a mainstream part, but its very advanced architecture and potential performance level may keep it out of the main race.

We expect multiple-sourcing negotiations to be going on for the next couple of years, as the suppliers without proprietary architectures align themselves with primary vendors. Texas Instruments signed on with National Semiconductor very early for the NSC32000 series family. This lends credence to National for its entrance into the MPU arena, and to TI for its remaining active in leading-edge technology. Motorola signed Thomson as the 68020 second source early in its introduction stage. Intel and Siemens are known to be holding second-source negotiations regarding the 80386 (details are not known at this time), and AT&T recently signed Zilog on as a second source for the WE 32100.

DATAQUEST believes that there are many factors influencing the growth of the 32-bit MPU market. One is the replacement of 16-bit devices by 32-bit devices, which has already been seen in the engineering workstation industry during the introductory stages of the 32-bit device. We also expect to see the use of 32-bit microprocessors in minicomputers and small business systems by the end of the current decade. However, office automation will be the force driving the 32-bit MPU market into rapid and high growth. The impact of this will be discussed further in a series of newsletters on 32-bit devices.

Besides product proliferation issues, we believe that the issues of pricing and return on investment will greatly influence the growth of the 32-bit MPU market. The dollars needed to develop a 32-bit microprocessor family of products, software, and development systems starts at $100 million. The early pricing strategies are key to the development of the market. In order to recover these high costs, the supplier must extract the maximum amount of money during the early years. OEMs will allow prices to remain high for awhile due to the substantial premium they receive on high-performance chips. However, with the growing number of suppliers on the market, the breadth of the supplier base guarantees fierce price competition. Cost reduction methods such as new packaging techniques will have to be developed to compete effectively.

The 32-bit MPU designers are stretching the limits of previous microprocessor designs. High density with high functionality and high-performance capabilities puts the 32-bit chip in a class all its own. Almost all 32-bit designs are in 1.5-micron CMOS with more than 200,000 transistors on-chip. The technical feature content varies from supplier to supplier depending on company strategies. Almost all suppliers have some form of caching either on-chip or as a separate component.

International competition has heated up in this area more quickly than with other microprocessor products. Japanese suppliers typically wait until standards and markets are further developed before aggressively taking action. This time they have not. All development being done in Japan is original design and all current Japanese microchip suppliers have 32-bit participation. Hitachi and NEC have announced plans to enter the 32-bit microprocessor merchant market, while others such as Matsushita, Mitsubishi, Oki, and Toshiba have just announced product development.

DATAQUEST finds the 32-bit market exciting but turbulent. The 32-bit MPU is believed to be the last product offering in the microprocessor evolution path. Word lengths longer than 32 bits will not optimize performance as the 32-bit chips do. The market is fierce and will remain very competitive because it is the last chance semiconductor manufacturers will have to participate in developing general-purpose, high-performing microprocessors.

The competition is savage. U.S. manufacturers plan no mercy on foreign manufacturers of 32-bit chips. Second-source agreements will be slow to develop, in order not to give away advanced technology too quickly. As mentioned earlier, Japanese semiconductor manufacturers are all developing original 32-bit designs. Whether these chips will be used internally, in cell libraries, or for merchant market sales is not known at this time. However, it is known that the Japanese are knowledgeable and capable of developing advanced high-performing microprocessors.

System manufacturers add to the restlessness of this market. There seems to be a clash between system and high-performance microprocessor manufacturers; both have different design needs. Many system manufacturers are developing proprietary 32-bit devices to improve the cost/performance ratio of their machines, while the semiconductor 32-bit microprocessor manufacturers are reaching for higher-performing chips than previous generations.

The 32-bit market is untamed. There are a lot of players with different directions and niches. The rules are different and traditional patterns of business have been altered. For instance, many are not waiting for a market need to develop product. They are developing product for an anticipated market. However, it will take awhile for new markets and applications to open up and for system manufacturers and semiconductor manufacturers to agree on common standards to spearhead high growth in the industry. DATAQUEST believes that there is a lot of turmoil in this area never seen before in the microprocessor industry, and the turmoil we are experiencing now will exist for a long time.

Janet Oncel

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RESEARCH NEWSLETTER

SIS Code: 1986-1987 Newsletters: May
1986-18

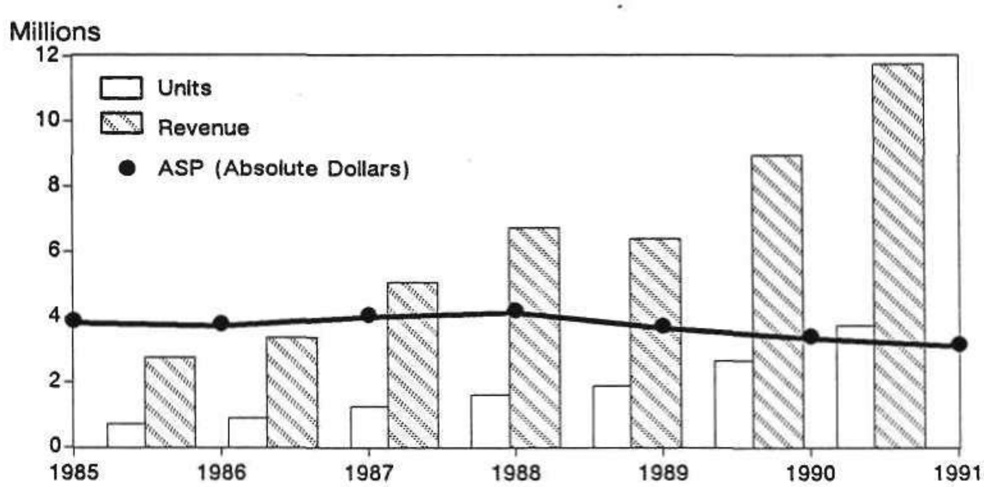
MOS MICROCOMPONENT FORECAST: INTEGRATION CONTINUES THROUGH THE DECADE

SUMMARY

This newsletter summarizes historical and forecast total revenues, unit shipments, and average selling prices (ASPs) of MOS microcontrollers, microprocessors, and microperipherals (see Figure 1).

Figure 1

MICROCOMPONENT MARKET FORECAST



Source: DATAQUEST
May 1986

DATAQUEST recently completed its 1986 MOS microcomponent forecast. The following briefly describes DATAQUEST's predictions for the microcomponents markets:

- We believe that 1986 and 1987 will be recovery years for the semiconductor industry, and we expect worldwide growth rates of 16 percent and 33 percent, respectively, for those years.

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- Microcomponent (MCU, MPU, and MPR) revenue is expected to grow 22 percent and 51 percent, respectively, during 1986 and 1987.

- The microcomponent revenue compound annual growth rate (CAGR) from 1986 to 1991 is expected to be 29 percent.

- The CAGR for microcomponent unit shipments during the same period is expected to be slightly higher, at 34 percent.

- An industry-wide downturn is expected in 1989, because of the cyclical nature of the semiconductor industry.

THE FORECAST

Microcontrollers

Tables 1, 2, and 3 show 1985 through 1991 annual unit, revenue, and ASP forecasts for microcontrollers.

We expect the 4-bit microcontroller (MCU) share of total market to decline through 1991. We believe that the product has reached the peak of its life cycle and is now in its mature stages, where declining growth is typical.

Eight-bit MCU costs have been driven down by large production volumes. Eight-bit MCU prices are low enough that, when appropriate, a 4-bit device will be replaced with an 8-bit device for the optimal price/performance advantages. We see this happening now. By the end of the decade, 8-bit MCUs will overwhelmingly dominate the MCU market with approximately 90 percent of total MCU shipments, maintaining a unit growth rate of 45 percent. We believe that more intelligence will be put into systems such as computer terminals, instruments, and peripheral controllers, furthering the growth of 8-bit MCUs. Module microcontrollers, or integrated MCUs, will represent a growth area for the 8-bit MCU from 1988 through 1991. The chip will integrate an MCU, a direct memory access (DMA), and an I/O interface for any standard, possibly an ISDN I/O interface unit.

The new high-performance 16-bit MCU will enter a rapid-growth phase during the later part of the decade. Intel, Mostek, and Texas Instruments have been shipping product for several years; however, Intel's 8096 dominated the market during 1985. Many 16-bit MCUs will be or have been introduced in 1986. National's HPC 16040, NEC's V25 and upd78312, and Zilog's Super 8 are future offerings. Currently, the automotive industry strongly influences the volumes of 16-bit MCU shipments. However, modems, robotics, and low-end digital signal processor (DSP) applications are expected to increase and fuel 16-bit market growth during the market's rapid growth phase, from 1986 through 1991.

Table 1

MICROCONTROLLER FORECAST
(Millions of Units)

	Actual			Forecast						CAGR
	1983	1984	1985	1986	1987	1988	1989	1990	1991	1986-1991
4-Bit MCU Units	172.00	193.44	180.40	179.68	178.96	178.25	177.53	176.82	176.12	(0.4%)
Annual Growth	8.74%	12.74%	(6.74%)	(0.40%)	(0.40%)	(0.40%)	(0.40%)	(0.40%)	(0.40%)	
8-Bit MCU Units	92.70	164.36	161.35	240.41	382.26	527.52	675.22	1,065.50	1,544.98	45.1%
Annual Growth	71.32%	77.30%	(1.83%)	49.00%	59.00%	38.00%	28.00%	57.80%	45.00%	
16-Bit MCU Units	0.09	0.06	0.15	0.45	1.80	4.50	9.00	19.80	43.56	149.6%
Annual Growth	72.00%	(30.23%)	150.00%	200.00%	300.00%	150.00%	100.00%	120.00%	120.00%	
Total MCU Units	264.79	357.86	341.90	420.55	563.02	710.26	861.76	1,262.13	1,764.65	33.2%
Annual Growth	24.70%	35.15%	(4.46%)	23.00%	33.88%	26.15%	21.33%	46.46%	39.82%	

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

Source: DATAQUEST
May 1986

Table 2

MICROCONTROLLER REVENUE FORECAST
(Millions of Dollars)

	Actual			Forecast						CAGR
	1983	1984	1985	1986	1987	1988	1989	1990	1991	1986-1991
4-Bit MCU Revenue	$258.00	$ 475.86	$ 383.07	$ 350.12	$ 318.61	$ 294.72	$ 265.24	$ 233.42	$ 224.08	(8.5%)
Annual Growth	1.95%	84.44%	(19.50%)	(8.60%)	(9.00%)	(7.50%)	(10.00%)	(12.00%)	(4.00%)	
8-Bit MCU Revenue	$273.47	$ 935.21	$ 721.98	$ 996.34	$1,662.09	$2,326.92	$2,514.24	$3,268.51	$4,262.79	33.7%
Annual Growth	57.94%	241.99%	(22.80%)	38.00%	66.82%	40.00%	8.05%	30.00%	30.42%	
16-Bit MCU Revenue	$ 1.08	$ 0.66	$ 4.00	$ 7.20	$ 36.00	$ 79.19	$ 110.87	$ 199.56	$ 259.43	104.8%
Annual Growth	27.06%	(38.89%)	506.00%	80.00%	400.00%	120.00%	40.00%	80.00%	30.00%	
Total MCU Revenue	$532.55	$1,411.73	$1,109.05	$1,353.66	$2,016.70	$2,700.83	$2,890.35	$3,701.49	$4,746.30	28.5%
Annual Growth	24.70%	165.09%	(21.44%)	22.06%	48.98%	33.92%	7.02%	28.06%	28.23%	

Source: DATAQUEST
May 1986

Table 3

MICROCONTROLLER ASP FORECAST
(Dollars)

	Actual			Forecast						CAGR
	1983	1984	1985	1986	1987	1988	1989	1990	1991	1986-1991
4-Bit MCU ASP	$ 1.50	$ 2.46	$ 2.12	$ 1.95	$ 1.78	$ 1.65	$ 1.49	$ 1.32	$1.27	(8.2%)
8-Bit MCU ASP	$ 2.95	$ 5.69	$ 4.47	$ 4.14	$ 4.35	$ 4.41	$ 3.72	$ 3.07	$2.76	(7.8%)
16-Bit MCU ASP	$12.56	$11.00	$26.66	$16.00	$20.00	$17.60	$12.32	$10.08	$5.96	(17.9%)
MCU ASP	$ 2.01	$ 3.94	$ 3.24	$ 3.22	$ 3.58	$ 3.80	$ 3.35	$ 2.93	$2.69	(3.5%)

Source: DATAQUEST
May 1986

Microprocessors

Tables 4, 5, and 6 show 1985 through 1991 annual unit, revenues, and ASP forecasts for microprocessors.

The market for 8-bit microprocessors (MPUs) will continue to grow both in units and in revenue for the remainder of the decade as a result of the new high-integration chip offerings. The mix of 8-bit MPU product offerings will shift during 1988 and 1989, replacing the older, mature MPUs with the new high-integration chips.

Because of their cost/performance effectiveness and capabilities, 16-bit MPUs will continue to replace 8-bit devices in many applications such as hardware support for multitasking, virtual memory, memory management, and memory protection. We expect the 16-bit unit CAGR to be 47 percent from 1986 through 1991. This is greater than the total MPU market CAGR of 35 percent. The 16-bit MPUs will maintain more than 50 percent of total MPU revenue and shipments until the mid-1990s, when 32-bit devices will edge out the 16-bit devices, as happened to the 8-bit MPUs.

The technology for 16-bit MPUs will shift from NMOS to CMOS in 1987 and 1988, in contrast to the 32-bit MPU, which was introduced using CMOS technology because of its high density and functionality attributes.

Activity is increasing in the 32-bit market. The performance and functional capability of the 32-bit MPU enable it to reach new markets unavailable to 8- and 16-bit MPUs, thus encouraging high growth. There are also more 32-bit suppliers than there were for 8- or 16-bit microprocessors. The 32-bit devices are expected to grow 115 percent in 1986 and 65 percent in 1987.

Business computers with shared resources using LAN technology will be a major application for 32-bit MPUs during 1989 and 1990, when we believe that the 32-bit device will enter a rapid growth phase. Typically, there is a seven-year period of introduction before a product experiences rapid growth. We believe that this will be true of 32-bit devices because of the difficulty in designing a 32-bit system. Another hindrance to rapid growth is the lack of tools available to support a 32-bit design today.

Table 4

MICROPROCESSOR FORECAST
(Millions of Units)

	Actual			Forecast						CAGR
	1983	1984	1985	1986	1987	1988	1989	1990	1991	1986-1991
8-Bit MPU Units	68.10	75.46	60.37	70.63	105.95	132.43	147.00	198.45	279.81	31.7%
Annual Growth	41.90%	10.81%	(20.00%)	17.00%	50.00%	25.00%	11.00%	35.00%	41.00%	
16-Bit MPU Units	7.11	10.00	7.90	11.38	19.79	31.27	35.97	51.43	77.15	46.6%
Annual Growth	72.67%	40.57%	(21.00%)	44.00%	74.00%	58.00%	15.00%	43.00%	50.00%	
32-Bit MPU Units	0.00	0.01	0.10	0.29	0.71	1.42	2.63	4.73	8.52	96.6%
Annual Growth										
Total MPU Units	75.21	85.47	68.37	82.30	126.45	165.13	185.59	254.61	365.48	37.7%
Annual Growth	44.34%	13.64%	(20.00%)	20.37%	53.65%	30.59%	12.39%	37.19%	43.54%	

Source: DATAQUEST
May 1986

Table 5

MICROPROCESSOR REVENUE FORECAST
(Millions of Dollars)

	Actual			Forecast						CAGR
	1983	1984	1985	1986	1987	1988	1989	1990	1991	1986-1991
8-Bit MPU Revenue	$221.33	$306.37	$ 178.00	$199.36	$288.81	$ 346.58	$ 332.71	$ 425.87	$ 558.70	22.9%
Annual Growth	45.65%	38.43%	(41.90%)	12.00%	44.87%	20.00%	(4.00%)	28.00%	31.19%	
16-Bit MPU Revenue	$101.37	$289.00	$ 239.00	$267.68	$412.23	$ 568.88	$ 540.44	$ 691.76	$ 907.52	27.7%
Annual Growth	60.96%	185.08%	(17.30%)	12.00%	54.00%	38.00%	(5.00%)	28.00%	31.19%	
32-Bit MPU Revenue	$ 1.60	$ 1.20	$ 16.80	$ 36.12	$ 59.60	$ 92.38	$ 138.57	$ 200.92	$ 321.47	54.84%
Annual Growth	(11.11%)	(25.00%)	1,300.00%	115.00%	65.00%	55.00%	50.00%	45.00%	60.00%	
Total MPU Revenue	$324.30	$596.57	$ 433.80	$503.16	$760.64	$1,007.83	$1,011.72	$1,318.55	$1,787.69	28.9%
Annual Growth	49.63%	83.96%	(27.28%)	15.99%	51.17%	32.50%	0.39%	30.33%	35.58%	

Source: DATAQUEST
May 1986

Table 6

MICROPROCESSOR ASP FORECAST
(Dollars)

	Actual			Forecast						CAGR
	1983	1984	1985	1986	1987	1988	1989	1990	1991	1986-1991
8-Bit MPU ASP	$ 3.25	$ 4.06	$ 2.95	$ 2.82	$ 2.73	$ 2.62	$ 2.26	$ 2.15	$ 2.00	(6.7%)
16-Bit MPU ASP	$14.25	$ 28.90	$ 30.25	$ 23.53	$20.83	$18.19	$15.03	$13.45	$11.76	(12.9%)
32-Bit MPU ASP	N/A	$120.00	$168.00	$124.55	$83.88	$65.01	$52.71	$42.46	$37.74	(21.2%)
Total MPU ASP	$ 4.31	$ 6.98	$ 6.35	$ 6.11	$ 6.02	$ 6.10	$ 5.45	$ 5.18	$ 4.89	(4.4%)

N/A = Not Available

Source: DATAQUEST
May 1986

Microperipherals

Table 7 shows 1985 through 1991 annual unit, revenue, and ASP forecasts for microperipherals, and Table 8 shows unit and revenue forecasts for total MOS microcomponents.

We estimate a 3-to-1 drag factor related to microperipheral (MPR) revenue to MPU revenue shipments. We believe that there is a 4-to-1 drag factor related to MPR unit to MPU unit shipments. Microperipheral revenue is growing at the same rate as overall microcomponent revenue, with a predicted CAGR of 28 percent from 1986 through 1991. Unit shipments of microperipherals are also growing at the same rate as overall shipments of microcomponents, with a predicted CAGR of 34 percent from 1986 through 1991.

Hardware interrupts such as I/O peripherals play a key role in all computer systems, with a system comprising a mixture of various types of peripherals that include slow character-oriented devices like printers and very high speed block-oriented peripherals like hard disks. We believe that as computational applications for such computers continue to grow, microperipheral devices will continue to grow also.

Graphics and LAN technology will be the high-growth areas for microperipheral technology during the second half of the decade. Prices will be high for these devices; however, there are millions of low-priced microperipherals to offset any severe ASP increases.

Janet Oncel

Table 7

MICROPERIPHERAL FORECAST

	Actual			Forecast						CAGR
	1983	1984	1985	1986	1987	1988	1989	1990	1991	1986-1991
Total MPR Units (M)	236.52	296.25	305.04	369.10	564.72	739.78	828.56	1,143.41	1,612.21	34.4%
Total MPR Revenue ($M)	$1,068.58	$1,253.00	$1,208.52	$1,498.44	$2,277.63	$3,025.15	$3,036.95	$3,945.00	$5,227.12	28.4%
MPR ASP	4.27	4.23	3.96	4.06	4.03	4.09	4.67	3.45	3.24	(4.4%)

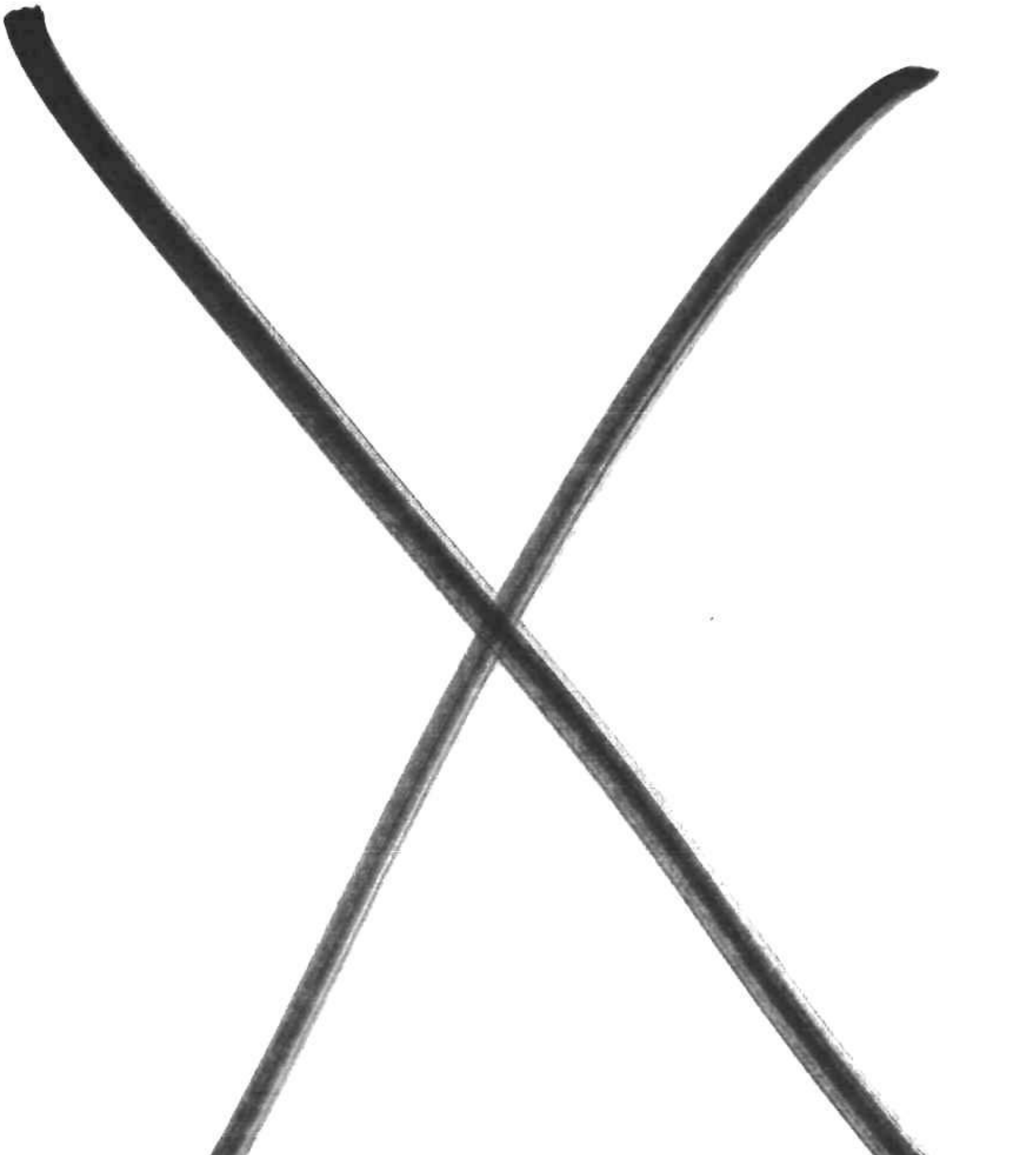
Source: DATAQUEST
May 1986

Table 8

MICROCOMPONENT FORECAST

	Actual			Forecast						CAGR
	1983	1984	1985	1986	1987	1988	1989	1990	1991	1986-1991
Total MCU/MPU/MPR Units (M)	576.52	739.58	715.31	871.94	1,254.19	1,615.18	1,875.91	2,660.15	3,742.34	33.8%
Annual Growth	45.2%	28.3%	(3.3%)	21.9%	43.8%	28.8%	16.1%	41.8%	40.7%	
MCU Units	45.9%	48.4%	47.8%	48.2%	44.9%	44.0%	45.9%	47.4%	47.2%	
MPU Units	13.0	11.6	9.6	9.4	10.1	10.2	9.9	9.6	9.8	
MPR Units	41.0	40.1	42.6	42.3	45.0	45.8	44.2	43.0	43.1	
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	
Total MCU/MPU/MPR Revenue ($M)	$1,925.42	$3,261.30	$2,751.37	$3,355.26	$5,054.95	$6,733.82	$6,939.02	$8,965.04	$11,761.12	28.5%
Annual Growth	62.5%	69.4%	(15.6%)	21.9%	50.7%	33.2%	3.0%	29.2%	31.2%	
MCU Revenue	27.7%	43.3%	40.3%	40.3%	39.9%	40.1%	41.7%	42.3%	40.4%	
MPU Revenue	16.8	18.3	15.8	15.0	15.0	15.0	14.6	14.7	15.2	
MPR Revenue	55.5	38.4	43.9	44.7	45.1	44.9	43.8	44.0	44.4	
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	

Source: DATAQUEST
May 1986



June Newsletters

The following is a list of newsletters in this section:

Dataquest
a company of
The Dun & Bradstreet Corporation

RESEARCH NEWSLETTER

SIS Code: 1986-1987 Newsletters: June
1986-26

1986 CAPITAL SPENDING:
STORMY WEATHER IN JAPAN SENDS CLOUDS OVER THE INDUSTRY

SUMMARY

DATAQUEST expects that worldwide capital spending will bottom out in 1986 at $6.3 billion, down 5.4 percent from 1985's level of $6.7 billion. Fundamental changes in the Japanese market for semiconductor capital equipment are primarily responsible for this decline. Japanese capital spending for calendar year 1986 is expected to decrease by approximately 11 percent from $3.3 billion in 1985 to just under $3.0 billion in 1986 (see Table 1). North American capital spending is forecast to be basically flat in 1986, declining only 0.8 percent to $2.193 billion. European capital spending is expected to increase almost 13 percent from $381 million to $430 million. The Rest of World (ROW) region is also forecast to increase its capital spending from $242 million in 1985 to $263 million in 1986, an increase of almost 9 percent. We believe that capital spending by captives will basically reflect spending patterns in the U.S. merchant market and will be basically flat, declining slightly from $486 million in 1985 to $482 million in 1986.

JAPAN: A STORMY TRANSITION YEAR WITH FOURTH-QUARTER SUN

Skies Darker in Yen than in Dollars

The decline of the dollar relative to the yen masks the actual magnitude of the decline of the Japanese equipment market. Table 2 illustrates this point, which is explained below. It is also possible that any further appreciation of the yen could cause a decline in Japanese semiconductor revenues. Such a decline would, of course, further weaken the demand for capital goods.

In 1985, when the yen/dollar rate was 237, Japanese capital spending was ¥793 billion, down 6.3 percent from 1984. (It should be emphasized that this 6.3 percent decline is for calendar 1985.) For the fiscal year ending March 31, the decline in capital spending was more severe,

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15.9 percent. In 1986, Japanese capital spending is expected to decline 23.7 percent to ¥605 billion. However, because the yen will buy more dollars in 1986, the decline expressed in dollars is only an estimated 10.9 percent, going from $3,346 million in 1985 to $2,980 million in 1986. The yen/dollar rate in 1986 is assumed to be 203 yen to the dollar.

Whether expressed in dollars or yen, there is no escaping the fact that the market for semiconductor equipment in Japan will likely be down by a large amount in 1986. The reason for this steep decline is that the industry is in a state of overcapacity, and the industry is now in a position to do something about it. Japanese semiconductor manufacturers are in this position because they now, in effect, own the markets in which they participate. They therefore no longer have to scramble to build market share.

DATAQUEST believes that this steep decline represents the beginning of a fundamental readjustment in the Japanese semiconductor industry. If the Japanese semiconductor industry had continued to spend at its historic capital spending-to-revenue ratio of 30 percent, its revenue-per-dollar value of property, plant, and equipment (PPE) would have fallen to below unity. To avoid this, we believe that the capital spending-to-revenue ratio will fall from a 30 percent level to slightly below 22 percent (see Table 3).

Japanese Company Spending

Several of the larger Japanese semiconductor manufacturers have cut back their capital spending plans for calendar 1986 by amounts greater than 30 percent. Among those that we believe have done so are Hitachi, Matsushita, Mitsubishi, and Toshiba. (See Table 4 for a list of changes in the Japanese semiconductor companies' capital spending in yen.)

Because of the appreciation of the yen relative to the dollar, some companies' capital spending expressed in dollars will increase (Rohm or Sony, for example), while expressed in yen they will decrease. (See Table 5 for the same companies' capital speding changes in dollars.)

This could be an opportunity for North American equipment manufacturers. The yen will now buy more dollars than it did a year ago. Therefore, the cost of purchasing North American equipment expressed in yen is now less for Japanese semiconductor manufacturers.

Long-Term Forecast

The long-term growth for capital spending in Japan is basically sound since it is basically a function of the growth of the Japanese semiconductor industry. DATAQUEST believes that Japanese capital spending will bottom out in the third quarter of calendar 1986, and will thereafter begin to rise at a compound annual growth rate (CAGR) of 17 percent between 1986 and 1990.

NORTH AMERICA: POSSIBILITIES OF SUNSHINE

Ambiguous Winds

There are differing signs in the wind about which way the North American industry will go in 1986. DATAQUEST has unofficially surveyed the major semiconductor companies, and the results are a disheartening decline of 18 percent from $2,227 million in 1985 to $1,827 million in 1986. In spite of these results, we are forecasting merchant capital spending to be substantially higher in 1986 than our survey indicates--at a level of $2,193 million.

The reason for our optimism is because at $1,827 million, the capital spending-to-revenue ratio is less than 13 percent. The industry has not been at this level since 1978. It is DATAQUEST's opinion, confirmed by industry sources that we contacted, that as the market for semiconductors increases, plans that were generated in the depths of 1985 will be revised upward. We are therefore adding an adjustment factor of $365 million onto our survey for our 1986 forecast, resulting in only a 0.8 percent decline (see Table 6).

North American Equipment Spending Up

A decline of 0.8 percent is still a decline. However, when one subtracts the spending for bricks and mortar, we believe that merchant capital spending for equipment will increase from $1,632 million in 1985 to $1,821 million in 1986. This is because equipment as a percent of total PPE is expected to increase from 74 percent in 1985 to 83 percent in 1986 (see Table 7).

This shift from bricks and mortar toward equipment is a continuation of a trend that DATAQUEST noted previously. (See the SEMS Research Newsletter dated October 4, 1985, entitled "Capital Spending: Japan to Continue to Outspend the United States"). The industry is continuing its shift away from areas of overcapacity and toward those technologies where future demand is expected to exceed capacity, such as devices with submicron geometry. Because of the industry's continuing need to achieve better line balance, increase utilization, and lower both contamination and breakage from handling, spending for automation should be robust. We also expect the demand for sub-2-micron equipment to be vigorous.

AFTER THE STORM: 1987 THROUGH 1990

DATAQUEST believes that semiconductor capital spending in Japan will begin to rebound in the third quarter of 1986 and will increase a robust 31 percent in 1987. We expect it to have healthy growth in 1987 even though capital spending as a percent of revenue will continue to decline. We expect this ratio to approach stability in the 21 to 22 percent range (see Table 8). Because of this fundamental readjustment of the Japanese industry, we have lowered our earlier forecast from 22 percent to 17 percent--which is still a healthy growth.

We expect North American semiconductor merchant capital spending to experience a CAGR of 25 percent from 1986 to 1990. As we have noted previously, the North American merchant semiconductor industry has been more tied to the ups and downs of business expansions and contractions than the Japanese industry has. Specifically, North American industry has matched its capacity to the business cycle. We therefore expect North American capital spending to be more in line with historical patterns than the Japanese industry.

We forecast European semiconductor capital spending to increase from $381 million in 1985 to $430 million in 1986. This reflects the continuing commitment of both European companies and their governments to re-emerge into the forefront of the industry. We expect capital spending to grow at a CAGR of 27 percent through 1990 and to break the $1 billion mark in 1990.

Rest of World capital spending was the only area that did not experience a downturn in 1985. It grew from $201 million in 1984 to $244 million in 1985. We expect ROW capital spending to reach $263 million in 1986, up 8 percent from 1985. Overall, ROW capital spending will grow at an estimated CAGR of 30 percent, the highest of any region, and reach an estimated $751 million by 1990.

Mel Thomsen
George Burns

Table 1

ESTIMATED WORLDWIDE CAPITAL SPENDING
(Millions of Dollars)

	1985	1986	1987	1988	1989	1990	CAGR 1986-1990
North America	$2,211	$2,193	$3,569	$ 4,579	$ 4,528	$ 5,410	25%
Japan	3,346	2,980	3,905	4,495	4,679	5,509	17%
Europe	381	430	589	817	950	1,119	27%
ROW	242	263	394	533	593	751	30%
Captive	486	482	785	1,007	996	1,190	25%
Total	$6,667	$6,349	$9,242	$11,432	$11,746	$13,980	22%

*Columns may not total due to rounding

Source: DATAQUEST
March 1986

Dataquest
a company of The Dun & Bradstreet Corporation

RESEARCH NEWSLETTER

SIS Code: 1986-1987 Newsletters, June
1986-24

1986 CUSTOM INTEGRATED CIRCUIT CONFERENCE: PUSHING THE EDGE OF THE ENVELOPE

THE CICC BROADENS

DATAQUEST believes that custom design engineers and test pilots have a great deal in common. Both groups like to push the state of the art or, as the test pilots say, "push the edge of the envelope." Like highly skilled test pilots swapping stories on their high-performance aircraft, the custom-design engineering community gathered May 12 through 14 to report the leading-edge technology in the application-specific integrated circuits (ASIC) industry. The conference represents the limits in process technology, gate count, and integrated circuit computer-aided design (IC CAD).

This conference, more than any other, showed how:

- The technology base has broadened
- The IC CAD technology has broadened
- The gate array performance has broadened

From a technical perspective, the Custom Integrated Circuit Conference (CCIC) continues to improve in content and quality. While attendance (1,200 people) was nearly the same as last year, the total paper count grew by 29 papers and the quality of the papers was better. The technical committee received 243 papers but accepted only 145 papers. As Table 1 shows, there was no change in the regional or technology split; MOS papers still outnumber bipolar papers by 4 to 1. But there was a change in authorship. The most noteworthy change was the increased number of papers submitted by the academic community. We believe that this represents the educational institutions' growing interest in ASIC. As the ASIC industry expands, most academic institutions must face the challenge of how to train the technologist of tomorrow.

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Table 2 shows the leading sources of papers presented at the 1986 CICC, with IBM, GE, and Tektronix all presenting five papers. Again, it is interesting to note that this year was the first year that numerous academic institutions appear on the leading-source table. This supports our belief that ASIC is indeed a growing area of interest in educational institutions.

THE TECHNOLOGY BASE WIDENS

In the past, the CICC presented papers only on MOS and bipolar process technology, but today's technology has broadened. This year, the CICC presented papers on gallium arsenide (GaAs), linear ASIC, BiMOS, IC CAD, and topics of general interest. Table 3 summarizes the sessions by regional origin, source, and technology. Note that in the technology category, IC CAD leads in paper count, while the industrial group dominates the source category. This year's CICC had a remarkable diversity of GaAs papers. There were GaAs papers on standard cells, gate arrays, and charge-coupled devices used in analog signal processing applications. Another session that had considerable diversity was analog ASIC. The eight papers presented ranged from CMOS A to D converters to custom 400-MHz 8-bit bipolar D to A converters.

The BiMOS papers drew wide attention, causing us to believe that this technology will play a larger role in future conferences as its commercial value emerges. Two papers suggested future directions: General Electric's paper on a high-voltage analog and digital gate array that can support voltage up to 1,200 volts, and Motorola's paper on 6,000-gate BiMOS gate array using a 2-micron CMOS process. These papers solve major problems in the application of gate arrays. The GE array can be used to switch high voltages and the Motorola array solves the problem of high fan-out. As gate arrays grow in gate count, the number of logic elements that can be driven from a single output is expected to diminish sharply. BiMOS solves this problem, thus allowing speeds to be maintained in applications that require high fan-out. Both the GE and Motorola products will find application in systems that are bus-oriented or have distributed processing requirements. Other applications include disk drives and high-speed graphics controllers.

IC CAD EVERYWHERE

By far the largest topic was IC CAD. As Table 4 shows, 57 papers were presented, ranging from compilers to design methodologies. The two largest categories were compilers and simulation and fault grading. We believe that this was not a random occurrence. Every user and supplier is acutely aware of the critical role these tools will play. Attendance at this session was large and the tone of the questions from the audience suggested that most attendees were sensitive to advances in this area.

Compilers

Today's compilers come in all shapes and sizes. There are general-purpose compilers, specialized compilers, and compilers that are used in the academic environment. Most of the attendees were somewhat wary of the general-purpose compilers that promised more than they delivered. Those who had actually used compilers tended to favor specialized systems that solve a specific application problem. For example, a compiler that was used with a particular megacell was of great interest. Furthermore, most of the engineers were interested in finding compiler tools that would simplify the conversion of standard product into compilable megacells.

Simulation and Fault Grading on a Complex ASIC

As Table 4 notes, 16 papers were presented on simulation and fault grading. As ASIC technology moves to more complex functions, the chip becomes the system. This means that the problem of simulating and finding errors will become more difficult. As more and more of the functions become a part of ASIC, the verification of the chip becomes very complex. Both the IC CAD suppliers and the ASIC suppliers are beginning to offer solutions. While a wide variety of solutions were offered, two papers stand out as practical solutions. Silicon Compiler, Inc., presented a paper on how a chip can be designed with a built-in test capability. By using shiftable test latches around a major megacell, the engineer can test portions of the chip that otherwise would have been impossible to test. The second paper, from LSI Logic, proposed a way to test a large block of logic by using a scan path technique. The scan concept could also be expanded to other chips on the board, thus making the entire system more testable.

GATE ARRAYS: PUSHING PERFORMANCE AND COMPLEXITY

Nowhere at the CICC was the growth of performance and complexity more apparent than in the gate array sessions. In terms of speed and functional complexity, the progress is impressive. Table 5 shows nine papers that push the limits of technology. In addition to the BiMOS papers mentioned earlier, VLSI Technology presented a paper that demonstrated how a large megacell, (a CRT controller) can be incorporated into a gate array. Toshiba and LSI Logic presented a paper on compacted channelless arrays with more than 100,000 gates and propagation delays of 230ps per gate. A paper from NTT Electrical Communication Labs described a 7,000 gate bipolar gate array using a 3-layer metal that can operate at up to 2.6 GHz.

WHAT DOES IT ALL MEAN?

DATAQUEST believes that this year's CICC is a bellwether of the trends that are expected to emerge in the commercial market in the next two years.

Enter BiMOS

ASIC with BiMOS is here to stay. We believe that most ASIC suppliers will announce products that have BiMOS capability in order to meet those critical high-performance applications. BiMOS ASIC will carve out a niche in those applications where speed and high fan-out are critical.

Compilers Are Changing

We believe that compiler technology is making progress but not in the directions that were most commonly expected a few years ago. The general-purpose compilers are an elusive goal and continue to be too abstract for most users. Instead, we believe that there will be a rush to specialized compilers aimed at applications such as digital signal processing. Most CICC attendees apparently believe that the challenge is how to convert existing standard products into compilable megacells. This leads DATAQUEST to conclude that we will see a rush to compilable megacells over the next few years as ASIC suppliers try to position their ASIC portfolios to gain market share.

Gate Arrays Move Closer to Cell-Based Designs

As gate arrays continue to push the limits in gate count and functionality, we expect the dividing lines between gate arrays and cell-based designs (CBD) to become blurred. Gate array suppliers will offer megacells that can be placed anywhere on the chip, thus offering many of the features of CBD.

Impressive Performance

As it is with those glamorous test pilots who push the outer limits, so it is with the engineers at the CICC. The CICC continues to impress us with its diversity and technical performance.

Andy Prophet
Kelly Gustus

Table 1

CICC PAPERS PRESENTED

Country of Origin	1984	1985	1986
Region			
North America	97	87	114
Europe	7	17	23
Japan	14	11	12
ROW	3	1	1
Total*	121	116	150
By Authorship			
Region			
Industry	101	89	112
Academic	19	25	42
Government	1	2	2
Total*	121	116	156
By Technology			
Technology			
MOS	-	-	43
Bipolar	-	-	11
BiMOS	-	-	4
Linear	-	-	9
GaAs	-	-	9
CAD and General	-	-	69
Total	-	-	145

*Totals exceed actual number of papers due to coauthors' overlapping in the categories.

Source: DATAQUEST
June 1986

Table 2

LEADING SOURCES OF CICC PAPERS IN 1986

Sources	1986	Comments
Companies		
IBM Corporation	5	Coauthored 1
GE Semiconductor	5	Coauthored 1
Tektronix	5	Coauthored 1
AT&T	4	
NEC	4	
SGS Microelectronics	3	
Fujitsu	3	
Honeywell Information Systems	3	
TRW Microelectronics Center	3	
LSI Logic	3	Coauthored 1
Gould Semiconductor	3	Coauthored 2
Academic Institutions		
University of California Berkeley	4	Coauthored 1
Rensselaer Polytechnic Institute	4	Coauthored 1
Duke University	3	Coauthored 1
University of Illinois	3	
Total	55	

Source: DATAQUEST
June 1986

Table 3

1986 CICC SESSION SUMMARY

Session	Total Papers	Region: No. Amer.	Region: Europe	Region: Japan	Region: ROW	Source: Industry	Source: Government	Source: Academic	Technology Employed: MOS	Technology Employed: Bipolar	Technology Employed: BIMOS	Technology Employed: Linear	Technology Employed: GaAs	Technology Employed: IC CAD & Other
High-Performance Cell Libraries	6	6	0	0	0	5	1	2	4	1	0	0	0	1
Custom Sensor Circuits	5	3	1	1	0	5	0	1	2	1	0	1	0	1
Fabrication Technologies	6	5	0	1	0	5	0	1	4	0	1	0	1	0
Building Block ICs for Digital Signal Processing	7	4	3	1	1	5	0	2	0	1	0	0	0	6
Silicon Compilers	7	7	0	0	0	4	0	5	1	0	0	0	0	6
Integrated Power and Interface Techniques	7	5	2	0	0	7	0	0	4	1	1	0	0	1
Digital Signal Processing in Custom ICs	7	3	4	0	0	4	0	4	2	0	0	0	0	5
Device and Circuit Modeling	6	5	1	0	0	2	1	4	4	0	0	0	1	1
Design Methodologies	6	5	1	0	0	6	0	0	3	2	0	0	0	1
Packaging and Interconnection	5	4	1	0	0	4	0	1	0	1	0	0	0	4
Placement and Routing	6	4	1	1	0	3	0	3	1	0	0	0	0	5
Fault Grading and Detection	6	5	0	1	0	6	0	2	3	0	0	0	0	3
Module Generators	8	7	1	1	0	7	0	1	2	0	0	0	0	6
Analog Circuit Techniques	8	4	4	1	0	6	0	3	0	0	0	8	0	0
Testing and Reliability	8	7	1	0	0	6	0	1	2	0	1	0	0	5
Custom Digital Applications	6	5	1	0	0	5	0	1	4	0	0	0	0	2
CAD for Circuits and Systems	6	5	1	0	0	3	0	3	1	0	0	0	0	5
GaAs Integrated Circuits	7	7	0	0	0	7	0	0	0	1	0	0	6	0
Symbolic and Procedural Design Approaches	6	5	1	0	0	4	0	2	1	0	0	0	0	5
Gate Arrays	7	4	0	4	0	7	0	0	4	2	1	0	0	0
Advanced Processing Techniques	6	6	0	0	0	3	0	4	0	0	0	0	0	6
Circuit Analysis and Simulation	5	4	0	1	0	4	0	2	1	1	0	0	1	2
Papers of General Interest	4	4	0	0	0	4	4	0	0	0	0	0	0	4
Total*	145	114	23	12	1	112	2	42	43	11	4	9	9	69

*Some categories may not add equally across the tables due to coauthorship overlap.

CICC Luncheon: "Computer Graphics at Lucasfilm"
Keynote Address: "ASIC--A Look Ahead"
Evening Panel Discussions:
"Hardware Accelerators--Is Faster Always Better?"
"DSP Alternative: Custom vs. Standard Components
"ASIC: Where We Are, Where Are We Going, and How Do We Get There?"
"Breadboarding vs. Logic Simulation"

Source: DATAQUEST
June 1986

Table 4

IC-CAD TECHNOLOGY PAPERS

Company and/or Institution	Compiler	Placement & Routing	Simulation & Fault Grading	Circuit Analysis	Symbolic Procedural	Design Methodologies
University of Illinois	2					
University of California, Berkeley	2	1			1	
Gould Research Center and	1					
Electronic Tech & Device Lab*						
Duke University	1					
University of Washington and	1					
Seattle Silicon*						
Cirrus Logic	1					
MIT Artificial Intelligence and	1					
Gould Semiconductor*						
University of Aachen			1			
Meta Software			1			
H. Hughes Naval Research Lab and			1			
Harvard University*			1			
Gould Inc.			1			
Oakland University			1			
General Electric Company	1	4				1
Hughes Aircraft Company		1				
Toshiba Corporation		1				
University of Sydney		1				
University of Rochester		1				
IMP and						
University of Cleveland*			1			
TRW Microelectronics Center			1			
Fujitsu	1		1			
Honeywell Inc.			1			
Microelectronics Center of						
North Carolina and			1			
Duke University*						
Caedent Corporation			1			
Texas Instruments	1					
LSI Logic	1					
VLSI Technology	1					
IBM Corporation	1					
Gould Semiconductors	1					
Xilinx						1
Bell Communications Research						1
Tektronix Inc.						1
Ferranti Electronics	1					1
University of Waterloo				1		
National Semiconductor			1			
Carnegie-Mellon University			1			
Stanford University				1		
NCR Microelectronics				1		
Rockwell International					1	
CSELT					1	
SDA Systems					1	
Silicon Design Labs				1	1	
Georgia Institute of Technology				1	1	
Oregon State University and				1		
Tektronix Inc.*						
Shiva Multisystems Corporation				1		
NEC Corporation				1		
Ford Microelectronics				1		
Total	17	6	14	9	6	5

*Paper was coauthored

Source: DATAQUEST
June 1986

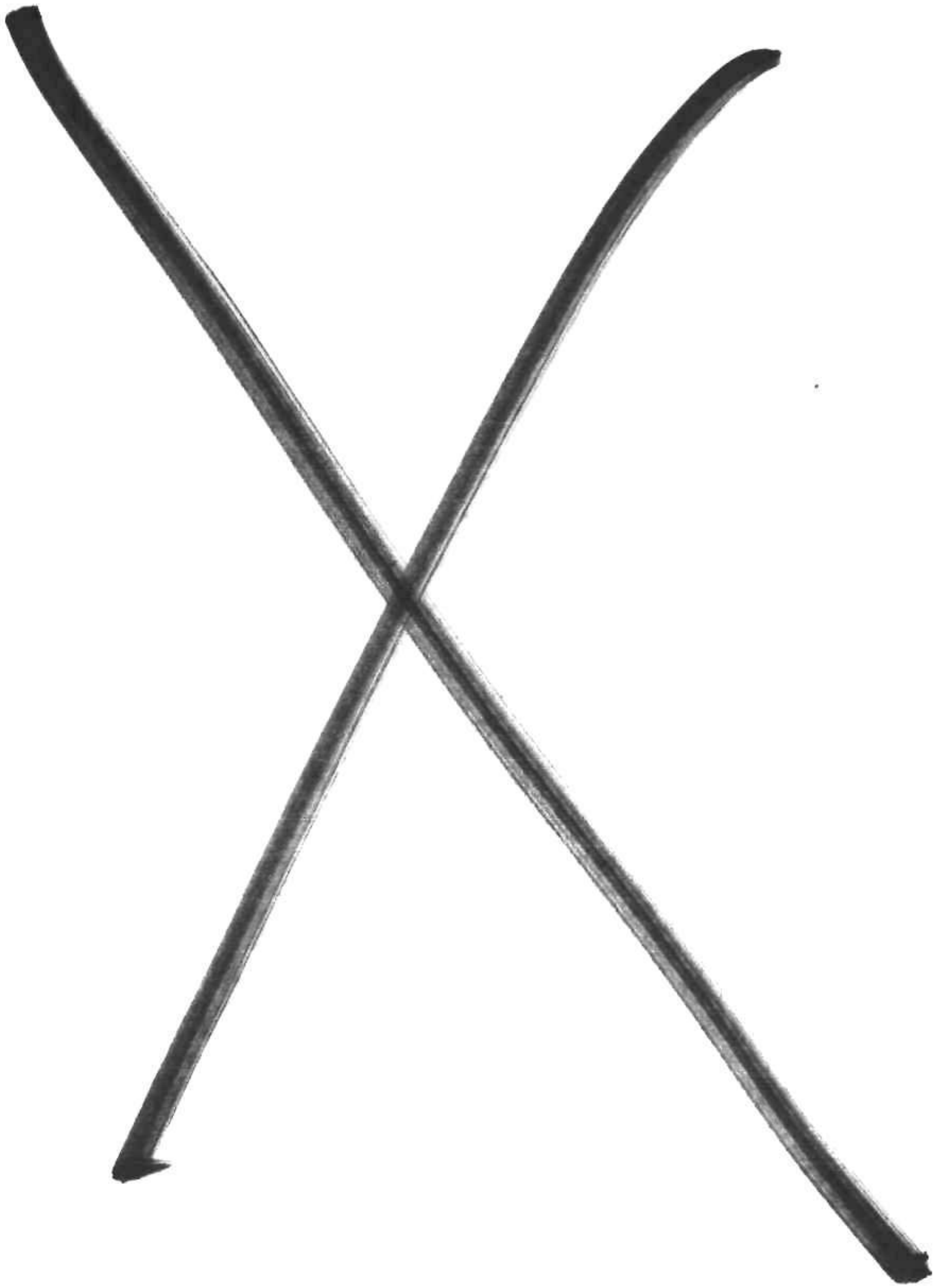
Table 5

GATE ARRAY PAPERS

Company	Technology MOS	Technology Bipolar	Technology GaAs	Minimum Feature Size (Micron)	Gate Count	Comments
Honeywell Inc.	1			1.2	30K	A 450-psec, 285-pin gate array Features built-in test for fault isolation and chip and board-level testing
Honeywell & Mayo Foundation			1	-	2K	A Schottky diode FET logic gate array Chip includes an 8-bit multiplier with a gate delay of 4ns and 100mw per gate
GE Semiconductor	1			2	6K	HVIC analog and digital gate array Contains N & P channel MOSFETs, NPN and PNP transistors, Zener diodes, capacitors, and resistors
Motorola, Inc.	1*		1*	2	6K	Fabrication with BiMOS technology Chip provides TTL- and/or ECL-compatible outputs, with 0.5 watt standby power
VLSI Technology	1			2	2K	Mask-programmable CMOS array custom-designed 6845 CRT controller with 2K gate array
LSI Logic Corporation and Toshiba	1			1.5	100K	100K gate equivalent channelless HCMOS array Double metal process comprises RAM, ROM, and logic megacells
Mitsubishi Electric Corporation	1			1.3	540	A variable-track CMOS masterslice arranged as 180K sets of P-N-N channel transistors Double-metal CMOS process
NEC		1		1.5	540	A 540-gate 1Gb/sec array Does not require a forced air cooling system Developed for optical communications
NTT Electrical Communication Labs		1		1	7K	Flip-flop toggle frequency of 2.6 GHz at 5.2mW/cell power dissipation

*BiMOS technology

Source: DATAQUEST
June 1986



July Newsletters

The following is a list of the newsletters in this section:

(continued)

July Newsletters

Dataquest
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RESEARCH
BULLETIN

SIS Code: 1986-1987 Newsletters, July
1986-35

PRELIMINARY SECOND QUARTER 1986 MICROCOMPONENTS WORLDWIDE UPDATE

After some signs of recovery during second quarter 1986, worldwide microcomponent business began weakening. Orders had improved since second quarter 1985, when orders were at the lowest point of the downturn. Second quarter 1986 experienced the highest microcomponent booking since third quarter 1984, seven quarters earlier. During second quarter 1986, the turns business was high, indicating quick turnaround of microcomponent device inventory. And, the microcomponent book-to-bill ratio had been approximately 1:1 for the last few quarters. Recovery appeared to be in sight, but, orders at the end of June became soft. Furthermore, the third quarter appears to be weak due to typical slow summer months. Dataquest has updated its quarterly microcomponent forecast, as shown in Table 1. We estimate that most of the year's growth occurred in the first half of 1986, with a slow third quarter and slight growth expected in the fourth quarter. Real recovery is expected during the first half of 1987.

Table 1

WORLDWIDE QUARTERLY MICROCOMPONENTS FORECAST
(Millions of Dollars)

	1986				
	Q1*	Q2*	Q3	Q4	Year
MCU	$322	$359	$359	$389	$1,429
MPU	99	135	153	171	558
MPR	378	397	380	405	1,560
Total	$799	$891	$892	$965	$3,547

*Actuals

Source: Dataquest
July 1986

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North America remains the weakest consumption region with the data processing segment in the doldrums. Europe continues to be stable with predictable telecom and consumer markets. Japan continues its fierce competition among high-volume, low-cost microcomponents, and is gaining market share in microcontrollers and low-end microprocessors. The ROW region experienced extremely high growth during the first half of 1986. U.S. OEMs apparently are buying in the Far East because of lower-priced products. The 32-bit microprocessor is expected to be a major source of revenue for the few semiconductor companies shipping product this year. However, for the majority of microcomponent manufacturers, slow micro revenue and low demand is expected during the remainder of 1986.

Janet Oncel

Dataquest
a company of The Dun & Bradstreet Corporation

RESEARCH NEWSLETTER

SIS Code: 1986-1987 Newsletters: July
1986-34

A LOOK AT THE TI CHIP SET FOR LOCAL AREA NETWORKS

BACKGROUND

In 1982, IBM contracted with Texas Instruments (TI) to develop a chip set to implement IBM's Token-Ring protocol for a local area network. These chips were intended to implement protocols supporting the majority of IBM's product line and to operate with twisted-pair wiring at speeds from 2 to 16 Megabits per second. The chip set was to conform to the IEEE 802.5 Token-Ring specification.

The IBM Token-Ring was designed as an open system architecture. The TI chip set will support IBM products but will also provide a standard interface for attaching computers, terminals, telecommunications equipment, and other information-processing equipment from other manufacturers. This compatibility is possible since the IBM Token-Ring network specifications are public and allow anyone who has the initiative to create the combination of circuit boards, software, and wiring that constitutes this LAN.

It was widely reported that TI had experienced difficulties in the development process. It was not until May 1984 that IBM announced its Token-Ring Network statement of direction, saying products would be in development for two to three years. The first products were unveiled in IBM's October 15, 1985 announcement. Dataquest understands that the long development cycle of the Token-Ring was due in part, but not in whole, to the delays experienced by Texas Instruments in the chip set development.

THE TMS380

The TMS380 chip set has significant implications for the LAN industry from the perspectives of semiconductor design and marketing impact. The issue of price per connection and cost improvements associated with increasing volume have been fundamental in the growth of the LAN market.

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Design Characteristics

The TMS380 comprises five chips, which collectively include about 350,000 transistors. Of the five-chip set, three are metal oxide semiconductor (MOS) large scale integration (LSI) chips and two are bipolar medium scale integration (MSI) chips. The three MOS devices are 2.4-micron NMOS (N-channel MOS) using the single-level polysilicon manufacturing process, and the two bipolar chips are low-power Schottky transistor transistor logic (LSTTL). A total of 2.8 watts of power is consumed by the five-chip set. Two of the three MOS devices use 48 dual in-line pin (DIP) packaging, and the two bipolar chips use 20 and 22 DIP packaging. The remaining MOS chip has a 100-pin grid array (PGA) and connects directly to the system bus.

Marketing Impact

The IBM Token-Ring Network was one of the most anticipated announcements of strategic direction of this decade. Although the affected industries were aware of many of the characteristics of the product prior to the announcement, the act of unveiling the specifics of a general-purpose local area network from the world's most successful computer manufacturer has had wide-ranging consequences. Competitive LAN vendors with advance knowledge of the IBM Token-Ring announced similar and/or compatible products simultaneously with the IBM announcement. These companies purchased early Token-Ring chip sets and development kits from Texas Instruments, after signing a non-disclosure agreement with IBM.

Potential LAN customers are expected to stop postponing their buying decisions in anticipation of IBM's direction, and they may or may not opt for the competition. Telecommunications companies are concerned about the Token-Ring's compatibility with voice and data PBXs, as well as its competitive effects on their own proprietary networking schemes. Semiconductor companies will benefit from contracts for manufacturing interfaces from other popular networks to the Token-Ring, as well as second-sourcing the Texas Instruments TMS380.

IBM allowed TI to provide the Token-Ring chip set to companies such as 3Com and Bridge for development purposes before the Token-Ring was announced. This would allow the necessary development of compatible interfaces to take place by the time of IBM's announcement and would increase the Token-Ring's chances of becoming an industry standard, general-purpose network. Dataquest believes that IBM will develop interfaces only for IBM products, while supporting these other companies in their development of interfaces to connect equipment from other vendors. At the time of the October 15, 1986, announcement, Texas Instruments indicated it was working with more than 25 vendors using the chip set to develop products for the Token-Ring.

An unexpected revelation was that IBM uses its own chips in manufacturing the PC adapter card, even though IBM had jointly developed the TMS380 with TI. Although the two separate chip sets are functionally compatible, a variety of technologies is used (such as gate arrays in the IBM chip set), disallowing any interposing of the two chip sets. Dataquest understands that IBM is developing a second source for the chip set, and is not buying chips from Texas Instruments.

Network Management Capabilities

IBM and TI have incorporated a number of embedded chip features within the TMS380 design, which may prove difficult for other chip manufacturers to duplicate. These features relate to network management services and what both companies are calling reliability, availability, and serviceability (RAS).

The key features included within the TMS380 for network management services are:

- Transferral of fast data bursts by the dual-bus system interface chip
- Capabilities for alleviating throughput problems
- Network management superset of the IEEE's network-messaging protocols
- Addressing of network performance information to designated Token-Ring management stations
- Self-test diagnostics
- Expansion capabilities for off-loading the processing of higher-level network protocols from the host

Due to implementing these on-chip features that minimize delay time on the network, IBM may decide to add further network control capabilities through medium-access-control (MAC) frames. MAC frames are network-management messages circulating on the Token-Ring between the attached computer systems. The basic TMS380 chip set will handle the MAC frames at the data link layer (Layer 2 of the Open Systems Interconnect model). The Token-Ring adds 21 new MAC frames to the 6 already included in the IEEE 802.5 specifications for medium-access-control. These additions are expected to be included in the IEEE 802.5 standard for Token-Rings.

The RAS implementation came about as a result of software code integration in read-only memory (ROM) and features in the hardware. This capability is not confined to any one chip, but resident throughout the five-chip set.

Availability/Pricing

TI offers a Design-In Accelerator set for customers designing their own interface boards. The set includes three chip sets, software EPROMs (erasable, programmable ROMs), an adapter bring-up guide, a user's guide, and admission to a three-day regional workshop hosted by TI. The current price for the set is $1,985. Potential customers are also being offered development boards for their evaluations of the chips and the embedded networking services.

Pricing for OEM orders of the TMS380, in quantities of 50,000 or greater, will be $125 during the second half of 1986. TI anticipates a 20 percent to 30 percent per-year price decline through 1989, resulting in a price of less than $50 by the end of the decade. This price decrease is attributed to conversion of component design from ceramic to plastic in late 1986 and early 1987; combining of certain chips within the chip set; design process change from MOS to CMOS; eventual, widespread availability of 1MB DRAMs; and manufacturing cost reductions associated with the classical learning curve of semiconductor manufacture.

THE LAN CHIP MARKETPLACE

The LAN chip market is divided into two areas--custom device designs and standard device designs. These two design approaches have helped lower the price of interfacing or connecting devices to local area networks, while improving the overall performance of network operations. Growth of local area networks has not matched the expectations of the industry for two reasons:

- Their high price

- The delayed IBM Token-Ring Network

The expense of early standard and custom chip designs, which were produced in quantities commensurate with market demand, did not allow the cost/price economies that could be realized through large-volume production. A "chicken and egg" quandry was apparent. The acceptance of LANs hinges on the lowering of the costs for network interface, and yet lower interface costs are dependent on the growth of the total network users.

The second limiting factor was the delayed announcement of IBM's Token-Ring Network. Both vendors and potential users were hesitant to move ahead in the LAN marketplace until IBM revealed the nature and characteristics of its Token-Ring.

Standard Chip Manufacturers

Semiconductor manufacturers have been supplying standard devices to LAN interface board builders for a number of years. These manufacturers and their devices are shown in Table 1.

Table 1

STANDARD CHIP DESIGNS

Manufacturer	Standard Chip Devices
Intel	82588 Starlan, 82586 LAN controller
Motorola	68590 Ethernet LAN controller
Mostek	MK68590
Advanced Micro Devices (AMD)	Lance 7990
National Semiconductor	DP8392, 8391, 8390
Rockwell International	R68802 LAN controller

Source: Dataquest
July 1986

Custom Chip Manufacturers

A variety of semiconductor manufacturers and equipment/network manufacturers have jointly developed custom LAN interface devices. These manufacturers and their devices are shown in Table 2.

Table 2

CUSTOM CHIP DESIGNS

Manufacturer	Custom Devices
IBM/Sytek	Custom design for Local Net
Texas Instruments (TI)	TMS380 developed for IBM Token-Ring
Standard Microsystems	Arcnet LAN controller chip for Datapoint Corporation
SEEQ Technology Inc.	DQ8001 Controller, DQ8023 Manchester encoder/decoder designed for 3Com Corporation
Fujitsu Microelectronics	Chips custom designed for use in Ungermann-Bass LAN Interface units
NEC	Omninet LAN controller chip for Corvus Systems Inc.

Source: Dataquest
July 1986

DATAQUEST ANALYSIS

Dataquest believes that IBM's announcement of the Token-Ring legitimizes the LAN as the technology of choice for intraoffice communications. The Token-Ring will still have to compete with Ethernet LANs for the overall share of the LAN business, but we can expect a heated contest. The Token-Ring's ability to operate over standard (unshielded) twisted-pair telephone wiring provides a market advantage for this type of network, although the applications for the unshielded wire are very limited and most sites will use the shielded wire more extensively.

We also believe that the TMS380 affects the PC network market due to IBM's dominance in the computer industry, which positions the Token-Ring as a de facto standard, the option of NETBIOS or APPC operating systems, and the on-chip superset of network management services. In addition to PC networks, these chips will be incorporated within minicomputers, CAE and CAD workstations, and peripheral products. In short, the Token-Ring chip set may prove to be the catalyst the world of computer networking has needed to realize its full potential.

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Janet Oncel
Kent L. Nutt

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July 29, 1986

Dear SIS Client:

From time to time an interesting newsletter from another Dataquest service comes across my desk, that I believe will be of interest to our SIS clients. The attached newsletter is one such case. It's an excellent analysis prepared by the CAD/CAM Industry Service and we believe it makes noteworthy comments on a recent survey of design centers. This research newsletter is of particular interest to those clients who are involved with Application Specific ICs (ASIC), since it provides analysis on how IC-CAD equipment is currently utilized.

The CAD/CAM Industry Service (CCIS) is one of more than 24 industry information services at Dataquest. CCIS analyzes and reports on the markets, products, technologies, and major companies in the CAD/CAM industry. In addition, CCIS assesses the effects of new developments in products, processes, competition, regulation, and other factors affecting the industry.

I hope you find it as interesting as I did.

Best regards,

Andrew M. Prophet

Andrew M. Prophet
Senior Industry Analyst
Semiconductor Industry Service

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RESEARCH NEWSLETTER

SIS Code: 1986-1987 Newsletters, July
1986-33

ASIC DESIGN CENTER CAD SURVEY

INTRODUCTION

ASIC design center CAD purchases are driven by the changing requirements of their customers. The lead indicator of a design center's CAD/CAM purchase plans is the ASIC customer rather than the ASIC house itself. Ultimately, the ASIC customer is the target for all ASIC products, both CAD and silicon.

This newsletter discusses the results of DATAQUEST's CAD/CAM Industry Service's design center survey. In compiling the results, we have identified three specific areas of controversy:

- Personal computers--engineering or office automation tool?
- Integrative design environment--is it possible in design centers?
- Bottlenecks--is the customer a bottleneck?

DEMOGRAPHICS

DATAQUEST polled 146 U.S.-based IC design centers, which is nearly 100 percent of the U.S. merchant ASIC design centers. Our survey tabulations represent a 50 percent response rate from 73 design centers.

The respondents primarily consisted of three types of design centers:

- Semiconductor vendor affiliated
- Distributor affiliated
- Independent/unaffiliated

These types of design centers accounted for 90 percent of the total responses. The remaining 10 percent were vendor-affiliated centers that typically received their funding from private sources.

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Designs

Cumulatively, there were 3,259 annual design starts in the sample, designed by 503 engineers. This translates into an average of seven design starts per engineer, and an average of seven engineers at each design center. Please refer to Figure 1 and Table 1 for information on the types of circuits being designed and the average number of gates.

PERSONAL COMPUTERS--ENGINEERING OR OFFICE AUTOMATION TOOL?

IBM PCs comprised nearly one-third of the nonturnkey-supplied CAD/CAM hardware. Yet, Figure 2 indicates that the PC's primary application is not engineering automation. PCs are used most often for office automation--even in such an intense engineering environment as an ASIC design center. Schematic capture represents the only engineering application for which the PC is used with any frequency.

We believe that the PC is so widely accepted because it also allows engineers to run office automation products. This suggests that vendors with PC or low-cost solutions must provide a path for end users to run general-purpose applications.

Purchase plans by product type are shown in Figure 3. Nearly 38 percent of the respondents indicated that they plan to purchase PCs. Standalone workstations plans, however, were even higher, at 46 percent.

We believe that engineers have a realistic attitude about the personal computer--by itself, it cannot run the computationally intensive applications that are typically run on a host or standalone computer. We expect personal computers to continue to be used for general-purpose applications and serve as a low-cost design entry nodes in networked engineering environments.

THE INTEGRATIVE DESIGN ENVIRONMENT

Software Perspective

Figure 4 shows the usage of analysis tools and the sources from which they were acquired. This figure suggests that in spite of the closed-door environment of ASIC software, there are a lot of commercially developed general-purpose analysis tools available on design center CAD systems. The most frequently cited analysis tool purchased from a software vendor is circuit simulation. This high response clearly contradicts the widespread myth that transistor-level simulation is not run on ASICs.

Although simulation tools are winning substantial design center acceptance, this is not the case with analysis tools addressing the manufacturability issues such as design rules check (DRC), electrical rules check (ERC), and layout-versus-schematic. Even though a significant number of design centers stated that they purchased these tools from outside sources, these applications were also cited most frequently as tools developed in-house, indicating that customization to a particular manufacturing process is frequently required.

We believe that ASIC design centers will continue to purchase analysis tools for their customers' use rather than for internal use. CAD vendors' products must be integratable with ASIC companies' in-house tools. Process-dependent tools must be easily customized to meet the process-specific requirements of individual manufacturers.

Turnkey Perspective

Figure 5 shows the installed bases of the five most frequently mentioned CAD vendors. These top five companies comprise 47 percent of all systems cited in the survey. Another 21 vendors comprise the remaining 53 percent of systems.

Figure 5 also illustrates buying plans and repeat purchases. Clearly, no respondent is so committed to any one CAD vendor that it excludes that vendor's competitors. The relatively low repeat business rates do not necessarily reflect dissatisfaction with any one vendor. Rather, they mirror the nature of the design center business itself--to avoid excluding potential ASIC customers, design centers must provide support and completion of customers' designs on corresponding CAD systems at the center. Therefore, systems purchased by design centers are an indication of general ASIC design community demands.

IS THE CUSTOMER A BOTTLENECK?

ASIC customers are strongly involved in the design process. Figure 6 shows that nearly half of the responding design centers' customers are responsible for their own designs. The survey also indicates that 44 percent of the customers are responsible for simulation.

Figure 7 shows the distribution of time spent on each design cycle phase. Nearly 60 percent of the time it takes to complete a design is spent on logic creation and simulation or the phases in which customers are directly involved. Yet design centers identify one of their biggest bottlenecks as the customer.

It appears that the design centers, as well as the CAD vendors, have not yet completed the end-user education process. CAD and ASIC vendors are not acknowledging customers' steep learning curves and are expecting expert results from novice users.

DATAQUEST CONCLUSIONS

Personal computers are only a platform; survey results show that PCs are not perceived in the end-user community as low-cost end-to-end design automation solutions. Although engineers use personal computers for schematic capture, the major application for PCs is office automation.

Dataquest believes that CAD vendors must concentrate on positioning PCs as design entry nodes that are easily integrated into networked design environments. The acceptance of PCs is dependent on networking and its ability to run general-purpose programs.

Dataquest believes that achieving the goal of widespread acceptance of ASICS will require semiconductor vendors to release their physical libraries and layout programs. As novice users become more proficient, they will want more control over their designs, and therefore need more information. This, in turn, will require a higher level of customer support.

What clearly emerges from the results of the survey is an end-user mandate for CAD vendors and ASIC vendors to take responsibility for supporting their customers. Dataquest believes that CAD vendors need to structure profitable and effective customer service so that all users get the experience necessary to make their systems produce.

If the CAD vendors' training ends with the design center engineers, they are ignoring the actual end-user market--the ASIC users--where penetration is still very low. Using a design center CAD system may be a customer's first opportunity for hands-on experience with ASIC design automation. In reality, the existing CAD systems in a design center are a sales opportunity in disguise; every time a design center customer uses a CAD system, it is actually a real-world demonstration of that system's capabilities. As prices continue to decrease and it becomes feasible for more engineers to purchase design automation systems, it behooves CAD vendors to ensure that every customer who uses that design center's system is adequately supported.

The ASIC design centers' perceptions of their customers as one of their biggest productivity bottlenecks is a example of the semiconductor industry's discrete parts mentality. For the relationship between the design centers and their customers to change, we believe that it is necessary for the relationship between the design centers and the CAD vendors to become a customer service partnership, with each assuming responsibility for their common customer--the ultimate end user.

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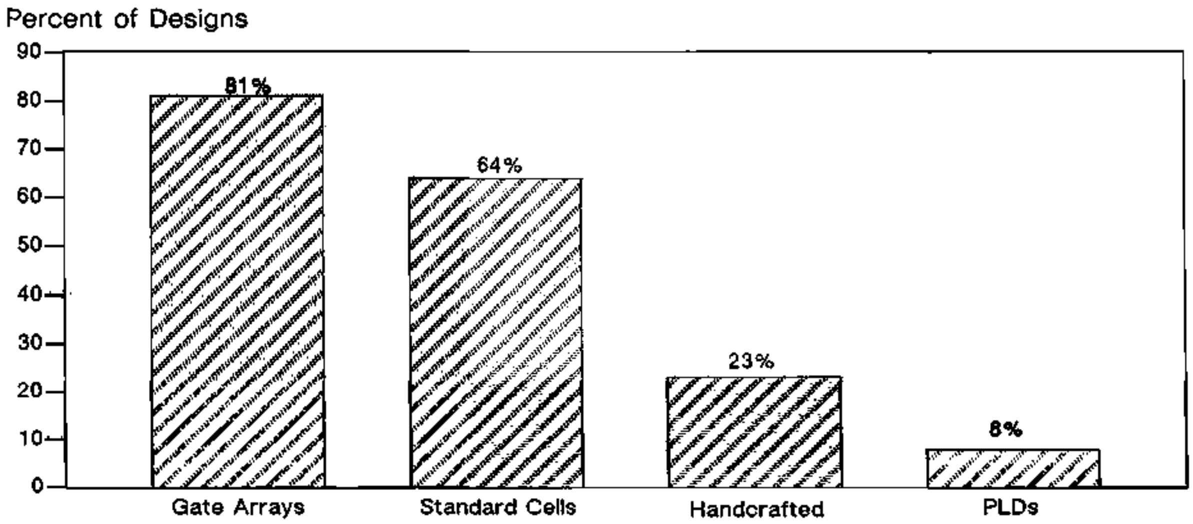
Andrew M. Prophet
Kelly D. Leininger

Figure 1

TYPES OF ASICs DESIGNED



Source: DATAQUEST
July 1986

Table 1

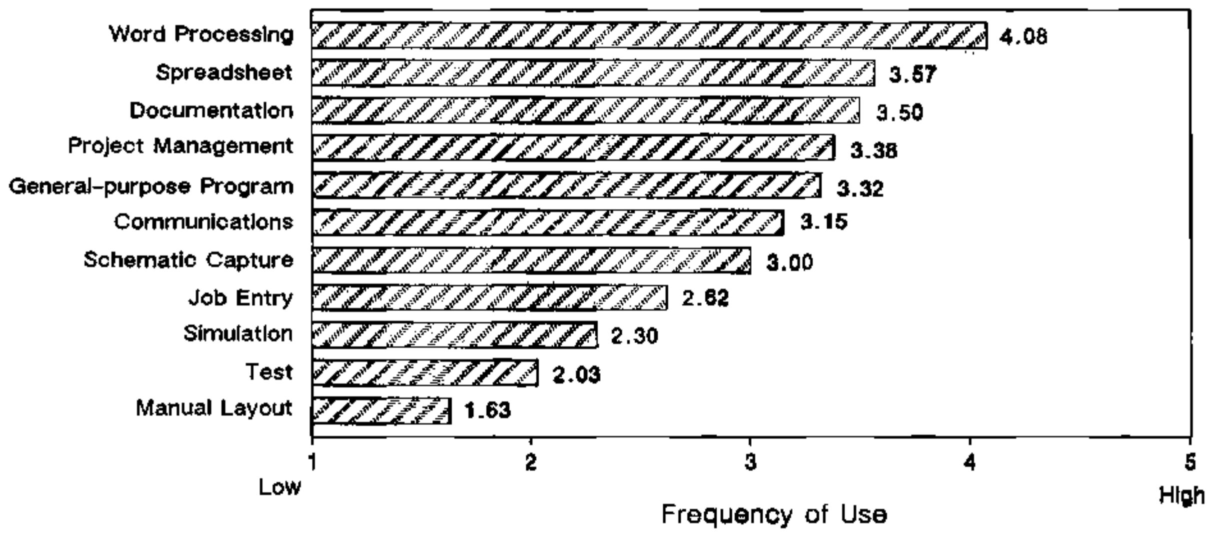
AVERAGE NUMBER OF GATES BY CIRCUIT TYPE

Type of Circuit	Average Number of Gates
Gate Arrays	1,930
Standard Cells	1,879
Handcrafted	1,058
PLDs	283

Source: DATAQUEST
July 1986

Figure 2

USE OF PERSONAL COMPUTER SOFTWARE TOOLS



Source: Dataquest
July 1986

Figure 3

PURCHASE PLANS BY PRODUCT TYPE

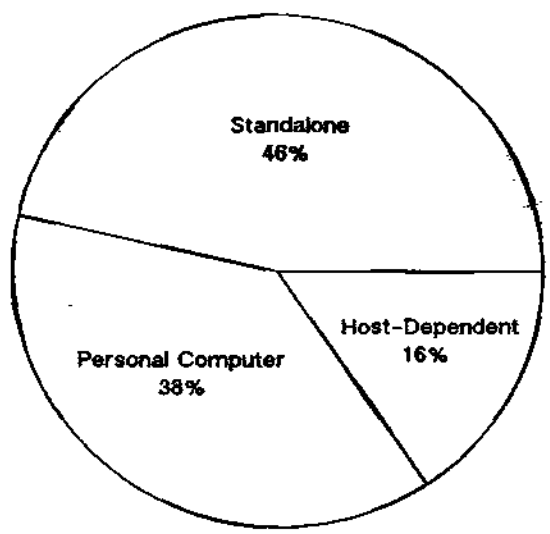


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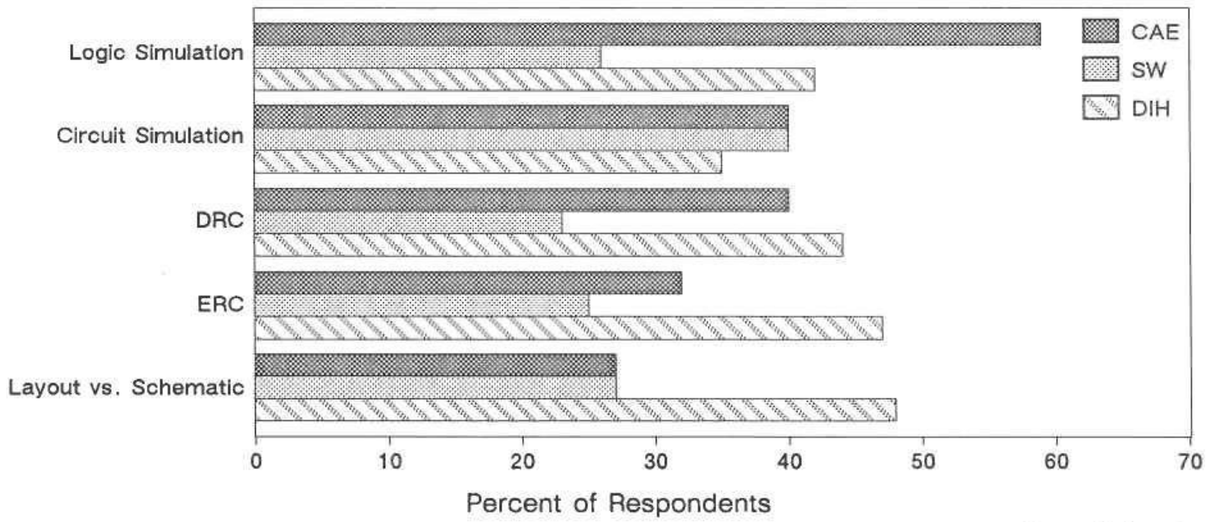
Figure 4

ANALYSIS TOOLS: USAGE AND SOURCES



Source: Dataquest
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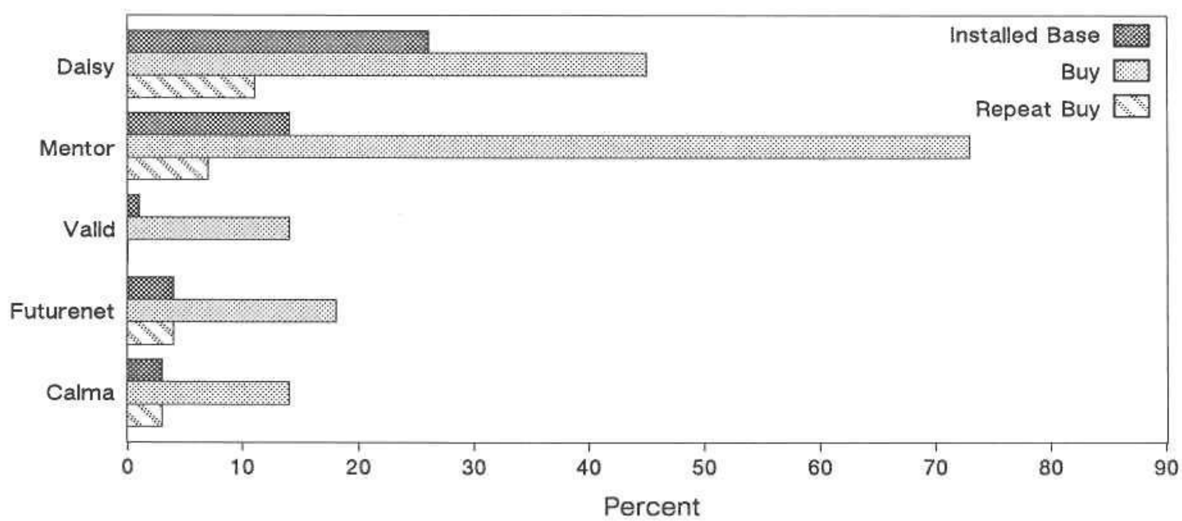
Figure 5

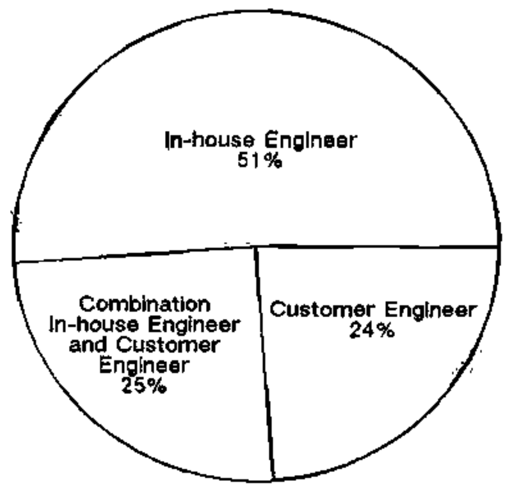
ANALYSIS TOOLS: INSTALLED BASES AND BUYING PLANS



Source: Dataquest
July 1986

Figure 6

WHO DOES THE DESIGN?



Source: Dataquest
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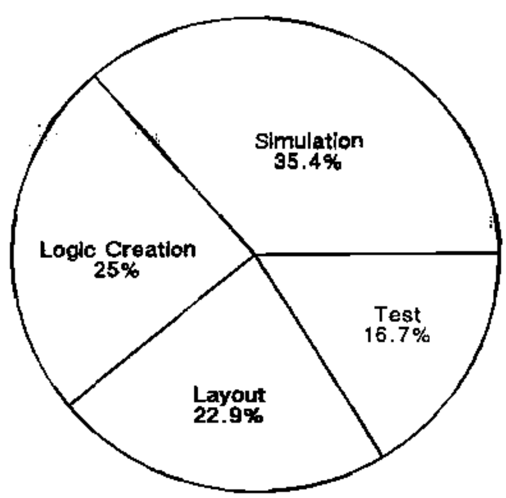
Figure 7

AVERAGE DISTRIBUTION OF TIME PER DESIGN PHASE



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July 1986

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RESEARCH NEWSLETTER

SIS Code: 1986-1987 Newsletters, July
1986-31

SPECIALTY MEMORIES: FOUR EXAMPLES

SUMMARY

Specialty memories have recently attracted a great deal of attention. Many semiconductor manufacturers are looking at this marketplace as a way to escape from the roller coaster of commodity memory pricing and, through their designs, to offer high-value-added products aimed at simplifying system design problems.

An overview of market factors is discussed in a companion SIS newsletter, "Perspectives on Specialty Memories," dated July 1986.

This newsletter discusses four specialty memory products, along with their suppliers, product availabilities, applications, and current and projected market sizes. The products discussed are dual-port RAMs (DPRs), First-In First-Out memories (FIFOs), video RAMs (VRAMs), and content-addressable memories (CAMs).

DUAL-PORT RAMs (DPRs)

A dual-port RAM is a RAM (static or dynamic) that has two independent access ports consisting of a pair of address, data, and control signals. Hence, a DPR has a relatively large number of pins associated with it (almost double that of traditional single-ported SRAMs). The two ports act independently of each other, and each side has full access to the memory array. (A certain amount of "arbitration" may be included to handle almost-simultaneous accesses from both sides.)

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The major technical advantage that a dual-port RAM device has over its single-port rival is that it is significantly easier for the systems designer to "share" memory between two processors. On-chip arbitration and the incorporation of all the access pins onto the same device saves tremendously in external buffers, multiplexers, and latches for such an application. Hence, cost savings is a major factor--as evidenced by reduction in the number of packages used, as well as reduction in board area.

DPR design-ins generally are found in systems where there are two (or more) processors on the same board, such as a main microprocessor with an intelligent peripheral controller. Systems that warrant use of large buffer memory between two processors are typically complicated (or just large) computer/communications interfaces; these applications require more than the small number of bytes of buffering generally found in peripheral controllers. Another major application area is in the distributed processor field, where separate computational units must communicate their data at nearly real-time speeds. The number of such designs, however, is quite small. Very few users have been able to apply such features to their own systems due to the overall complexity of that particular implementation technique.

DPR Replacement Potential

A 1Kx8 DPR chip in one package replaces the following equivalent TTL parts:

- An address multiplexer (8-bit buffers/latches)--four packages
- Two data in/out latches and buffers--two packages
- An arbiter/controller--one package
- A 1Kx8 SRAM--one package

The single-chip DPR can replace a minimum of eight packages. Unlike the FIFO, however, a DPR is a high-pin-count device because all the address pins (two sets for both ports) are input to the chip. That point has led a number of suppliers to consider multiplexing address inputs for higher-density DPRs.

Product Availability

Actual DPR devices have been available only recently in a steady enough supply for design-ins to take place. The first commercially and application-viable DPR was a Synertek 1Kx8 part, the 2130. When the product was initially introduced, it generated much customer interest; however, due to Synertek's inability to remain a supplier, the design-ins did not pick up. Only recently, after being reintroduced through Signetics and then VTI, is the device getting some consideration. IDT is the largest supplier of DPRs, with its 8K and 16K CMOS parts; IDT has contributed significantly to the establishment of the dual-port RAM market. The following suppliers either have just recently started to supply DPRs or are about to enter this market:

- Vitelic recently entered the DPR market with 8K- and 16K-density devices. Incorporation of special features for two-processor organizations makes Vitelic's parts very useful in multiprocessor communications.

- AT&T Technology's entrance in this market is with a 68-pin PLCC 2Kx9 part. AT&T's strategy is to introduce high-density monolithic DPRs at moderate speeds. AT&T also has 512x8 and 512x9 devices.

- AMD has recently introduced a 1Kx8 DPR. AMD's marketing expertise and experience has helped the company in generating much customer interest.

- IDT offers monolithic 1Kx8 and 2Kx8 DPRs, as well as 64K- and 128K-density hybrid modules. Access speeds that are sub-80ns are one of IDT's strengths, as well as a commitment to offer a variety of DPR products. It is estimated that IDT owns more than 50 percent of the DPR market today.

- VLSI Technology has inherited the Synertek 1Kx8 and has the largest market share after IDT. VTI's experience with semicustom design techniques is being used to provide a wide product offering based on a common DPR memory core.

Table 1 lists the dual-port RAMs currently available. (The dual-port RAM market described here does not include video RAMs; they will be discussed later in this newsletter.)

There are many important issues in the DPR market: customer inputs, density, pin count, "features," speed, power, and packaging. There is no single criterion that Dataquest believes is the most important in supplying or selecting a "good" DPR device, but rather there is a combination of features that are appropriate for each particular application. For example, interrupt features would be useful in communications but might not necessarily be an advantage in a multiprocessing environment. Multiplexed inputs might be appropriate for mass memory applications, but not for peripheral function controls.

Discussion with some suppliers and users indicates a common misconception that any dual-port RAM will do for most applications. However, even within the dual-port RAM market there is room for product differentiation, and there will be a need for many different types of DPRs in the marketplace.

Table 1

DUAL-PORT RAM AVAILABILITY

Company	Part No.	Technology	Device Organization	Access Time	Package
AMD	29705	TTL	16x4	25ns	DIP
	2130	CMOS	1Kx8	70ns	DIP
AT&T	78004	NMOS	512x8	200ns	40 P-DIP
	79004	NMOS	512x9	200ns	40 P-DIP
	79018	CMOS	2Kx9	150ns	68 PLCC
	79072	CMOS	8Kx9	N/A	68 PLCC
Cypress	7C130	CMOS	1Kx8	N/A	48 DIP or 48 PLCC
ERSO	2433	CMOS	2Kx8	N/A	48 DIP
IDT	7130 Master	CMOS	1Kx8	55ns	48 DIP or LCC
	7132 Master	CMOS	2Kx8	55ns	48 DIP or LCC
	7140 Slave	CMOS	1Kx8	55ns	48 DIP or LCC
	7142 Slave	CMOS	2Kx8	55ns	48 DIP or LCC
	7M134	CMOS	8Kx8	100ns	Module 600 mil
	7M135	CMOS	16Kx8	100ns	58 CERDIP
MOSel	6130	CMOS	1Kx8	55ns	48 sidebraze DIP
	6132	CMOS	2Kx8	55ns	48 P-DIP
TCMC	4511	CMOS	512x9	120ns	28 P-DIP or 32 P-DIP
UMC	2130	NMOS	1Kx8	N/A	DIP
Vitelic	61C30	CMOS	1Kx8	70ns	48 DIP
	61C32	CMOS	2Kx8	70ns	48 DIP
VTI	2130	NMOS	1Kx8	100ns	48 DIP
	2131	NMOS	1Kx8	100ns	48 DIP

Source: Dataquest
July 1986

Market Size and Growth Prospects

Dataquest estimates that sales of DPR devices for the 1985 calendar year were approximately $5 million. Most 1985 sales were from initial prototyping. It is expected that 1986 sales for dual-port RAMs (not including video RAMs) will be on the order of $18 million to $20 million. A necessary cross-check when establishing market size and growth prospects for DPRs at this time is to look at the number of customer target designs and the diversity of these applications. Suppliers' data indicate that more than 250 companies in the United States are currently designing-in DPRs from a number of vendors (including IDT, VTI, AMD). These particular systems vary from one-of-a-kind aircraft simulators to minicomputers to magnetic disk buffers. The levels of volume production are expected to vary just as widely.

Factors that will contribute to the growth of this market include the breadth of applications and the increasing popularity of these chips with board-level designers.

FIRST-IN FIRST-OUT MEMORIES (FIFOs)

A FIFO is similar to a dual-port RAM in that it has two access ports. However, the addition of the internal indexing and the restriction of the ports to being write-only and read-only, respectively, shape the device for some very useful applications. This memory has no address inputs, as the control clocks increment and decrement internal address counters. One can think of a FIFO as a "rubber-band memory," dynamically stretching in capacity when more storage is required and shrinking when there is less data to buffer.

FIFOs are most widely used in communications-buffering applications. It is no surprise that AT&T is the largest single consumer of FIFO memories. When an asynchronous data stream must be interfaced with a tightly controlled processor, a FIFO is ideal. The depth of the FIFO (number of memory locations) required is proportional to the degree of lack of coupling of the two systems and, to a certain extent, to their speeds and speed disparities.

An application where very shallow FIFOs have been used is in the bit-slice architecture market. There FIFOs are used for register-like temporary storage. FIFOs are also being used today in digital signal processing (DSP) systems where they can implement a variable and adaptable digital delay unit.

Because of the major target application of communications buffering, FIFOs typically have been used for high-bandwidth operation. Speed is generally a more critical factor with FIFOs than it is with DPRs. Another important issue with FIFOs used as buffers is that of flags. Many FIFOs have a number of output signals representing the fullness of the buffer. Some FIFOs have a half-full flag, while others have a full-minus-two flag, and so on. The exact function of the flag in commercial FIFOs is a point of disagreement among suppliers and users alike. FIFO output flags are truly an application-specific issue and should be treated as such.

FIFO Replacement Potential

A FIFO chip in one package can replace a number of external "glue logic" packages by internally integrating the functions very efficiently. In order to implement a 1Kx8 FIFO function using a generic static RAM, the systems designer must use the following (for a minimal implementation using standard TTL parts):

- Two sets of address counters (one for each port, each consisting of three 4-bit counters)--six packages
- An address multiplexer (four buffer or multiplexer chips)--four packages
- A data in and data out buffer/latch--two packages
- An address comparator for (simple) flag generation--two packages
- Control logic to perform access arbitration and counter and buffer control--three packages
- The 1Kx8 SRAM--one package

Clearly, the monolithic FIFO single chip is an efficient solution to the implementation of such a memory, compared to 18 other packages. Another important point to remember regarding the FIFO is that there are no address inputs needed on the chip; hence, the number of pins on a FIFO is not large.

Product Availability

Traditionally, small shallow register-based FIFOs (32- to 128-bit density) have been implemented in bipolar technology. Major suppliers for such bipolar parts are AMD, TRW, and MMI. More recently, a number of vendors have begun offering CMOS versions of these small FIFOs, where the speeds have been comparable (20- to 40-MHz clock rates) at significantly lower power.

Larger RAM-based FIFOs have also emerged in the past few years, where the depth has been significantly increased. FIFOs of increasing depth can be packaged using the same pinout, as there are no address inputs. Thomson Components Mostek Corporation's (TCMC's) introduction of a 512x9 FIFO began a wave of design-ins, and the part has emerged as a pinout standard, much like Synertek's DPR. A number of suppliers have plans to introduce deeper FIFOs with the same pinout.

Table 2 lists FIFO suppliers and their product offerings, including the following:

- TCMC's 512x9 FIFO has set a pinout standard in the marketplace as a result of its early market entry. The company's strategy is to increase depth and speed, as these are two critical FIFO areas.

- IDT is the other strong contender in FIFOs, as in DPRs. IDT's FIFOs are offered in both monolithic and hybrid forms, with TCMC-type pinouts. IDT's main strength is the speed of operation of its FIFOs.

- TRW's FIFOs consist of low-density, high-speed bipolar FIFOs aimed mostly at the military market. TRW's market experience in the military area allows it to emphasize the low-density, rad-tolerant/hard FIFO devices.

- Monolithic Memories is also a military supplier of FIFOs, although its strategy is to use CMOS for small, lower-power devices. MMI is also attempting to break into the large communications FIFO market by developing a deeper device.

- Cypress has used its advanced CMOS process to attack the niche military and bit-slice architecture FIFO markets. Cypress' strength is in providing a full product line for the implementation of bit-slice systems.

Table 2

FIFO AVAILABILITY

Company	Part No.	Technology	Device Organization	Package
AMD	2812	PMOS	32x8	CERDIP
	2813	PMOS	32x9	CERDIP
	3341	PMOS	64x4	CERDIP
Cypress	7C409	CMOS	64x4	CERDIP & P-DIP
	7C402	CMOS	64x5	CERDIP & P-DIP
Fairchild	74F403	TTL	16x4	24 CERDIP, P-DIP
	74F413	TTL	64x4	16 CERDIP, P-DIP
IDT	7201	CMOS	512x9	28-pin P-DIP, PLCC,
	7201	CMOS	1Kx9	28-pin CERDIP,
				32-pin ceramic LCC

(Continued)

Table 2 (Continued)

FIFO AVAILABILITY

Company	Part No.	Technology	Device Organization	Package
MMI	67401	TTL	64x4	16-pin & 18-pin
	67402	TTL	64x5	CERDIP, flatpack
Thomson-Mostek	4501	CMOS	512x9	28-pin side brazed, CERDIP, 32-pin
TI	232	TTL	16x4	16-pin DIP, 150 mil SO
	233	TTL	16x5	20-pin DIP, 300 mil SO
Vitelic	61C01	CMOS	512x9	DIP
	61C02	CMOS	1Kx9	DIP

Source: Dataquest
July 1986

Market Size and Growth Prospects

The market for FIFOs today is as dispersed and undefined as the DPR market. While low-density FIFOs have been commercially available in the market for more years than the large ones, small FIFOs have tended to go into specialty military applications where the ASPs are high and vary tremendously and where quantities are small. Dataquest estimates that in 1985, the total FIFO market was $53 million. We also estimate that in 1986, sales will reach $70 million to $80 million. The wealth of possible design applications coupled with explosion of the telecommunications market and expanding activity in digital signal processing are fueling the FIFO market niche's growth.

MMI is the leading supplier of FIFOs, with its low-density devices. IDT and TCMC have approximately equal shares of the high-density FIFO market, and these two suppliers combined represent about one-half to two-thirds of the high-density FIFO market.

VIDEO RAMs

Video RAMs (VRAMs, sometimes referenced as multiport DRAMs) are true application-specific memories, designed in response to the increasing fraction of dynamic RAMs that are used in graphics applications. Video RAMs have one random access port and one serial access port. Initially derived from a basic x4 DRAM core, video RAMs attach a virtual 256x4 serial shift register to the DRAM array. Dual porting allows simultaneous memory access while being able to sustain an uninterrupted serial data stream during screen scan, increasing CPU efficiency to nearly 100 percent, compared with 50 to 60 percent typical with conventional DRAMs used in video applications.

Product Availability

Video RAMs were first introduced by Texas Instruments in late 1984, with its TMS4161, a 64K device. As this was rather late in the 64K DRAM product life cycle, it was not long before 256K devices were available. NEC's uPD41264 was available early in 1985 and became the first 256K VRAM available. It also incorporated what was to become the standard 256K feature set: Subsequent 256K feature sets either matched or exceeded those of NEC's part. Present announced suppliers of 64K and 256K VRAMs are shown in Table 3. Others include Motorola, Toshiba, and existing or potential licensees of the announced participants.

Video RAMs at the 1Mb density are not expected before the end of 1986. Most are expected to be CMOS, built around a 256Kx4 DRAM core, but there may also be some diversion to x8, x1, and x2 configurations, as well.

Table 3

VIDEO RAM AVAILABILITY

Company	Part No.	Device Organization	Technology	Package**	Speed
TI	TMS4161	64Kx1	NMOS	20 PLCC, DIP*	-15, -20
ATT Tech.	M51064	64Kx1	NMOS	20 P-DIP	-15, -20
AMD	Am90C644	64Kx4	CMOS	24 P-DIP	-10, -12
Fujitsu	MB81461	64Kx4	NMOS	24 P-DIP	-12, -15
Hitachi	HM53461/2	64Kx4	CMOS	24 P-DIP	-10, -12
Mitsubishi	M5M4C264P	64Kx4	CMOS	24 P-ZIP	-12, -15
				24 P-DIP	-12, -15
NEC	uPD41264	64Kx4	NMOS	24 P-DIP	-12, -15
Texas Inst.	TMS4461	64Kx4	NMOS	24 P-DIP	-12, -15
Vitelic	V51C264	64Kx4	CMOS	24 P-DIP	-12, -15

*Also available in 4-5 chip SIP modules
**400 mil DIP package for 256Ks

Source: Dataquest
July 1986

Market Size and Growth Prospects

The total market for video RAMs was estimated to be $10 million to $12 million in 1985, split about 60 to 70 percent for 64Ks and 30 to 40 percent for 256Ks. The 1986 market is expected to be about $25 million, with at least six producers in volume production by the end of the year.

From an applications perspective, there is little doubt that graphics (and related serial-output) applications will constitute an increasingly large part of the DRAM market in years to come. Digital TV alone could eventually be a market equal to the total dynamic RAM bit consumption in 1985 (30 million TV units annually, at 4Mb each). Higher-resolution and color graphics displays also add considerable incremental demand for graphics RAMs.

Most estimates point to as much as 15 to 20 percent of the bit demand in the early 1990s coming from graphics applications. This demand may be met by video RAMs per se, or by other memories that are not quite so specialized but may not be hindered by the difficulties in building a specialty memory market. Those difficulties include:

- Uncertain initial feature set and available second sources
- Unacceptable price premiums
- System designer education time
- Lack of availability in the market until 18 to 24 months after standard parts of equal density

Most DRAM suppliers offer fast page mode, nibble mode, static-column devices, and x4 organization devices long before the more tailored video RAMs of the same density.

On the other hand, suppliers, through standardization committees such as the EIA JEDEC organization, are making every effort to define and adhere to a standard feature set, with upscale options for those users needing more functionality. SIP modules, incorporating four or five PLCC (or SOJ) monolithic chips, can provide improved packing densities prior to availability of monolithic chips. After initial early market pricing, VRAMs are often quite cost competitive with their standard DRAM counterparts: $3.00 for 64K VRAMs; $5.50 for 256K VRAMs. Volume multisourced competitive pricing should eventually put VRAM prices within 20 to 30 percent of standard dynamic RAMs. So, in spite of some drawbacks, VRAMs can offer a substantial improvement in price/performance ratio and reduced chip count.

CONTENT-ADDRESSABLE MEMORIES (CAMs)

The content-addressable memory (CAM) is an old memory concept that has only recently gained some research interest. It is included in this newsletter in order to demonstrate to the user the breadth of possibilities for special application memories that are nonstandard, and hence, application-specific.

A CAM is a memory that stores both a tag and associated data. The data are accessed via the tag, which may or may not be present inside the device. The memory architecture of a CAM is significantly different from traditional memories, although the basic function of storage is an integral part of the chip's operation.

Applications for CAMs are diverse: Cache modules can be constructed using a CAM as a building block, hardware data base systems can be implemented, or even Prolog language processors can be realized using these memories. The CAM is a nonconventional memory unit that has yet to be truly understood and appreciated by the general semiconductor sector.

Current CAM Activities

Since CAMs are highly application specific and application intensive, it is generally true that the few research projects for building these devices are found largely in systems companies rather than in semiconductor firms. The role of the user as the real driver in the definition (and sometimes even in the development) of these specialty memories is an important aspect that Dataquest believes is not particularly appreciated in the industry.

Dataquest believes that CAM devices are beginning to be incorporated into systems, although they are not being seen on the open market yet. Nevertheless, small CAM circuits do have many more conventional applications, and at least one semicustom vendor, LSI Logic, offers a small CAM as a standard cell library module.

NEW DIRECTIONS IN SPECIALTY MEMORY DESIGN

Specialty memories provide a challenge in integrating quick-turnaround semicustom design cycles with high-performance, high-density specialty memories. We believe that there is much innovation to be exploited in order to satisfy these two diverging requirements.

A number of semicustom vendors have begun to incorporate FIFO- and DPR-like features as part of their standard cell libraries. It is difficult to predict the effect that such devices can have on the component-level specialty memories, although the semicustom threat is real and appreciable. These vendors' strategies are very simply to incorporate significant amounts of memory on the chip, along with programmable access modes (i.e., multiport RAMs with two, three, or more ports) while maintaining all the peripheral logic required to implement any special features and computations. Semicustom techniques are highly applicable to the specialty memory marketplace.

DATAQUEST CONCLUSIONS

Dual-port RAMs, FIFO memories, video RAMs, and content-addressable memories are but subsets of conceivable specialty memory products. They benefit from technology developed for high-density commodity memories and from design techniques for semicustom ICs. Because of the recent introduction of a number of such devices, customer design-in activity has been booming, but manufacturing and volume shipments have been lagging behind by 12 to 18 months. There is great diversity in applications and product definitions that are available for marketing. However, a number of suppliers have already encountered pitfalls, particularly by relying on narrow product line offerings in FIFOs and/or DPRs as though they were commodity memories with which a "one part fits all applications/sockets" attitude is prevalent. One very crucial criterion for success in this exploding market niche is customer participation in the definition and development process, and, indeed, a few semicustom vendors entering the specialty memory market have already benefited from their previous experience.

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RESEARCH NEWSLETTER

SIS Code: 1986-1987 Newsletters: July
1986-30

PERSPECTIVES ON SPECIAL-PURPOSE MEMORIES

SUMMARY

Tucked away among the large commodity memory markets of dynamic and static RAMs, EPROMs, ROMs, and bipolar PROMs, there have always existed small, inconspicuous markets for "specialty memories." These products, and the markets they service, have characteristics that are substantially different from the larger commodity memory markets. These differences are so great that, in many ways, while they are functionally used as "memories" in systems' applications, they rarely exhibit the product or market characteristics of commodity memories. Indeed, the term "memory" has come to be almost synonymous with that part of the market that: (1) has extremely high-volume production runs of the same part; (2) requires leading-edge processing skills; (3) is usually served by 12 to 15 suppliers, each selling what are essentially interchangeable parts; (4) is highly elastic in the long run, but subject to periods of rapid price erosion and oversupply in the short run; and (5) exhibits a reasonably clear evolutionary product development path from one generation to the next.

In the last two to three years, there has been increased interest in diversifying the memory product line. This has come about largely as a result of three developments: (1) circuit designers have gotten closer to applications engineers and have begun to design devices more from a user systems viewpoint; (2) companies have tried to buffer their exposure in the commodity memory markets, resulting in increased interest in broadening memory product portfolios and looking for smaller, more defensible niches in which to compete; and (3) several manufacturers now try to offer a synergistic product set, focused at specific application areas (e.g., graphics, DSP, parallel processing, speech, or imaging) that have special-purpose memories as key ingredients. As a result, there has been a significant increase in activity in designing memories for special applications, or memories with unique features that can take an extra step to solve a system designer's problem and afford the chip designer and manufacturer certain advantages in the marketplace as well.

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While the term "Application-Specific Memory" has been applied to memories of this type, there is little consensus as to what precisely should be contained in this category. Certainly, there is a clear distinction between a commodity, 256Kx1 NMOS dynamic RAM on the one hand, and a 2Kx8 dual-port static RAM (DPR) on the other hand. In fact, there is a whole range of density gradations, feature-content options, performance differences, packaging options, and true application-specific enhancements that exist between these two extremes. Indeed, we can identify certain products such as a video RAM, which is at once, an Application-Specific Memory, a close kin to the dynamic RAM, as well as what will eventually be a multisourced commodity memory.

Recognizing the broad gray areas that exist in the market, for purposes of this newsletter we would like to restrict our discussion to only those memory product enhancements that are not strictly performance oriented such as access speed or power, are not merely density or architectural variants (x1, x4, x8, etc.), and are not just variations of packaging options. We will discuss only those memories that contain special enhancements of a basic memory core and offer users a substantial improvement (at the systems level) in reduced chip count, or significant improvements in data rate, or features that significantly improve the memory device's utility in specific applications. These more specialized memories necessarily serve a narrower and more directed market and application base; i.e., more performance targeted at a smaller market.

We expect that as time passes, more and more chip designers will seek to identify and incorporate systems' features onto their chips, both as a means of producing value-added products and of protecting themselves from the strong pressures and risks of the commodity memory market.

MARKET CHARACTERISTICS

In general, the market characteristics and competitive situation that exist in the specialty memory markets differ significantly from those that exist in the commodity memory markets (such as 256K dynamic RAMs, 64K static RAMs, or 256K EPROMs). While it is clear that some markets lend themselves better to high degrees of product differentiation, others are extremely homogeneous and little means of product differentiation has been brought to the marketplace yet. Among "commodity memories," fast SRAMs fall in the first category and EPROMs fall in the latter.

Design for Success

In markets for specialty memories, key factors for success are device feature content and product definition. These factors are weighted much more heavily than sheer high-volume manufacturing expertise, which generally characterizes success in the commodity memory area.

Fewer Competitors

Specialty memory markets, at the present time at least, tend to have far fewer competitors than the commodity memory markets. There are several reasons for this. (1) They are newer markets, and fewer of the possible market opportunities have been explored. There are several dozen design options in SRAMs and DRAMs alone. (2) Specialty memory markets are smaller and offer less revenue opportunity. High-volume manufacturers have focused on commodity memories first, in order to grow revenues rapidly, whereas numerous U.S. start-ups have focused on high performance and specialty memories. (3) With feature sets still unsettled, there is less second-sourcing and more product variation.

Opportunity or Avoidance

A manufacturer's decision to focus on specialty memories or feature-enhanced memories can be viewed both as a result of an opportunity that is perceived to exist in those markets for high value-added products, price stability, or a less competitive market environment, and/or concurrently, as avoidance of the mainstream market where the competition consists of manufacturers with large financial resources, high-volume manufacturing expertise, and perhaps relatively less sophisticated marketing operations. For specialty memories, there is more engineering in product design and more effort is required in marketing and sales.

Bigger Fish to Fry?

It is generally true, but not without exception, that small U.S. manufacturers have been much more active in exploring the niches of the specialty memory markets than have the major Japanese suppliers. It may also be true, however, that leading mainstream commodity memory manufacturers will turn their attention to specialty memory markets when and if an adequate market opportunity presents itself: i.e., when features and standards have been agreed upon and a large enough revenue opportunity exists. For example, the EEPROM market, now that IC cards are becoming more of a reality, has gained increased interest from Japanese manufacturers.

Specialty memory markets are, by their very nature, niche markets that tend to be design intensive, low volume, (in terms of total units produced out of each design), and potentially yield high and stable profit margins.

Table 1 lists many innovations in memory functionality that have occurred over the years. All have offered new functional capability to systems designers. Some "special-purpose" innovations have now been folded into the mainstream: e.g., nibble-mode DRAMs are de rigueur for all dynamic RAM suppliers. Some remain distinct minimarkets.

Table 1

SEMICONDUCTOR MEMORY DEVICE INNOVATIONS

Device Type	Year	Initiating Company(ies)
Static RAMs		
Resettable RAM	1982	AMD
Fast MOS SRAM	1977	Intel
Content Addressable Memory	1978	Digital Equipment
Separate I/O Fast SRAM	1982	IDT
Output Enabled Fast SRAM	1982	IDT
Color Palette RAM	1983	Inmos
Dynamic RAMs		
Ripple Mode DRAM	1983	Intel
Nibble Mode DRAM	1981	Inmos, Fairchild
Video RAM	1983	TI
CMOS DRAM	1985	Intel
16Kx4 DRAM	1981	TI
DRAM with Onboard ECC	1984	Micron Technology
Hierarchical RAM	1984	Visic
Pseudostatic RAM	1980	Mostek/NSC
EEPROMs		
NMOS EAROM	1969	NCR, Westinghouse
EEPROM Enhancements	1981-84	Xicor
EEPROM--Floating Gate	1981	Intel
Flash EEPROM	1984	Toshiba
High-endurance Q-cell	1983	Seeq
PROMs		
Diagnostic PROM	1982	AMD, MMI
Registered PROM	1982	AMD, MMI

Source: Dataquest
July 1986

PRODUCT CHARACTERISTICS

The products that make up the specialty memory market exhibit somewhat different characteristics than commodity memory products in terms of chip design, auxiliary benefits to the larger MOS product line, and rates of design-in and production rampup.

Future Product Visibility

In commodity memory products, successive generations of product are easily conceived, although at each generation there continues to be minor uncertainties as to the packaging and pinouts, and perhaps other characteristics external to the silicon chip itself. These are often standards questions. In specialty memories, however, since the products are applications driven, it often takes some time for the optimum feature set to be agreed to, a situation that today's general-purpose memories experienced in the early 1970s.

Create Your Own Socket

Because these are innovative products, the mere existence of a new product on the market does not mean that it will be selling into an established socket. In fact, for these early ground breaker specialty memories, that is certainly not the case. New suppliers of 256K dynamic RAMs today can ramp up their production extremely rapidly because they are selling in an existing market in excess of $1.2 billion.

Specialty memories, at the same time they are trying to identify the proper feature set, must (1) educate the systems designers to the new capability that they have as well as (2) satisfy their users' requirements for second-sourcing, price, and performance relative to alternative implementations such as multichip solutions, standard product plus gate array, etc., and (3) solve all the typical production/process difficulties that accompany new product introductions.

As a result, specialty memories face the additional burden of essentially creating a market for their new capabilities. In every case, it takes substantially longer to build volume than it does selling a commodity memory in an existing market.

Reduced Learning Curve Benefits

In every case so far, specialty memories do not exhibit the high-volume, steep learning curve pricing of commodity memories. Quite the contrary, it takes years to sort out the correct design, educate the user, win the designs, and ramp up production. For the most part, reduced manufacturing costs for specialty memories will be driven by production rates of their commodity cousins, not by production of the specialty part itself.

Specialty Memories as Process Drivers

One of the most important differences between specialty memory products and commodity memory products is the fact that as a consequence of their design intensity, their market-making requirement, and their low-volume production, specialty memories are not altogether sufficient to drive processes, as is generally the case with high-volume commodity memories selling on established markets. Lacking this VLSI (Vault into

Large Sales Instantly) capability, specialty memories cannot be utilized to serve this very basic function that currently appears only to be met by commodity memories.

In fact, if we look at the attributes of a "process driver," namely, (1) large die size/high transistor complexity; (2) fine-line lithography; (3) next-generation part easily conceptualized (no mistakes); (4) long production runs; (5) selling on an established market; and (6) quick recoupment of investment costs, then specialty memories have none of these attributes.

Specialty memories, to the extent that they often derive their designs from enhanced feature additions to commodity memories, must necessarily be viewed only as high value-added spinoffs from the mainstream parts, produced for purposes of raising the ASP and stabilizing the pricing of the product mix. They cannot be expected to be spearhead process drivers in themselves. Manufacturers who have only specialty memories in their portfolio will not be "memory makers" in the grander sense of the word, and will very likely find their markets being lost to successful coproducers of both commodity and specialty memories as the specialty memory markets expand and create bigger revenue opportunities where manufacturing expertise is king.

Defensible Niche

For a specialty memory to thrive, it must be positioned into a "defensible niche." It must add value to the system designer such as reduced cost, reduced chip count, improved performance, or even performance unachievable using standard building-block products.

Since many specialty memory functions replace assemblages of existing standard product, alternatives to use of the specialty memory often do exist. The system designer's reason to use the new device must outweigh the inertia and advantages of using the old.

MARKET TIMING

Because commodity memory markets exhibit steady and rapid price erosion, some specialty memories that are derived from standard products may have an added difficulty in becoming design choices because of time to market.

Video RAMs (VRAMs), in particular, are a fourth or fifth development priority for most DRAM suppliers, behind the commodity DRAMs (e.g., x1, x4, fast page, nibble, etc., plus various packages). Today, 1Mb DRAMs are probably shipping at a higher rate than 256K VRAMs . . . and coming down in price faster. Being a generation behind could, in many cases, make it difficult for a specialty memory that is a commodity memory derivative to achieve a design win. So, though 15 percent of DRAMs in 1990 may go into graphics, a smaller percent may be implemented using VRAMs instead of various standard DRAMs.

EXAMPLES OF SPECIAL-PURPOSE MEMORIES

Current examples of specialty memories now on the market include the products listed below. The list is in no way intended to be comprehensive, but to show the diversity of directions that product designs have taken.

Dynamic RAM with "Data Fill Mode"

One start-up manufacturer has designed a 64Kx4 dynamic RAM that incorporates a special feature known as "data fill mode," which enables the RAM to copy one row into the adjacent row. This feature is especially useful in graphics applications where scrolling is implemented, and will likely be a "standard" feature on the 1Mb generation of DRAMs.

HRAMs (Hierarchical RAMs)

Visic Corporation, a Silicon Valley start-up, has developed a number of high-speed dynamic RAMs with fast static RAM speeds. In addition, these parts have special operating modes, which in certain applications instances can provide data accessing much faster than any static RAM on the market. An example of these is the HRAM V64H1, which is a 64Kx1 device. Under normal circumstances, truly random access is necessary; the data can be accessed in 35ns. In static column mode, which is applicable in a more limited number of applications, data can be accessed in 25ns. The SNAP mode (Static Nibble Access Path), provides a random read access cycle of 10ns to the four bits contained in the static column defined by addresses A0 and A1 serially in 10ns. The static column mode and SNAP mode are not general-purpose, fully random accessing schemes. There are instances in certain applications (such as signal processing) in which the data to be accessed can be stored in specified addresses, and then can be accessed extraordinarily fast. A special case of this, of course, is the static column and serial access mode available in other dynamic RAMs.

A truly random accessing scheme and all of the inherent clock time consuming flexibility required by random data accessing is not necessary. Relaxing this requirement has enabled the designer, in the case of the HRAM and other advanced dynamic RAMs, to achieve very high data rates and extremely fast data access, which are of high utility in a limited number of applications. By and large, these have emerged from U.S. manufacturers, including some design concepts from major U.S. captives who, as one would expect, have the appropriate systems view and motivation to solve systems' problems.

Resettable RAM

Advanced Micro Devices offers a 4K resettable RAM, the Am9150, which is a specialty static RAM sold into cache memory applications. It has the added feature that, by controlling the reset and chip select pin, all bits go to zero so that the memory "blackboard" is cleared before further information is written on top of it. This can be used as a data security feature or as a means of preventing the use of preexisting data in a subsequent application.

Video RAM

Texas Instruments' TMS4161, a 64K video RAM, was the first video RAM introduced. It is a dual-port RAM with a 256x4 bit shift register accessible through the second serial port, which enables very high data rates for graphics applications. It came to market in 1984 as a part of a special TI program to design new products to address the graphics market. This product has since been followed at the 256K level by at least seven suppliers, including TI. While it is clear that graphic display applications will eventually take significant amounts of the dynamic RAM output in the long run, even in today's 256K market less than 0.5 percent of the output of 256Ks are in video RAM configurations.

The video RAM market has probably exhibited many of the characteristics that specialty memories in general will be faced with, namely, (1) unsettled feature set, (2) initial lack of agreement on pinouts and functionality, (3) education of designers, and (4) improvements in price performance, vis-a-vis multichip implementations using standard products. All of this settling down of the market takes time, while the commodity memory cousins--the plain vanilla 64K, 256K, and 1Mb--race forward at a tremendous rate.

RAM with On-board Error Correction

In 1984, Micron Technology offered the first commercial memory with on-board error correction circuitry (ECC), its 256K DRAM, the MT1256. At an earlier ISSCC session (1983), Hitachi described a 1Mb ROM with ECC, but this device never became a commercial offering.

Micron also has a 1Mb DRAM with ECC. The most attractive application for error-corrected chips appears to be in systems where there is no system error correction, but the soft error rate would be unacceptably high without on-chip error correction. Even at the 1Mb level, all manufacturers and users seem to be fully satisfied with the soft error rate of the product now coming to the market, none of which has ECC except that of Micron Technology.

Indeed, new CMOS dynamic RAMs, which are expected to be overwhelmingly dominant at the megabit RAM level, exhibit soft error rates 10 to 100 times lower than demonstrated by their NMOS counterparts at prior generations.

Color Palette Memory

Advanced Micro Devices (Am8151), Inmos (IMSG170), and others offer devices that are known as color palette memories. These devices integrate the lookup tables with D/A converters and MPU interface circuitry. These are used as lookup tables for color graphics systems, and enable the user to access 256 colors from a palette of many hundreds of thousands of color choices for each of the various screen locations.

KEEPROMs

In 1985, Intel described its KEEPROM, a Keyed-Access EPROM. This is not strictly a memory device; it is a single-chip security system based primarily on information stored in a 128K EPROM that restricts access to certain systems through a user code and password method. In this case, Intel has gone far beyond the limited concept of a specialty memory and incorporated so much functionality onto the KEEPROM that its identity as a memory storage device is totally concealed.

FIFO

One of the oldest types of special-purpose memories, First In-First Out memories (FIFOs), are used to even up the flow of data between two parts of an electronic system that are running at different rates.

Dual-Port RAM

Dual-port RAMs allow access to common chip addresses through each of two ports. They are often used in multiprocessor systems where memory must be shared, in Local Area Networks, or as intermediary memories between intelligent peripherals and host computers.

TRENDS IN PRODUCT DIVERSIFICATION

There is a clear trend, in the semiconductor industry in general and in MOS memories in particular, to develop devices whose designs increasingly reflect the needs of the systems in which they are being utilized. This trend runs counter to the trend toward general-purpose memory building blocks, such as we saw from 1975 to 1985. In the memory area, we are seeing increased tailoring of memories to more specialized functionality.

This has in part been caused by the severe pricing pressures in the commodity memory market and the value-added opportunities open to applications-oriented designers. It is also a natural consequence of the sheer size and maturity of the market, which has, over time, created identifiable, specialized applications for which (1) special-purpose memories can be tailored, (2) it is economic to design special-purpose memories, and (3) alternative building block implementations are less cost-efficient than a specialized monolithic device.

The problem is being attacked at all levels, from minor feature additions to what are otherwise general-purpose memories, to wholesale redesigns, in which the memory identity has been entirely obscured. It is clear that up and down the entire spectrum of new product possibilities, both opportunities and pitfalls exist. But it remains to be seen which of these market opportunities can best be exploited by applications-oriented enterprises and which will fall into the domain of high-volume, efficient manufacturers.

Lane Mason

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RESEARCH NEWSLETTER

SIS Code: 1986-1987 Newsletters: July
1986-29

MOS MEMORY LICENSING AGREEMENTS AND JOINT VENTURES 1982 TO 1986

SUMMARY

The MOS memory marketplace has experienced a large number of licensing agreements and joint ventures during the last few years. Several trends are emerging in these agreements. The trends include:

- Increasing numbers of agreements
- Increasing complexity of agreements
- Technology being supplied by U.S. companies
- Technology being purchased by Japanese and Korean companies
- More sharing of fab capacity

JOINT VENTURE AND LICENSING AGREEMENT TRENDS

Increasing Numbers of Agreements

Licensing agreements and joint ventures pertaining to MOS memory products are increasing. There were 7 exchanges in 1982, 14 in 1983, 17 in 1984, and 18 in 1985. There have been 9 agreements just in the first few months of 1986.

There are many reasons for this increase in licensing agreements and joint ventures. One of the most evident is the need for capital. In 1985, many semiconductor companies experienced deep financial losses. The selling of technology was a means of creating revenue in a very depressed market. Venture capital has been tight over the last few years, and many start-up companies were not able to attract the additional rounds of financing needed to sustain their growth. These companies sold their designs as a means of survival. Other companies

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were rich in manufacturing capabilities but in need of technology and products to fill their factories; these companies sold fab space to create revenue.

Increasing Complexity of Agreements

Licensing agreements and joint ventures have become more complex over the last few years. In the early agreements, technology was often simply purchased from one company by another. Other arrangements were made where wafers and processing were purchased in foundry deals between one company with a chip design and another with excess capacity. Agreements now include any number of combinations of purchase or trade of process, technology, or fab capacity. Stipulations are made as to what markets the participating companies can sell to.

Transfers of high-level personnel have also taken place. For example, Toshiba assigned Dr. Yoshio Nishi, manager of Toshiba's 1Mb DRAM team, to head Hewlett-Packard's VLSI Research Center for three years.

Technology Supplied by U.S. Companies

Currently, nearly all MOS memory agreements utilize technology from U.S. companies. One reason for this primarily one-directional flow is that the United States is still the largest innovator of new technology. Another, and perhaps more significant reason, is that the Japanese are very reluctant to sell their technology for short-term gains in revenue or market share.

Overall, companies in the United States have been less successful at semiconductor production than those in Japan and Korea. Japanese and Korean companies often have fab capacity that is subsidized by larger parent corporations, allowing them to run very efficient fab facilities. This has encouraged a large number of U.S. companies to trade technology for Japanese and Korean fab capacity (see Figure 1).

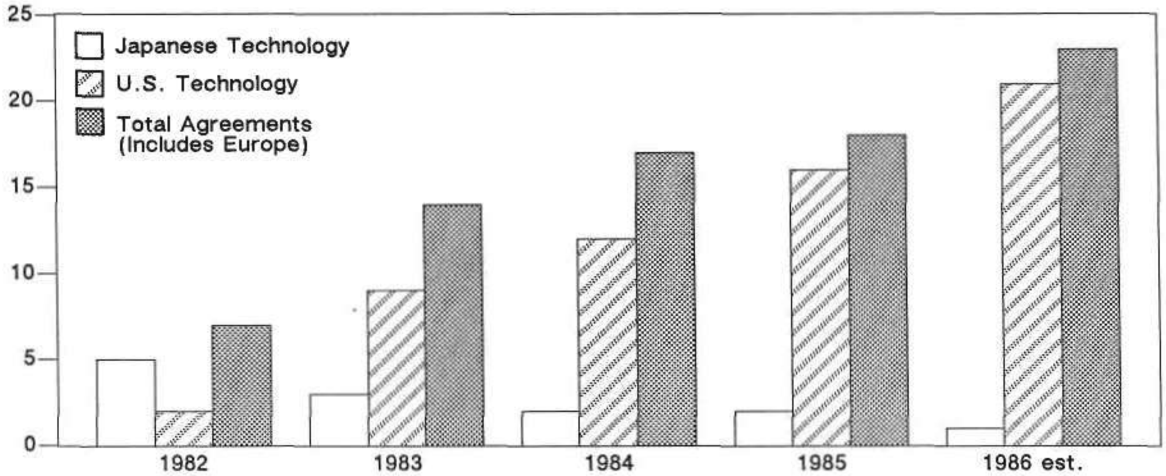
Another reason for the large number of U.S. technology transfers has to do with the semiconductor industry slump of 1985. While the world MOS memory market was down 39 percent in dollars from 1984 to 1985, U.S. companies suffered the most with a drop of 46 percent. This drop in revenue encouraged the U.S. sale of technology.

Technology Purchased by Japanese and Korean Companies

The technology that is being supplied for the most part by U.S. companies is being purchased by Japanese and Korean companies. Since 1982, Japanese companies have been the recipients of technology in 24 percent of licensing agreements. Korean companies, while commanding only 1 percent of the MOS memory market in dollars, received technology in 25 percent of the agreements. Japanese and Korean companies are gaining the technological advances necessary to obtain a much higher proportion of the MOS memory market share in the near future.

Figure 1

JOINT VENTURE AND LICENSING AGREEMENTS
BY SOURCE OF TECHNOLOGY



Source: Dataquest
July 1986

More Sharing of Fab Capacity

There has been a worldwide excess in semiconductor wafer fab capacity since 1984. Because of this, venture capital agreements have typically not included funds for companies to build their own fabs. This has caused an increase in the number of agreements associated with the sharing of fab capacity. Currently, more than half of all licensing agreements and joint ventures include fab arrangements.

CLASSIFICATION OF AGREEMENTS

Dataquest has classified these exchanges into five main categories:

I. Company A sells the right to produce a product to Company B for a price.

   A. Company B can compete with Company A in all markets.

   B. Company B is forbidden to compete with Company A (in-house use only) or must sell the product only in restricted markets.

II. Company A trades a product for allocated production capacity at Company B.

A. Company A's process is installed at Company B.

B. Company A's process is not installed at Company B.

III. Two companies agree to develop methods for achieving consistent specifications, ensuring a second source.

IV. Company A makes a product; Company B buys the product and markets it under the Company B label.

V. Company A and Company B exchange technology; this may or may not include a transfer of money.

Table 1 lists, in reverse chronological order, specifics of some of these agreements.

Table 1

MOS MEMORY LICENSING AGREEMENTS AND JOINT VENTURES
1982-1986

Number	Company A	Company B	Type	Products	Date
1	MOSel	Sharp	II	256K fast SRAM	86/05
2	Inova	UMC	IIA	Monolithic Macro Circuits	86/05
3	Vitelic	Philips	V	CMOS SRAM	86/04
4	GI/Amtel	Hyundai	II	64K CMOS EEPROM; OTP EPROM	86/03
5	Lattice	Seiko-Epson	IB, IIA	16Kx4 Fast SRAM	86/02
6	AMD	Sony	V	Joint Development	86/02
7	Vitelic	Hyundai	IIA	64K, 256K, 1Mb CMOS DRAM; 16K CMOS SRAM	86/02
8	MOSel	Hyundai	II	8Kx8 Fast SRAM	86/01
9	Dallas	Thomson-Mostek	IA	Multiport Memory; FIFO	86/01
10	Mostek	Samsung	I	256K DRAM	85/11
11	Vitelic	NMB	IIA	1Mb CMOS DRAM	85/11
12	Cypress	Matra-Harris	IA	4K, 16K fast SRAM	85/10
13	MOSel	Fuji Electric	IIA	64K SRAM	85/10
14	National	VLSI Technology	II, IV	CMOS EPROM	85/10
15	WSI	Sharp	II	64K, 256K CMOS EPROM	85/10
16	Toshiba	Hewlett-Packard	V	1Mb DRAM	85/09
17	Intel	Signetics	IA	256K EPROM	85/09
18	SEEQ	Silicon Compilers	IA	All EEPROM Designs	85/07
19	Synertek	UMC	IA	4K, 16K SRAM; 8K, 16K, 32K, ROM	85/07

(Continued)

Table 1 (Continued)

MOS MEMORY LICENSING AGREEMENTS AND JOINT VENTURES
1982-1986

Number	Company A	Company B	Type	Products	Date
20	Toshiba	Siemens	IA, V	1Mb DRAM	85/07
21	Vitelic	Sony	IIA	256K, 1Mb, 4Mb CMOS DRAM	85/07
22	Xicor	Intel	III	EEPROM	85/07
23	Fairchild	GoldStar	IB	64Kx1 CMOS Fast SRAM	85/06
24	Exel	Oki	IA	2Kx8 NMOS EEPROM	85/03
25	AMD	GoldStar	IB	64K, 256K DRAM	85/01
26	Atmel	General Instrument	IIA	OTP EPROM; UV EPROM; EEPROM	85/01
27	Synertek	Signetics	IA	Dual Port RAM	85/01
28	Inmos	Hyundai	I	64K, 256K DRAM	84/12
29	RCA	Sharp	V	256K CMOS DRAM	
30	WSI	Sharp	II	64K, 256K CMOS EPROM	84/12
31	Micron	National	IA	64K DRAM	84/11
32	Visic	Monolithic Memories	V	CMOS Memory	
33	Oki	Thomson	IIA	64K, 256K DRAM	84/10
34	Modular Semi.	Ricoh	IB	16K SRAM; 256K DRAM	84/09
35	Intel	Altera	V	CHMOS EPROM Technology	84/08
36	Lattice	VLSI Technology	IIB	CMOS EEPROM; 64K SRAM	
37	Lattice	Synertek	IIA	64K Fast SRAM	84/07
38	National	Synertek	III	2K EEPROM	84/07
39	MOSel	UMC	IIA	EEPROM; 2Kx8 SRAM	84/06
40	Inmos	NMB	IB, V	64K, 256K, 1Mb CMOS DRAM	84/06
41	Philips	Siemens	V	4Mb DRAM	84/06
42	Vitelic	ERSO	V	EPROM; 64K, 256K CMOS DRAM	84/05
43	Motorola	Thomson	I	64K DRAM	84/03
44	Visic	VLSI Technology	V	64Kx1, 16Kx4 CMOS DRAM	84/02
45	Intel	Inmos	III	64K, 256K CHMOS DRAM	83/12
46	ICT	Hyundai	V	1K CMOS EEPROM; 64K EPROM	83/10
47	Inmos	General Instrument	III	8Kx8 EEPROM	83/10
48	AT&T	GoldStar	I	64K, 256K DRAM	83/09
49	Micron	Standard Telecom	I	64K DRAM	83/09
50	VLSI Technology	Ricoh	V	64K, 128K, 256K ROM	83/09
51	Micron	Commodore	I	64K DRAM	83/08
52	Micron	Samsung	IA, V	64K, 256K DRAM	83/08
53	Philips	General Instrument	III	1K EEPROM	83/06
54	Exel	Samsung	V	16K EEPROM	83/04
55	Mitsubishi	TI	IV	64K EPROM	83/03
56	National	Eurotechnique	I	16K, 32K CMOS EPROM	83/03
57	Sharp	Hyundai	I	2Kx8 CMOS SRAM	83/03
58	Seiko	RCA	IV	2Kx8 CMOS SRAM	83/01
59	Oki	National	IIB	64K DRAM	82/12
60	Ricoh	Rockwell	V	32K, 64K CMOS EPROM	82/12
61	Intel	IBM	IB	64K DRAM	82/09
62	Mitsubishi	Sperry	V	64K NMOS DRAM	82/08
63	SEEQ	Rockwell	IA	16K EEPROM; 64K UV EPROM	82/07
64	Toshiba	Zilog	V	16K CMOS SRAM	82/04
65	Hitachi	Hewlett-Packard	IB	64K DRAM	82/03

Source: Dataquest
July 1986

LICENSING AGREEMENTS AND JOINT VENTURES

1. MOSel and Sharp

MOSel exchanged a license for its 256K fast SRAM with Sharp Electronics in May of 1986. MOSel obtained foundry capacity from Sharp.

2. Inova and UMC

An agreement was reached in May of 1986 between Inova Microeletronics and United Microelectronics Corp. (UMC). Inova will receive base wafers with their IC designs from UMC and will use its proprietary interconnect technology on these 1.5μ CMOS wafers to form multichip devices. The agreement also provides Inova with access to any process advances developed by UMC.

3. Vitelic and Philips

A joint-venture agreement between Vitelic and Philips was signed in April of 1986. In exchange for access to Philip's proprietary process technology, Vitelic was to design a family of high-performance CMOS SRAMs for manufacture, use, license, and sale by both companies.

4. General Instrument/Atmel and Hyundai

An agreement was reached between General Instrument (GI), Atmel, and Hyundai in March of 1986. In this agreement, Hyundai obtained license to manufacture GI's 64K CMOS EPROMs and EEPROMs.

5. Lattice and Seiko-Epson

Lattice Semiconductor announced a manufacturing and second-source agreement with Seiko-Epson and SMOS Systems on February 4, 1986. Seiko-Epson acquired the license to Lattice's 16Kx4 SRAM design and process technology, and SMOS acquired the rights to market the part in North America.

6. AMD and Sony

A joint technology-development agreement between Advanced Micro Devices (AMD) and Sony was signed in February of 1986. Sony gained access to part of AMD's current product line. The two companies planned joint development of the next generation of ICs.

7. Vitelic and Hyundai

In February 1986, Hyundai obtained license to Vitelic memory products in exchange for manufacturing capability at Hyundai. Products covered in this agreement included 16K CMOS SRAMs, as well as 64K, 256K, and 1Mb CMOS DRAMs.

8. MOSel and Hyundai

MOSel traded fast 8Kx8 SRAM technology for foundry capacity at Hyundai in January of 1986.

9. Dallas Semiconductor and Thomson-Mostek

In January of 1986, Thomson-Mostek agreed to second source a multiport memory device under development by Dallas Semiconductor. Thomson gained royalty-free rights to the part; Dallas Semiconductor will be able to buy a percentage of the output. Dallas will also obtain laser production equipment from Thomson and technical information on Thomson-Mostek's MK4501, a FIFO memory device.

10. Mostek and Samsung

Early in 1986, Mostek and Samsung signed an agreement covering Mostek's 256K DRAM technology.

11. Vitelic and NMB Semiconductor

An agreement between Vitelic and NMB was signed in November of 1985. Vitelic granted license to its 1Mb DRAM in exchange for one-third of NMB's plant capacity.

12. Cypress and Matra-Harris

In October of 1985, Cypress transferred masks for its 4K and 16K fast SRAMs and its 1.2μ CMOS technology to Matra-Harris. In addition to an undisclosed amount of cash, Cypress will get 2 percent of Matra-Harris' stock. A similar deal for Cypress' 0.8μ process and 64K SRAM is also planned.

13. MOSel and Fuji Electric

In October of 1985, Fuji Electric agreed to produce CMOS 64K SRAMs for MOSel using MOSel's 1.5- to 2.0-micron CMOS process.

14. National Semiconductor and VTI

In October of 1985, National Semiconductor supplied CMOS EPROM technology to VTI. VTI produced the part and gave finished wafers back to National.

15. WSI and Sharp

In October of 1985, Wafer Scale Integration (WSI) and Sharp expanded their 1984 agreement to include WSI's 1.6-micron CMOS technology in exchange for royalties and plant capacity.

16. Toshiba and Hewlett-Packard

In September of 1985, Toshiba assigned Dr. Yoshio Nishi, manager of its 1Mb DRAM team, to head Hewlett-Packard's VLSI Research Center for three years.

17. Intel and Signetics

Intel provided its 256K EPROM technology to Signetics in September of 1985. Signetics already had a 64K EPROM on the market but did not choose to upgrade its own 64K part to a 256K version.

18. SEEQ and Silicon Compilers

In July of 1985, SEEQ provided all of its EEPROM designs for Silicon Compilers to use in ASIC designs.

19. Synertek and UMC

In July of 1985, United Microelectronics Corp. (UMC) gained nonexclusive product licenses for 18 types of ICs formerly produced by Synertek. UMC also purchased some production equipment and inventory from Synertek. In exchange, Synertek received $3 million plus royalties of 3 to 5 percent over the next three years. MOS memory products covered by this arrangement include 4K and 16K SRAMs, 8K, 16K, and 32K ROMs.

20. Toshiba and Siemens

In July of 1985, Siemens agreed to pay Toshiba for design, testing, and production data on Toshiba's 1Mb DRAM. Both companies agreed to cross-license their entire field of semiconductor components with mutual worldwide rights.

21. Vitelic and Sony

A joint-venture agreement between Vitelic Corporation and Sony was signed in July of 1985. Sony gained access to Vitelic's 256K, 1Mb, and 4Mb CMOS DRAM technology in exchange for providing fab capacity to Vitelic.

22. Xicor and Intel

In July of 1985, Intel and Xicor signed a letter of intent covering joint development of advanced EEPROMs. This also covered a second-sourcing agreement on other undisclosed products. Intel provided the bulk of the $10 million needed to cover the costs of the joint R&D program.

23. Fairchild and GoldStar

A 10-year agreement between Fairchild and GoldStar was signed in June of 1985. Fairchild provided its 64Kx1 fast SRAM technology to GoldStar. GoldStar obtained exclusive rights to market the part in Korea and nonexclusive rights to market it in other Asian countries.

24. Exel and Oki

Exel Microelectronics and Oki Electric reached an agreement in March of 1985, whereby Oki will be a second source for Exel's 2Kx8 NMOS EEPROM. Oki also planned to start producing 64K EEPROMs in mid-1985. Exel has been shipping its 2Kx8 EEPROM in volume since November of 1984.

25. AMD and GoldStar

GoldStar entered an agreement with Advanced Micro Devices (AMD) early in 1985. GoldStar will manufacture and obtain limited marketing rights to AMD's 64K and 256K DRAM.

26. Atmel and General Instrument

Atmel provided technology for its OTP EPROM, UV EPROM, and EEPROM to General Instrument (GI) in exchange for fab capacity at GI's plant in Chandler, Arizona.

27. Synertek and Signetics

Synertek's dual-port RAM technology was sold to Signetics after Synertek shut down.

28. Inmos and Hyundai

In December 1984, Hyundai signed a contract with Inmos Corporation for technology from Inmos to begin mass production of the 256K DRAM. Hyundai paid $6 million for the technology, and production was scheduled for the latter half of 1986. In April 1986, Hyundai charged Inmos with delaying the transfer of the technology and asked the U.S. District Court to order Inmos to enter into arbitration over this transfer.

29. RCA and Sharp

RCA and Sharp entered into a broad joint venture in December of 1984. This venture included the establishment of a jointly owned company, taking technology from the parent companies. Ownership was to be 51:49 in RCA's favor. The transfer included the design of a 256K CMOS dynamic RAM by Sharp for production by RCA.

30. WSI and Sharp

On December 20, 1984, Sharp announced that it had signed a technical cooperation contract with Wafer Scale Integration (WSI). By using WSI's technology, Sharp planned to produce the 64K CMOS EPROM. WSI received manufacturing capacity and royalties from Sharp. Development and production of 256K CMOS EPROMs were also planned.

31. Micron Technology and National Semiconductor

On November 30, 1984, National Semiconductor purchased a license to manufacture and sell Micron Technology's 64K dynamic RAM. It was estimated that this license cost National close to $5 million. This deal also involved an option on a 512K DRAM array that National could manufacture as a second source when Micron started up its own line. As of January 1985, National had still not decided whether or not to build the part in production volume.

32. Visic and Monolithic Memories

On November 8, 1984, Monolithic Memories signed a technology exchange and cross-licensing agreement with Visic. The agreement included joint development of a high-performance, 1.5-micron double-level metal CMOS process and an exchange of advanced proprietary products. Visic stated that its product line would be "high-performance CMOS memories," but would not specify the type of memory to be built. The relationship also ensured alternate sourcing for these products at initial market introduction.

33. Oki and Thomson

Thomson used its own technology for 64K RAMs but got substantial production assistance from a five-year industrial know-how exchange with Oki Electric in October of 1984.

34. Modular Semiconductor and Ricoh

In September 1984, Ricoh signed a five-year contract with Modular Semiconductor. Modular supplied the design and process technology for the CMOS 256K DRAM and the 16K SRAM. Ricoh planned to market those devices in Japan and also to supply them to Modular and Panatech Research and Development.

35. Intel and Altera

Intel and Altera signed a technology exchange agreement on August 13, 1984. Under the terms of the agreement, Intel was to provide Altera with its CHMOS EPROM design technology. In exchange for this, Altera would allow Intel to produce the Altera electrically programmable logic devices.

36. Lattice and VLSI Technology

In July of 1984, Lattice Semiconductor Corporation provided technology for CMOS EEPROMs and SRAMs to VLSI Technology in exchange for foundry services at VLSI Technology.

37. Lattice and Synertek

Lattice Semiconductor and Synertek signed a cross-licensing, second-source agreement on July 1, 1984. Under the terms of the agreement, Synertek was licensed to use Lattice's proprietary process in the manufacture of a 35ns, 64K static RAM in exchange for a portion of Synertek's production capacity at its wafer fab facility in Santa Cruz, California.

Synertek was also licensed to manufacture any other static RAM that Lattice makes using its proprietary "ultra MOS" process, which is a CMOS process. In exchange, Lattice was licensed to manufacture any products Synertek would design using this process.

38. National Semiconductor and Synertek

National Semiconductor and Synertek signed an agreement in July of 1984, under which National would serve as a licensed alternate source for Synertek's 2K EEPROM.

39. MOSel and UMC

MOSel, a small design group out of Fairchild, designed an advanced EEPROM and a high-speed 2Kx8 static RAM. In exchange for a fraction of the wafer start capacity, MOSel transferred rights to production of these products to UMC in Taiwan. In addition, the advanced process used to manufacture them would be used to bring up the 2-micron CMOS process at UMC in Taiwan.

40. Inmos and NMB

NMB obtained a five-year license to produce Inmos 256K CMOS DRAMs in June of 1984. Under the terms of the agreement, NMB was to pay Inmos a large initial sum and continuing royalties. The two companies also agreed to cooperate on the technology for Inmos' 64K DRAM and a 1Mb DRAM. Inmos would have the right to purchase up to 50 percent of NMB's 256K DRAM output, and NMB would sell Inmos products exclusively to Inmos' Japanese customer base.

41. Philips and Siemens

In June 1984, Philips and Siemens agreed to a joint venture to set up a semiconductor fabrication plant in Holland to produce 4Mb RAMs. This venture involved an investment of approximately $10 million.

42. Vitelic and ERSO

In May of 1984, Taiwan's government-sponsored Electronics Research and Service Organization (ERSO) signed a cooperative agreement with Vitelic Corporation of the United States with the aim of jointly developing VLSIs. Under the terms of the agreement, development of EPROMs and 64K and 256K CMOS DRAMs would be completed within a year.

43. Motorola and Thomson

Motorola transferred its 64K DRAM technology to Thomson in March of 1984.

44. Visic and VLSI Technology

Visic and VLSI Technology announced a joint development venture on February 22, 1984, to develop CMOS RAM technology and products. Included in this agreement were 64Kx1 and 16Kx4 CMOS DRAMs.

45. Intel and Inmos

Intel and Inmos entered into an agreement in December of 1983 to develop methods for achieving consistent specifications on 64K and 256K CHMOS DRAMs. Each company planned to develop, introduce, and market its own products independently, while adherence to the same CHMOS specifications would ensure a second source for users.

46. International CMOS Technology and Hyundai

Hyundai licensed International CMOS Technology (ICT) to do product development in 1983. This joint enterprise required ICT to develop three advanced CMOS products, while Hyundai would develop three other products. Hyundai funded ICT's initial product development and allocated a certain fraction of the wafer fab capacity at its Korean plant to produce ICT's part. Out of this venture, both manufacturers planned to produce a total of about seven or eight different parts, including 1K CMOS EEPROMs, fast SRAMs, and 64K EPROMs.

47. Inmos and General Instrument

In October 1983, Inmos licensed General Instrument to be a second source for an 8Kx8 EEPROM. The pact involved complete technology transfer including masks and processing information.

48. AT&T Technology and GoldStar

GoldStar Semiconductor was licensed by AT&T sometime before September of 1983 to produce 64K and 256K DRAMs.

49. Micron Technology and Standard Telecom

Sometime before September 1983, Standard Telecom, formerly IT&T, acquired the rights to produce the Micron Technology 64K dynamic RAM.

50. VLSI Technology and Ricoh

In September of 1983, Ricoh and VLSI Technology signed a contract to exchange production technology of large-capacity mask ROMs. VLSI Technology supplied 64K, 128K, and 256K mask NMOS ROM technology to Ricoh, and Ricoh supplied the same capacity of mask CMOS ROM to VTI.

51. Micron Technology and Commodore

In August 1983, Micron Technology licensed Commodore to produce Micron's 64K DRAM. This was the only semiconductor part used by Commodore in its personal computer and other microsystems that it did not make itself.

52. Micron and Samsung

Samsung obtained a license to manufacture and market the 64K DRAM design of Micron Technology in August of 1983. This pact provided Micron with cash and is believed to have involved a swap of technical information. This agreement was later extended to include Micron's 256K DRAM.

53. Philips and General Instrument

General Instrument (GI) and Philips reached an agreement in June of 1983 under which GI planned to develop a new line of nonvolatile memory devices that supported the Philips I^2C bus standard. The first product was planned to be a 1K EEPROM.

54. Exel and Samsung

In 1983, Samsung entered into a joint development project to act as a second source for Exel's forthcoming 16K EEPROMs.

55. Mitsubishi and Texas Instruments

Sometime before March of 1983, Mitsubishi supplied both loose dice and packaged 64K EPROMs to Texas Instruments (TI) to be sold through TI's distribution channel and with TI's markings on them. TI would continue to produce its own part at full capacity.

56. National Semiconductor and Eurotechnique

National Semiconductor transferred technology for its 16K and 32K CMOS EPROMs to Eurotechnique in 1983.

57. Sharp and Hyundai

Hyundai obtained the technology for 2Kx8 CMOS SRAMs from Sharp in March 1983.

58. Seiko and RCA

In 1983, Seiko was supplying loose dice and/or packaged parts of its 2Kx8 CMOS Static RAM to RCA to be sold through RCA's marketing chain.

59. Oki and National Semiconductor

In late 1982, Oki Electric supplied its 64K dynamic RAM technology to National Semiconductor. National allocated about half of its 64K DRAM output to Oki. National planned to market the Oki DRAM, using a National label and part number.

60. Ricoh and Rockwell

In December 1982, Ricoh and Rockwell International signed a cross-licensing agreement for memories, microprocessors, and other semiconductor devices. As part of that agreement, Ricoh and Rockwell would exchange production technology. Ricoh would provide Rockwell with its technology for producing 32K and 64K CMOS EPROMs. In return, Rockwell would provide its technology to Ricoh for producing 8-bit CMOS microprocessors.

61. Intel and IBM

In September of 1982, IBM purchased the tapes and process know-how for Intel's 64K dynamic RAM. This agreement also provided IBM with on-site technical assistance in setting up the production process. Intel agreed to supply IBM with finished 64K DRAMs until IBM's line was running. IBM would produce the part for in-house use only.

62. Mitsubishi and Sperry

In 1982, Mitsubishi agreed to supply 64K NMOS DRAM technology to Sperry. In exchange, Sperry agreed to train Mitsubishi engineers in large mainframe computer technology. Mitsubishi also obtained rights to sell Sperry products in Japan.

63. SEEQ and Rockwell

Rockwell signed an exclusive licensing agreement with SEEQ Technology on July 6, 1982. SEEQ provided Rockwell with its 16K EEPROM and 16K UV EPROM technology. In exchange, Rockwell paid SEEQ $5 million and leased $5.5 million of SEEQ's equipment. Rockwell also agreed to pay SEEQ a 3 percent royalty on sales of these products (up to $4 million). However, by October of 1984, Rockwell had not made any sales of products subject to this royalty.

64. Toshiba and Zilog

Toshiba provided Zilog with the design and process information for its 16K CMOS SRAM in April of 1982. The agreement allowed Zilog to market Toshiba's product worldwide. In return, Zilog provided Toshiba with masks for its microprocessors.

65. Hitachi and Hewlett-Packard

In March of 1982, Hitachi sold Hewlett-Packard (HP) its 64K DRAM technology. HP was planning to use the 64Ks in its minicomputers but not to market them to outside users.

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Dataquest
a company of The Dun & Bradstreet Corporation

RESEARCH NEWSLETTER

SIS Code: 1986-1987 Newsletters: July
1986-28

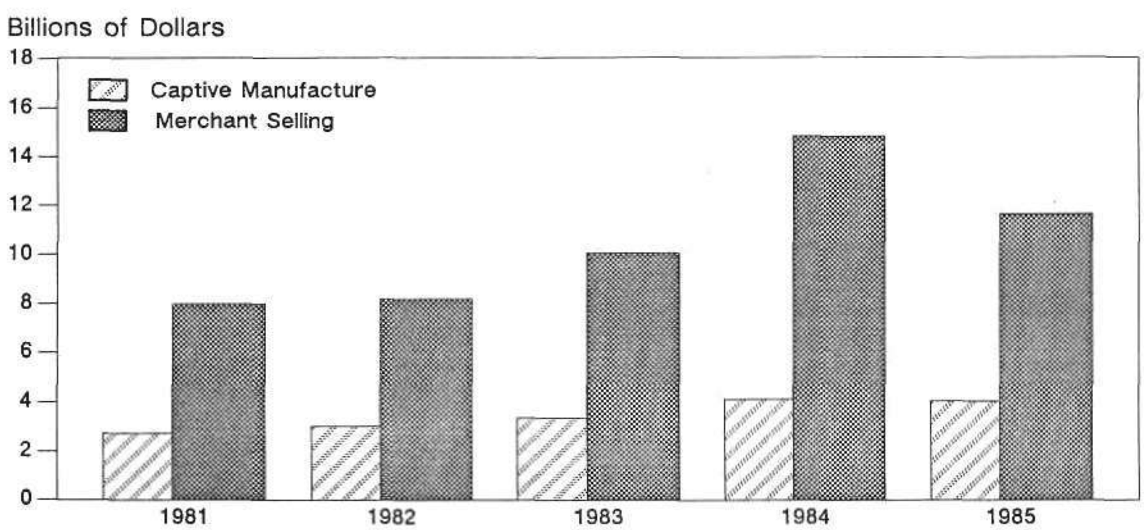
U.S.-BASED SEMICONDUCTOR MANUFACTURERS: THE MERCHANT AND CAPTIVE ENVIRONMENT

SUMMARY

The U.S. market is unique due to the characteristics of its merchant-selling suppliers and its large captive-producing segment. DATAQUEST's recent study of intracompany sales by major merchant suppliers in regional markets revealed that U.S. companies have the highest percentage of sales to the merchant market, 95 percent, of all world suppliers. Another aspect of the U.S. market is the large captive-producing sector. As shown in Figure 1, the value of products from this captive sector increases the value of U.S.-based production by approximately $4 billion.

Figure 1

U.S.-BASED SEMICONDUCTOR SUPPLIERS
MERCHANT AND CAPTIVE
(1981-1985)



Source: Dataquest
July 1986

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This newsletter asks, "Is the unique nature of the U.S. semiconductor industry an advantage or a disadvantage in the increasingly global semiconductor market?" DATAQUEST believes that the structure of American industry is a disadvantage because the large U.S. captive semiconductor makers do not have the stimulating effect of a competitive arena and because large U.S. merchant-selling manufacturers do not have the stabilizing financial effects of large systems businesses.

DEFINITIONS: MERCHANT, INTERNAL, AND CAPTIVE SALES

Definitions can become confusing when referencing semiconductor manufacturers. Most U.S. merchant-selling semiconductor companies manufacture products at a single semiconductor division; these products may then be sold inside or outside the company. But there are other companies that manufacture semiconductors in sister divisions solely for their own use. We refer to this latter type of manufacture as "captive." DATAQUEST has traditionally measured all suppliers selling into the merchant market, regardless of whether they sell to sister divisions or to outside users. But for this study, we are reviewing captive suppliers.

DATAQUEST recognizes three types of consumption, based upon the location of product manufacture within company divisions and the ultimate destination of the product. A merchant sale occurs when a product manufactured by a merchant-selling division is sold in its final form to outside consumers. An intracompany sale takes place when a product that was completely or partially manufactured in a merchant-selling division is consumed by a sister division. A captive sale is one in which a product is made and used within a non-merchant-selling division.

DATAQUEST believes that in most cases the transfer price of captive semiconductors does not accurately reflect their market value. Hence, valuation is an issue when estimating captive sales. To arrive at a fair market value, DATAQUEST estimates semiconductor content of equipment based on the merchant market semiconductor purchases of other equipment makers in the same market segment. From this estimate of total value, we subtract estimated purchases to arrive at a merchant value equivalent. By this procedure, we have arrived at our estimates of captive manufacturers such as AT&T and IBM.

U.S. MERCHANT-SUPPLYING COMPANIES

For the purposes of this newsletter, DATAQUEST has identified the top 10 U.S.-based semiconductor manufacturers and broken out their intracompany sales from total world sales (please see Table 1). The sum of these top 10 companies have intracompany shipments of between 5 and 7 percent from 1981 through 1985. During boom years, the intracompany consumption percentage decreases, while in recession years it rises. We believe that the remaining U.S. merchant-supplying companies have very small intracompany sales, probably between 2 and 3 percent. Our sum of all merchant-selling U.S.-based companies resultantly runs between 4 and 6 percent. Note that we have included AT&T in our captive list.

Table 1

INTRACOMPANY SEMICONDUCTOR SALES OF U.S. MERCHANT SUPPLIERS
(Millions of Dollars)

COMPANY		1981	1982	1983	1984	1985
Motorola *	Intracompany Sales	160	187	227	339	272
	Merchant Sales	1030	1032	1420	1981	1558
	Total Sales	1190	1219	1647	2320	1830
	% Intracompany	13%	15%	14%	15%	15%
Texas Instruments	Intracompany Sales	65	140	170	70	90
	Merchant Sales	1230	1165	1468	2410	1676
	Total Sales	1295	1305	1638	2480	1766
	% Intracompany	5%	11%	10%	3%	5%
Intel	Intracompany Sales	26	25	31	36	31
	Merchant Sales	499	600	744	1165	989
	Total Sales	525	625	775	1201	1020
	% Intracompany	5%	4%	4%	3%	3%
National	Intracompany Sales	20	7	3	5	6
	Merchant Sales	722	701	911	1258	934
	Total Sales	742	708	914	1263	940
	% Intracompany	3%	1%	0%	0%	1%
AMD	Intracompany Sales	1	1	1	1	1
	Merchant Sales	278	328	504	935	602
	Total Sales	279	329	505	936	603
	% Intracompany	0%	0%	0%	0%	0%
Fairchild	Intracompany Sales	1	2	2	3	3
	Merchant Sales	461	408	453	662	489
	Total Sales	462	410	455	665	492
	% Intracompany	0%	0%	0%	0%	1%
RCA	Intracompany Sales	15	14	17	22	23
	Merchant Sales	278	259	280	380	302
	Total Sales	293	273	297	402	325
	% Intracompany	5%	5%	6%	5%	7%
Signetics	Intracompany Sales	7	7	8	9	10
	Merchant Sales	359	333	427	756	460
	Total Sales	366	340	435	765	470
	% Intracompany	2%	2%	2%	1%	2%

* We believe that some of Motorola's intracompany sales, between $100 to $150 million, may actually be captive in nature.

(Continued)

Table 1 (Continued)

INTRACOMPANY SEMICONDUCTOR SALES OF U.S. MERCHANT SUPPLIERS
(Millions of Dollars)

COMPANY		1981	1982	1983	1984	1985
Harris	Intracompany Sales	3	3	4	7	11
	Merchant Sales	162	153	176	268	254
	Total Sales	165	156	180	275	265
	% Intracompany	2%	2%	2%	3%	4%
General Instrument	Intracompany Sales	14	15	16	21	18
	Merchant Sales	252	267	225	251	183
	Total Sales	266	282	241	272	201
	% Intracompany	5%	5%	7%	8%	9%
Other	Intracompany Sales	48	76	59	85	75
	Merchant Sales	2336	2448	2901	4178	3656
	Total Sales	2384	2524	2960	4263	3731
	% Intracompany	2%	3%	2%	2%	2%
TOTAL U.S. MERCHANT	Intracompany Sales	360	477	538	598	540
	Merchant Sales	7607	7694	9509	14244	11103
	Total Sales	7967	8171	10047	14842	11643
	% Intracompany	5%	6%	5%	4%	5%

Source: Dataquest
July 1986

INTRACOMPANY SALES OF MERCHANT MANUFACTURERS

Of the 10 U.S. companies listed in Table 1, Motorola consumes the largest percentage of semiconductors internally. Motorola has a very large systems organization that accounts for approximately two-thirds of total corporate revenues. Between 1982 and 1983, Texas Instruments also noted some significant intracompany sales. This was the era of its home computer, a product that was dropped in 1984. General Instrument, another large systems house, has also had some significant intracompany sales. Most of the other companies listed in Table 1 have fairly small intracompany sales. Note that the Signetics reference represents internal sales to Philips. Fairchild intracompany sales refer to Schlumberger internal consumption.

CAPTIVE U.S. SUPPLIERS

DATAQUEST believes that the captive segment of the U.S. market was about $4.1 billion in 1984. We believe that this market was flat or slightly depressed in 1985. Our estimates of the major captive suppliers are shown in Table 2. We have included IBM, AT&T, Delco, DEC, partial divisions of Hewlett-Packard and Honeywell, and numerous computer and military companies (included in Others). The table illustrates that captive markets are much more stable than merchant markets.

Table 2

CAPTIVE U.S. SEMICONDUCTOR MANUFACTURERS
(Millions of Dollars)

COMPANY	1981	1982	1983	1984	1985
IBM	1500	1680	1932	2318	2600
AT&T	675	720	755	980	600
Honeywell	60	76	90	95	81
Delco	68	75	80	95	111
DEC	47	61	65	80	71
HP (IC only)	116	118	134	165	180
Subtotal	2466	2730	3056	3733	3643
Others	250	275	300	370	395
TOTAL	2716	3005	3356	4103	4038

Source: Dataquest
July 1986

If we add U.S. captive manufacturing value to merchant manufacturing, we increase the size of U.S.-based semiconductor manufacturing in 1985 from about $11.6 billion to $15.6 billion (please see Table 3). It is interesting to note that the percentage of sales destined for internal consumption, whether intracompany or captive, is similar to Japanese intracompany sales. Of course, intracompany sales are not guaranteed placement by systems divisions, for products manufactured in merchant divisions must be as competitive in price as products purchased from the outside market.

Table 3

TOTAL U.S.-BASED SEMICONDUCTOR MANUFACTURING CAPABILITY
(Millions of Dollars)

TYPE	1981	1982	1983	1984	1985
Captive Production	2716	3005	3356	4103	4038
Merchant Suppliers	7967	8171	10047	14842	11643
TOTAL	10683	11176	13403	18945	15681
Captive (Percent)	25%	27%	25%	22%	26%
Merchant (Percent)	75%	73%	75%	78%	74%
TOTAL	100%	100%	100%	100%	100%

Source: Dataquest
July 1986

INTRACOMPANY SHIPMENTS--REGIONAL COMPARISONS

In researching the regional base markets of Europe, Japan, and the United States, DATAQUEST noted some interesting similarities and differences. Systems divisions offer companies some security in tough times, yet the mix of semiconductor and systems house seems difficult for some U.S. companies to manage. Examples of awkward U.S. unions include companies such as Zilog/Exxon and Fairchild/Schlumberger.

Japanese-based companies are interesting because of their vertical integration. Semiconductor companies are generally part of a very large conglomerate, or keiretsu. As a result, the semiconductor division of a vertically integrated Japanese company has a ready market for its product within the corporate conglomerate or keiretsu. DATAQUEST believes that in 1985 intracompany shipments for Japanese semiconductor companies comprised roughly 25 percent of total production or sales.

European semiconductor manufacturers are similar to the Japanese in that they are mostly divisions of large, vertically integrated electronics companies. Philips and Siemens have expanded their revenue through acquisition. Siemens has acquired numerous small U.S. companies (Crystal Technology, Litronix, and Microwave Semiconductor) to supply its semiconductor requirements and broaden its product portfolio, while Philips acquired Signetics in 1975 as a means of strengthening its market position. DATAQUEST believes that European companies sell about 15 percent of their products to sister divisions.

U.S. companies supplying the merchant market generally sell about 95 percent of their product to outside manufacturers. This figure contrasts sharply with Japanese companies, which sell only 75 percent of their product outside their companies. Europeans fit somewhere in between. It is interesting to note that many U.S. companies are pure players in the semiconductor area, that is, they manufacture only semiconductors. This is generally not true for Japanese and European manufacturers. Semiconductor activity for Japanese and European suppliers developed out of the need to support their systems groups. This characteristic is in contrast to the U.S. market where semiconductor companies evolved along with semiconductor technology.

The U.S. market, due to its segmentation of systems manufacturers and component manufacturers, is a volatile market. Although large internal sales in Europe and Japan absorb components and act as a buffer in poor economic cycles, U.S. component suppliers must bear the full weight of economic cycles since the majority of their product is sold into the merchant market. In Japan and Europe, systems groups in general can offer financial support to the company as a whole when the semiconductor market is depressed.

CONCLUSION

Characterized by and including such large captive semiconductor manufacturers as AT&T and IBM, the U.S. market is the largest consuming region in the world. U.S. merchant companies also have the highest concentration of sales to outside users. We believe that this is a disadvantage to the companies from a financial and applications perspective. Kinship with systems groups provides feedback in component design and also ready markets for the product.

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RESEARCH
NEWSLETTER

SIS Code: 1986-1987 Newsletters: July
1986-27

NEC VERSUS INTEL: BEHIND THE LAWSUIT LIES THE STRUGGLE FOR MARKET SHARE

The NEC/Intel copyright lawsuit, currently being tried in San Jose before U.S. District Court Judge William Ingram, raises several legal and competitive issues of great significance to the semiconductor industry. These issues deal with:

- The battle for market share between two of the world's leading producers of microprocessor products
- The effectiveness of current legal protection for microcode
- The manner in which second-source licensing agreements are negotiated and maintained

The outcome of the current trial may significantly affect the semiconductor industry in a number of ways. To begin with, a loss for NEC could deny its V-Series products access to the U.S. microprocessor market--a market that Dataquest predicts will be worth more than $550 million in 1990. A loss for Intel, on the other hand, will add a serious market share contender in not only the current 8- and 16-bit microprocessor arena, but in the promising market for 32-bit devices as well.

Above all, any ruling on the copyright issue would give the industry its clearest reading yet on the extent to which it can protect investments in that form of intellectual property known as microcode, the hardware implementation of instruction sets that regulate the flow of data in a microprocessor.

In this newsletter, Dataquest will review the history of the NEC/Intel lawsuit, the legal arguments presented by both sides, and the market share considerations at stake on the outcome.

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NEC/INTEL DISPUTE HISTORY--A CHRONOLOGICAL OUTLINE

The following outline reviews the events leading up to the present litigation:

- 1982--Intel claims that the NEC uPD 8086 contains a bit-for-bit copy of the 8086 microcode.

- April 1983--The dispute over the 8086 microcode is settled out of court.

- Mid-1984--Intel becomes aware of the NEC V-Series microprocessors (V20/V30), which are described as compatible with the 8086. Intel begins an investigation into possible copyright infringement of the 8086 microcode by NEC, a licensed second source for both the 8086 and 8088.

- December 1984--NEC files a declaratory relief action asking the court to declare that a) microcode is not copyrightable and that b) the V-Series does not infringe on the 8086 microcode copyright.

- February 1985--Intel files a counter claim alleging that the V-Series microcode infringes on the 8086 microcode copyright.

- August 1985--Judge Ingram of the Northern California Circuit Court denies a summary judgement motion by Intel that microcode is copyrightable as a matter of law, ruling instead that the issue should be part of the scheduled trial.

- October 1985--NEC files a summary judgement asking the judge to declare that Intel lost its 8086 microcode copyright because certain licensees (including NEC) were not marking their 8086 parts.

- December 1985--Intel amends its copyright infringement suit to include the NEC V40 and V50 series of microprocessors, claiming that these devices utilize the same microcode as the V20 and V30. Intel asks for an extension of the discovery period from February 20, 1986, to April 4, 1986.

- January 9, 1986--Judge Ingram denies NEC's October 1985 summary judgement motion.

- January 22, 1986--Judge Ingram grants Intel's request for extension of the discovery period and the inclusion of the NEC V40 and V50 microprocessors to the suit.

- March 1986--The court rules that damage claims filed by Intel against NEC and counterclaims of unfair competition by NEC should be tried separately and at a later date.

Intel's Legal Position

Intel argues that certain NEC V-Series microprocessors infringe on copyrighted microcode found in Intel's 8086 and 8088 microprocessors--both of which are licensed to NEC for second-source manufacture and distribution. To win its argument, the U.S. District Court must uphold the overall copyrightability of microcode, and must then be convinced that NEC is guilty of copying the Intel 8086/8088 microcode.

To support its arguments, Intel is relying on the United States Copyright Act and several precedent cases involving software copyright infringement. In 1980, Congress amended the Copyright Act to include "computer programs" to the list of copyrightable expression. The 1980 amendment defines a computer program as "a set of statements . . . instructions . . . to be used in a computer . . . to bring about a certain result." As a result of this legislation, software is treated as a literary work which, according to the Act, may be "expressed in words, numbers, or other verbal symbols . . . fixed in any tangible medium of expression now known or later developed . . . (and) can be perceived, reproduced, or otherwise communicated . . . with the aid of a machine or device."

Microcode, Intel maintains, clearly meets the criteria set forth in the Copyright Act for the following reasons:

- Microcode is expressed in numbers, or numerical or verbal symbols, and can be fixed on disks, paper, or magnetic tape. It can also be perceived by humans directly or indirectly by aid of machines.

- Microcode is a series of instructions generally created by a programmer in source code, which will direct a computer's operations when converted into object code. As a set of instructions, microcode is clearly distinguishable from the functions it directs in a microprocessor.

NEC's Legal Position

Despite the fact that NEC is the plaintiff in this case, its legal arguments more closely resemble a series of defensive perimeters. This should not be surprising, considering that NEC fired the first legal salvo (see Chronological Outline section) in an effort to head off a suit by Intel.

To begin with, NEC maintains that its V-Series microcode was developed independently of Intel's and does not constitute a copy of the microcode used in the Intel 8086/8088 microprocessors. More fundamentally, NEC challenges the assumption that the Copyright Act extends to microcode. Microcode, NEC claims, is more accurately described as a process or method of operation rather than as a literary expression, and as such is the domain of patent law.

NEC argues that the addition of computer programs to the Copyright Act has no bearing on its case since there are significant differences between instruction sets in a microprocessor and computer programs stored in read-only memory (ROM). In microprocessors such as the 8086/8088, NEC reasons, ROM is an integral part of the control mechanism and cannot be externally accessed without very specialized equipment.

Finally, it is NEC's contention that the creation of microcode is itself dictated by hardware design. While it may in theory be possible to build a "microprogrammable" general-purpose computing engine, such devices are not a commercial reality. A single-chip microprocessor is a merger of ROM sequence and logic circuits, with microcode falling into a gray area between software and hardware.

Beyond this perimeter, NEC maintains that Intel's negligence in its copyright policies invalidated the integrity of its copyright claims. The positions of both litigants on this issue will hopefully become clearer during the trial proceedings.

THE MICROPROCESSOR ARENA: A BACKGROUND

Behind the more ponderous legal issues of microcode copyright, two major chip manufacturers are fighting for market share in the arena of 8-, 16-, and 32-bit microprocessors. The microprocessor (MPU) market is a significant one. Dataquest predicts that the demand for microprocessor products will grow at a faster rate than the overall IC industry. In 1986, the MPU sector should see a 16 percent increase in revenue to approximately $503 million, with a 51 percent increase in 1987 to approximately $761 million.

We expect the lowering of the average selling price for MPUs to encourage systems designers to take advantage of the cost reductions, creating a rapid growth of demand that will strain limits of capacity and draw more capacity into the market in the 1987-1988 time frame. The long-term outlook for microprocessors through 1991 is for a 34.7 percent compound annual growth rate (CAGR) in units shipped.

If successful in this current lawsuit, Intel could not only prevent the future sales of NEC V-Series MPUs in the United States, but could, according to recent courtroom evidence, press for the same decision in Japan, which subscribes to the basic tenets of the Copyright Act through an international trade agreement.

To date, Intel has named four of NEC's six V-Series MPUs in its charges of infringement: the V20, V30, V40, and V50. Each of these devices directly competes with an Intel MPU, as Table 1 illustrates.

Table 1

COMPARISON OF INTEL AND NEC MPUs

Intel MPU	Competing NEC MPU	MPU Type
8088	V20	8-bit
8086	V30	16-bit
80188	V40	8-bit/High Integration
80186	V50	16-bit/High Integration

Source: Dataquest
July 1986

Intel, the leading U.S. supplier of microprocessors, largely withdrew from the random access memory market as a result of intense competitive pressure from the Japanese. Since then, Intel's success has depended heavily on the sales of its MOS microprocessor lines, which accounted for nearly 66 percent of its 1985 revenues. In 1981, when Intel's RAM sales represented approximately 24 percent of revenues, its MOS microprocessors accounted for 41 percent.

Intel now finds itself facing aggressive competition from Japan in the MPU market. In 1980, NEC trailed Motorola, Zilog, Intel, and Synertek with an 8.33 percent market share in 8-bit microprocessors. In 1982, NEC took the lead with a market share of 12.03 percent--nearly 2 percent more than Intel, its closest competitor. In the years following 1982, NEC's market share lead in 8-bit microprocessors has widened further, a fact that is attributable in no small part to the higher demand for these devices in Japan itself.

In the arena of 16-bit MPUs, NEC's impact on the market has been less dramatic. The Japanese electronics giant is currently ranked behind Intel and Motorola in market share. Intel enjoys a more than 30 percent lead in market share over NEC, which until 1985 competed in this sector as a second-source supplier of Intel 8086 microprocessors.

NEC'S CHALLENGE: THE V-SERIES MPUs

In 1985, however, NEC began volume shipments of its V20 and V30 CMOS microprocessors. The gains in sales of these devices, at the expense of Intel's 8- and 16-bit MPUs, is illustrated by Figures 1 and 2.

Figure 1

V20 VERSUS 8088/80C88--MARKET SHARE COMPARISON

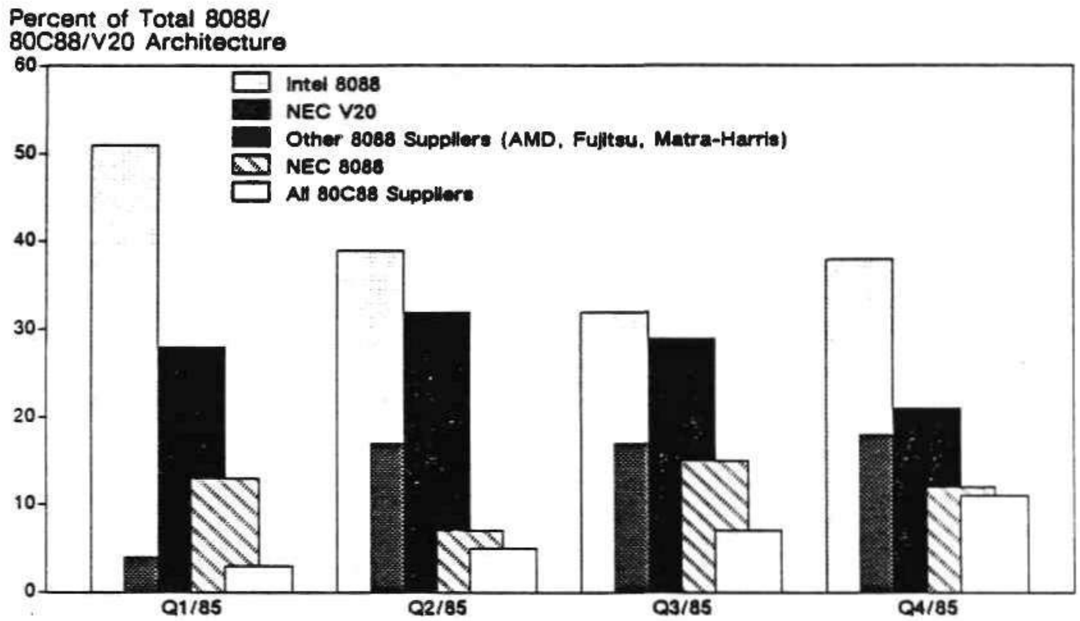
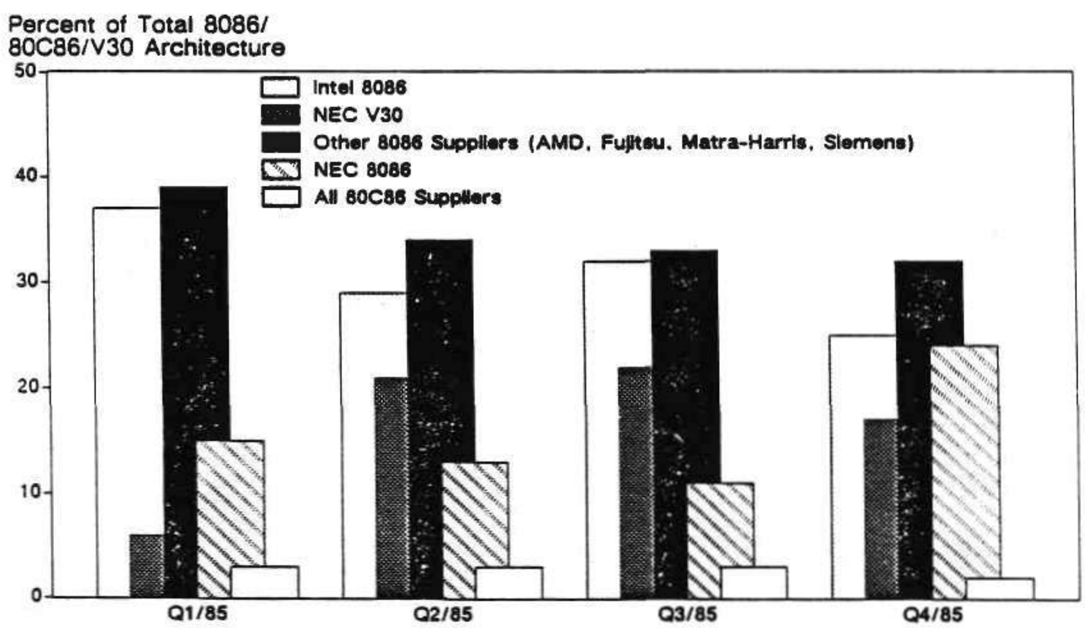


Figure 2

V30 VERSUS 8086/80C86--MARKET SHARE COMPARISON



Source: Dataquest
July 1986

In both figures, supplier revenues are compared with total revenues for V-Series and Intel 8088/8086 MPU architectures. The figures clearly show that throughout 1985, NEC managed to grow market share for its V-Series MPUs without adversely affecting the sales of its own Intel product lines. In fact, in the case of the NEC 8086, market share was increased by fourth quarter 1985 to a level nearly equal to Intel's. The price for V20 gains in 1985 was paid both by Intel and other 8088/80C88 suppliers, while sales of V30 devices primarily affected Intel's 8086 MPU market share.

The steady growth in sales of NEC's V-Series devices has certainly been aided by the existence of a sheltered domestic market, but the V20 and V30 also boast gains in performance over comparable Intel devices, and both NEC microprocessors are fabricated using CMOS technology. Although CMOS versions of the 8088 and 8086 are currently available, shipments of these devices have been lower than the NEC MPUs, as demonstrated by the above figures.

The CMOS Advantage

The move toward CMOS MPUs has clearly established itself. CMOS technology offers systems designers some significant advantages over comparable NMOS devices. To begin with, the lower heat dissipation of CMOS allows high-density circuits to be built with manageable die sizes. In addition, many growing applications require CMOS characteristics, including industrial products that require high noise immunity, tolerance to temperature extremes, low power consumption, and tolerance to voltage variations. Dataquest believes that CMOS MPUs will be a larger market in 1989 than the total 1985 MPU market ($597 million).

The Battleground

The battle for market share between Intel's 8088/8086 and NEC's V20/V30 MPUs may seem moot in light of the technology these devices represent. In 8-bit MPUs, the five devices that have controlled 85 percent of the market (Z80, 8085, 8088, 6802, and 6809) have reached their life cycle peaks. Dataquest believes that while 8-bit MPUs will continue to grow in units and revenue for the remainder of the decade, they will represent an increasingly smaller percentage of total MPU revenue.

Total shipments of 16-bit MPUs have increased nearly tenfold since the end of 1980 and are expected to increase at a compound annual growth rate (CAGR) of 46.6 percent from 1986 through 1991. Dataquest believes that 16-bit microprocessors will maintain more than 50 percent of total MPU revenue until the middle to late 1990s. Four devices controlled 85 percent of the 16-bit MPU market during 1985: the 68000, 80286, 80186, and 8086. NEC's 16-bit entry, the V30, has largely been consumed in Japan.

The real plum that Intel and NEC will be competing for is the more lucrative market for high-integration MPUs. Dataquest believes that there will be a definite market shift to such high-volume/high-integration devices, which will raise the average selling price (ASP) for microprocessors in 1988 and 1989. The greatest market share of the high-integration MPUs has so far gone to Intel's 80186 and 80188 devices. Coming into this market are Signetics' 68070, Hitachi's 64180, NEC's V40/V50, and Zilog's expected Z800. NEC is currently shipping its V40 for sampling, with the V50 having gone into volume production in first quarter 1986.

The Fork in the Road

NEC's marketing strategy does not rely solely on direct competition with pin-compatible/software-compatible Intel MPUs. Beyond the NEC V50 lies the V60, which will compete with the Intel 80286, a high-performance MPU featuring on-chip memory management aimed at multitasking environments. NEC is currently sampling the V60, with volume shipments scheduled third quarter 1986. While similar in function to the 80286, the V60 breaks a precedent set by all previous V-Series products: it is not operationally compatible with its Intel counterpart.

The "fork in the road" that the V60 establishes is aimed at the incipient market for 32-bit MPUs. Once a designer commits to the NEC V60, the upgrade path to a 32-bit MPU can lead only to the V70, which NEC plans to ship sometime next year. Switching to Intel's 32-bit 80386, which is scheduled to be in volume production by the third quarter of 1986, will be difficult and time consuming.

There are two ways that NEC can induce customers to migrate along the V-Series path. One way is to capture design-ins at the high-integration 16-bit level through successful competition with Intel's 80286. Running at 3.5 million instructions per second (MIPS) with a 16-MHz clock, NEC boasts an overall throughput 10 times better than Intel's, with the added advantages of CMOS fabrication. While high performance is a compelling argument, the fact remains that the 80286 is not only here today, but has been shipping since 1983.

NEC's chances of successfully competing for new designs would certainly have been improved had it concentrated on an earlier introduction of the V60, rather than putting its energies into the older technologies represented by the V20 and V30.

Such criticism, however, ignores the second, albeit longer, path to the 32-bit implementation--that of upgrades from 8- and 16-bit devices. Adept at long-range tactics, the Japanese are fully aware that the older 8-bit market alone still has plenty of vitality, particularly if lap-top computers ever take off. If the V-Series can successfully raid the market dominated by the Intel 8088, 8086, 80188, and 80186, then design upgrades must eventually lead customers to the NEC side of the fork in the compatibility road.

THE 32-BIT MPU MARKET OUTLOOK

This line of reasoning assumes, of course, that the industry will see a large-scale evolution of 8- and 16-bit systems to 32-bit MPUs. Some manufacturers believe that market growth for 32-bit MPUs will come as these devices replace minicomputers, rather than as the result of upgrades of 16-bit applications. According to this scenario, future MPUs will have microcoded instruction sets that can emulate minicomputer instruction sets. These devices will have the profound effect on the industry of destroying the distinction between computer companies, thus raising the level of competition.

Dataquest predicts three stages of 32-bit MPU adoption:

- The first stage of utilization will see the replacement of 16-bit devices. This will occur initially with engineering workstations.

- The second stage will see the use of 32-bit MPUs in minicomputers and small business systems.

- The third stage will occur once 32-bit MPUs are well understood and accepted. These devices will then become the basic design elements of many microprocessor-based systems. Rapid growth in consumption of 8- and 16-bit MPUs occurred about five years after they were first introduced. Following the same trend, rapid growth in 32-bit MPUs should occur beginning in 1989.

RAMIFICATIONS OF THE COURT'S RULING

A successful outcome for Intel in the current lawsuit could deprive NEC of a U.S. market in which to exploit its upgradability strategy. In this case, the Japanese beachhead into the U.S. market for 32-bit microprocessors will have to be won through direct competition with the Intel 80286 for new systems designs. Designers may be loath to hop on the V60 bandwagon if they have had no previous experience with the V-Series product line.

While a final ruling may be weeks or months away, the current litigation has already cast a pall over the NEC V-Series. NEC claims that sales have suffered as a result of the suit, and has charged Intel with unfair competition. The controversy surrounding the V-Series will also make second-source availability highly unlikely, although a license to produce the V60 has been granted to Zilog. For now, says NEC, the V60 will probably be limited to the Japanese market, with sales rising to 30,000 units in 1987.

The outcome of the Intel/NEC battle will certainly not decide who will dominate the 32-bit market. Out of an estimated 100,000 units shipped during 1985, Motorola controlled 60 percent of the 32-bit MPU market with an estimated 55,000 units shipped. National Semiconductor shipped an estimated 30,000 units of their 32032 and 32332, and Inmos shipped 5,000 32-bit devices. In its introduction year, AT&T shipped 1,000 units of its 32100, and is selling microprocessors for the first time on the merchant market. Because of its UNIX V expertise, Dataquest believes that the 32100 will be a winner in the future. Motorola's 68020 and National's 32032 will both have initial advantages since many existing workstations have been designed with their 16-bit predecessors. Captive manufacturers such as Data General, Digital Equipment, and Hewlett-Packard could also play a role if they offer devices to the merchant market.

A number of other companies have also thrown their hats into the ring, including Fairchild, Fujitsu, Hitachi, Matsushita, Oki, Sony, Texas Instruments, Toshiba, and Zilog. Many of these will use their designs internally or will second-source other 32-bit MPUs.

The stakes for all players are eminently high. While initial forecasts for numbers of 32-bit MPUs shipped in no way compare with 8- and 16-bit devices, the ASP for 32-bit microprocessors will represent significant revenue for leading manufacturers. Dataquest predicts that market activity will continue to pick up for the 32-bit MPUs and will become significant during the second half of 1986. The expected CAGR for this segment over the next four years is 96.6 percent.

A decision against NEC in the current trial will force the Japanese colossus to try and straddle the 32-bit MPU market on one leg of its marketing strategy--a serious disadvantage. A decision against Intel, on the other hand, will strengthen the position of its most formidable Japanese opponent in the playing field; and if a decision against Intel is reached on the basis of copyright's application to microcode, the legal outcome will surely cause the industry to seriously evaluate the effectiveness of its current means of protecting investments in microcode development.

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RESEARCH NEWSLETTER

SIS Code: 1986-1987 Newsletters: July
1986-25

CELL-BASED ICs IGNITE APPLICATION EXPLOSION

EXECUTIVE SUMMARY

From educational aids such as "Speak and Spell" to Smart Cards, application-specific integrated circuits (ASICs) are transforming our lives. What will be the next IC application? How will it impact our lives? We are accelerating into another era of amazing electronic achievements, and DATAQUEST expects cell-based integrated circuits (CBICs) to play a leading role. System designers require "no compromise" single-chip system solutions. Cell-based ICs, with the aid of silicon compilation, meet this requirement. We foresee silicon compilation as the future design methodology for cell-based ICs. DATAQUEST believes that specialized compilers dedicated to end-use markets will become mainstream products and receive widespread user acceptance.

During 1985, semiconductor suppliers worldwide were formulating plans to capitalize on the high growth rates of the cell-based IC and gate array markets. This newsletter will investigate the issues surrounding the cell-based IC market and how it impacts the gate array market. We will also explore futuristic ASIC design methodologies. Key questions to be addressed in this newsletter include:

- How large are the cell-based IC and gate array markets?
- Why is the gate array market larger than the cell-based IC market?
- What is the relationship between production volumes and gate count for cell-based ICs?
- What is the status of silicon compilation?
- What are some of megacells or circuit functions required for single-chip system solutions?

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- How will the Japanese companies impact the cell-based IC market?

- What will be the dominant design methodology in the 1990s for single-chip system solutions?

DATAQUEST Definitions

DATAQUEST defines the terms commonly used in this newsletter as follows:

- Cell-based ICs (CBICs): Digital or mixed linear/digital integrated circuits that are customized using a full set of masks and that comprise precharacterized cells or macros (includes standard cells, megacells, and compilable cells)

  The term "cell-based IC" is an outgrowth of "standard cells." Historically, IC cells had fixed heights and fixed widths and thus were called standard cells. Today's cell-based ICs have variable heights and variable widths, allowing for added dimensional flexibility far beyond that of "fixed" cells. The term "cell-based design" (CBD) is used to describe the methodology used to design cell-based ICs.

- Gate arrays: Digital or linear/digital integrated circuits containing a configuration of uncommitted elements. They are customized by interconnecting these elements with one or more routing layers

- Silicon compilers: A general term that applies to very sophisticated integrated circuit computer-aided design (IC CAD) systems employing a top-down, hierarchical design methodology that accepts high-level specifications and automatically generates the mask tooling. Included in this term are specialized IC CAD systems that work at the cell level

- Intracompany revenue: When an IC manufacturer sells a product line to both the merchant and captive markets, the revenue associated with the captive (internal) consumption is called intracompany revenue. The revenue from sales to outside companies is called merchant revenue. We do not count exclusively captive suppliers such as IBM or Hewlett-Packard

- NRE revenue: Nonrecurring engineering revenue, or simply the revenue associated with developing a device

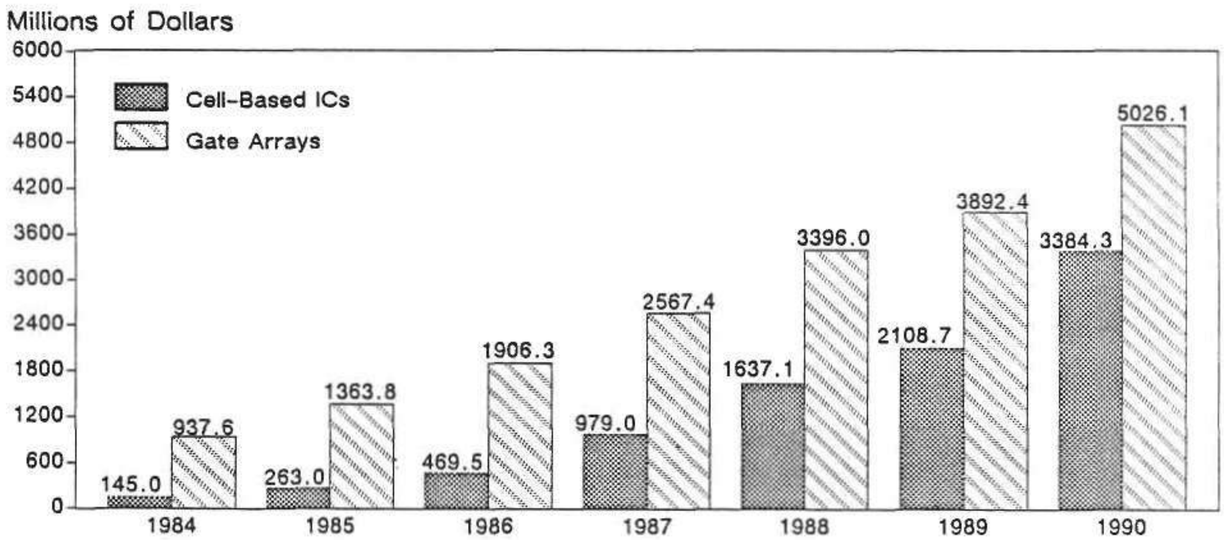
- Shipment revenue: DATAQUEST shipment revenue equals the estimated production revenue plus the intracompany revenue plus the NRE revenue. (Note: we count only processed wafers with interconnect layers, not blank wafer sales, since this would lead to double counting)

HOW LARGE ARE THE CELL-BASED IC AND GATE ARRAY MARKETS?

Figure 1 compares the estimated growth of the cell-based IC and gate array markets. The 1985 gate array market is more than five times larger than the cell-based IC market. However, the compound annual growth rate (CAGR) from 1985 through 1990 for cell-based ICs is 66.7 percent compared with 29.8 percent for gate arrays. The 1989 and 1990 cell-based IC shipment revenues are dependent on the success of silicon compilation.

Figure 1

ESTIMATED WORLDWIDE CBICs AND GATE ARRAYS



Source: Dataquest
July 1986

Table 1 contrasts rankings, revenue, and growth rates of the top five cell-based IC suppliers with those of the top five gate array suppliers in 1984 and 1985. It is interesting to note that the number one cell-based IC supplier had less revenue than the number five gate array supplier.

Table 1

WORLDWIDE ESTIMATES
TOP FIVE CBIC AND GATE ARRAY SUPPLIERS
(Millions of Dollars)

1985 Ranking	Cell-based ICs	1984	1985	Growth (1984-1985)
1	NCR	$35.0	$ 48.0	37%
2	VTI	16.0	38.2	139%
3	Gould Semi.	9.0	30.0	233%
4	TI	8.0	25.0	212%
5	Zymos	22.0	17.3	(21%)
	Total	$90.0	$158.5	76%
	Gate Arrays			
1	Fujitsu	$188.6	$257.6	37%
2	LSI Logic	84.5	140.0	66%
3	Motorola	40.4	91.2	126%
4	Fairchild	47.0	60.2	28%
5	NEC	41.1	57.9	41%
	Total	$401.6	$606.9	51%

Source: DATAQUEST
July 1986

Why Is the Gate Array Market Larger?

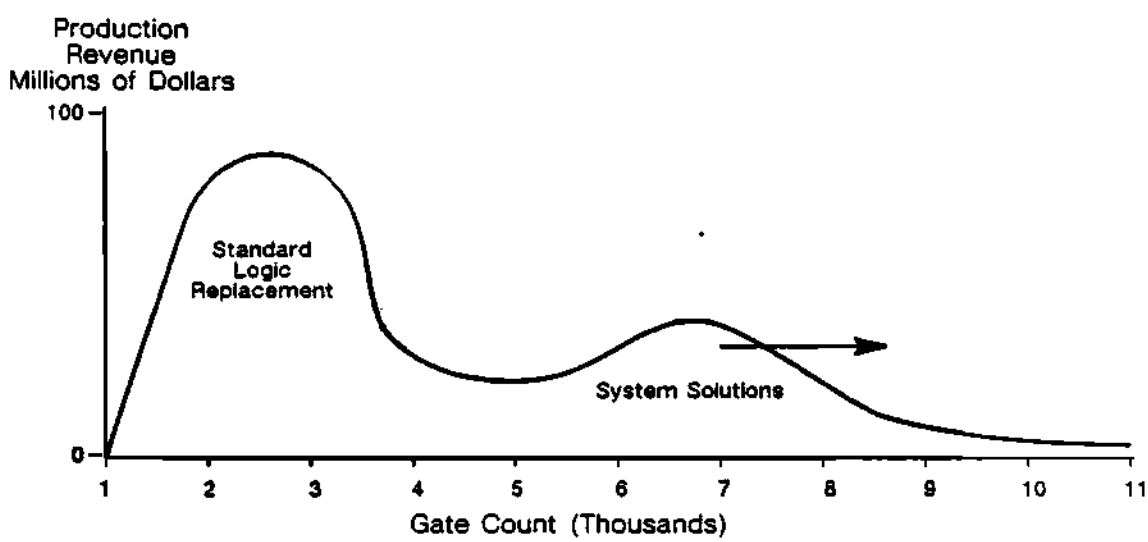
The following factors have contributed to this condition:

- Gate arrays are cost effective for replacement of standard logic.
- Gate array pricing has sharply declined over the last two years.
- Cell-based IC NRE is inherently more expensive than NRE for gate arrays.
- Gate array software is user friendly and well accepted.
- Gate array turnaround times are shorter.

We will first analyze the consumption of CMOS gate arrays. Figure 2 shows that the majority of revenue in CMOS gate arrays is derived from devices with less than 2,500 gates. This revenue is driven by gate arrays replacing standard logic. Gate arrays are cost effective for sweeping up numerous standard logic functions onto a single chip. There are many gate array applications for replacement of standard logic that only require low gate count devices.

Figure 2

ESTIMATED 1985 CMOS GATE ARRAY PRODUCTION (REVENUE BY GATE COUNT)



Source: Dataquest July 1986

DATAQUEST is currently tracking 67 CMOS gate array suppliers that all offer these low gate count devices shown in Figure 2. This large number of suppliers with comparable products has caused serious price erosions. The most popular gate array (CMOS, 2,000 gates, plastic package, in quantities of 5,000 to 10,000), took a sharp price-per-gate drop from between $0.010 and $0.012 in 1984, to between $0.002 and $0.004 in 1985. This decline in pricing has increased the cost effectiveness of gate arrays at the expense of cell-based ICs.

Nonrecurring engineering charges for cell-based ICs are inherently more expensive than those for gate arrays. Since cell-based ICs are customized using a full set of masks, average NRE charges range from $60,000 to $250,000 (this includes 12 to 14 masks at $4,000 to $6,000 per mask plus computer time). Gate arrays are customized using only the final layers for interconnect, so the NRE charges are much less ($20,000 to $80,000). In addition to lower NRE charges, most IC designers have found gate array software easy to use and a good way to get started in ASICs.

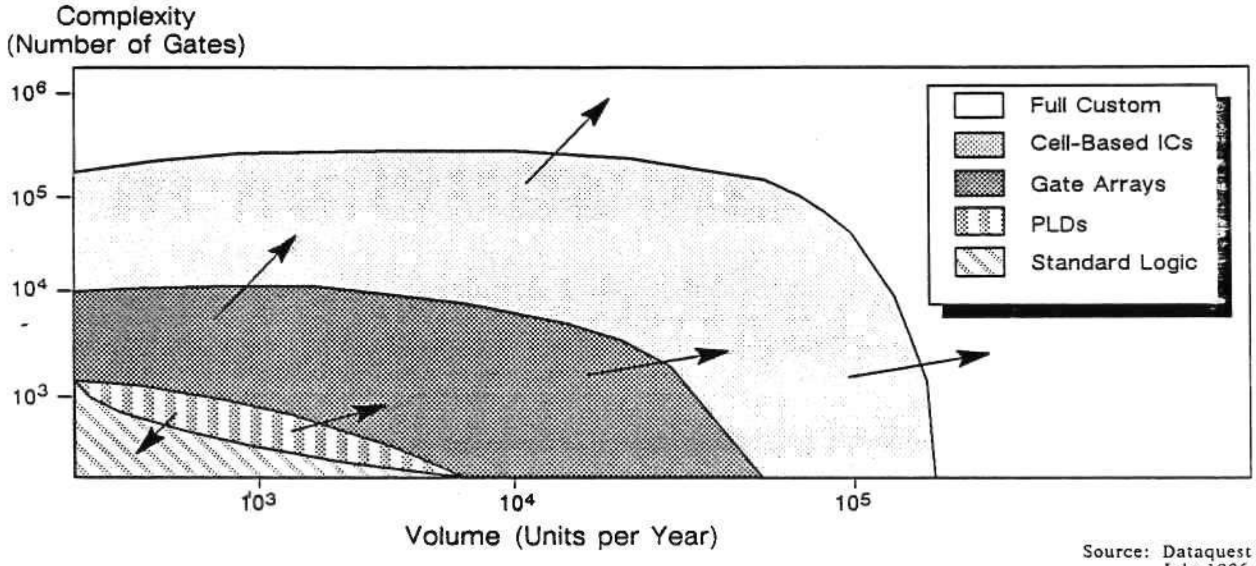
Turnaround times from postschematic capture to delivery of prototypes are also longer for cell-based ICs. Average turnaround times for cell-based ICs range from 10 to 12 weeks, compared with 6 to 8 weeks for gate arrays. Some gate array suppliers are quoting turnaround times as short as 2 weeks or less (see the DATAQUEST Research Newsletter "The Quick ASIC: Tomorrow's Prototyping Tool" dated March 28, 1986). Quick turn-around times are increasing in importance.

What Is the Relationship Between Production Volumes and Gate Count for CBICs?

The preceding gate array advantages (competitive pricing, low NRE charges, user-friendly software, fast turnaround times) have pushed CBIC suppliers to compete with higher gate count devices and in higher production volumes. In the early 1980s, ASIC users used CBICs rather than gate arrays when production volumes reached 8,000 to 10,000 units a year, with little concern for the gate count of the device. Today, the crossover point is very dependent on gate count and device functionality. If unit production volumes are less than 15,000 units a year, gate arrays will capture the business unless the device has a high gate count and the CBIC supplier can offer increased functionality. Figure 3 shows the current relationship between unit volumes and gate count for each of the ASIC design methodologies.

Figure 3

ESTIMATED 1985 ASIC PRODUCTION VOLUME
(UNITS BY GATE COUNT)



Source: Dataquest
July 1986

WHAT IS THE STATUS OF SILICON COMPILATION?

Silicon compilation is getting slow user acceptance. Silicon compilers are in the "early adopter" stage. DATAQUEST estimates that 99 turnkey silicon compiler systems were sold in 1985 compared with 12 in 1984. Successful designs are now being captured from these systems. However, the future of the CBIC market is dependent on widespread user acceptance of silicon compilers. DATAQUEST in not anticipating widespread user acceptance until the 1989 to 1990 time frame. During the next three years, we expect to see a growing cadre of users.

IC suppliers, silicon compiler companies, and workstation vendors are all trying to position themselves for long-term lucrative growth. Each player is currently experimenting with a variety of silicon compiler products and marketing strategies. Current silicon compiler products include turnkey systems, cell compiler generators, and software packages that include libraries with compilable cells. These products are being sold to a wide variety of users in different target markets. Key target markets include original equipment manufacturers (OEMs), IC suppliers, military users, and design centers.

What is apparent today is the trend for specialized compilable cells. IC suppliers are now offering compilable cells in their cell libraries. Compilable cells start with a standardized functional block or a standard product, such as a multiplier-accumulator, and then are altered by the user by inputting the desired cell specifications. These compiled cells are combined with standard cells and megacells to form libraries optimized for a specific end-use market.

LSI Logic, the leading MOS gate array supplier, is one of the first IC suppliers to market a compiler system (MACGEN) with a specialized cell library dedicated for a specific end-use market (digital signal processing). The MACGEN generates complex megacells with functions such as multiplier-accumulators (MACs), multipliers, and adders. These megacells combined with compiler technology provide the DSP IC designer with new device functions and reduced design times. We believe that this is just the beginning and that other IC suppliers will follow suit with end-use cell libraries.

WHAT CIRCUIT FUNCTIONS ARE REQUIRED FOR SINGLE-CHIP SYSTEM SOLUTIONS?

The end users will ultimately determine the functions required in the cell libraries. Most CBIC suppliers are analyzing the needs of the end-use markets (mainly the computer and telecom markets) and are offering the following types of cells:

- Microprocessors
- Memory blocks
- Linear/digital
- Compilable standard products

As sub-2-micron technologies emerge, these cells will reduce the part count and power consumption, improve reliability, and ultimately lower costs while improving performance.

- Microprocessor cells are some of the most important cells in designing systems for computer products. Most IC suppliers are building libraries that incorporate a version of Advanced Micro Device's 2901 bit-slice processor. The 2901 is popular because of its flexible architecture, small cell size, and fast speed. Other suppliers are implementing general-purpose microprocessors in cells such as the 6502, 80C49, 80C51, and the Z80. Today, microprocessors larger than eight bits are considered too complex for implementation as cells. This is not to say that you cannot design in a standard microprocessor with more than eight bits. However, most suppliers have simply found it uneconomical. Suppliers have found the most economical way to achieve 16- and 32-bit core processors is by stacking 2901s.

- Memory cells are the type of cell that most vendors have in common. Most all CBIC suppliers offer RAM and ROM in a variety of configurations. Some of the suppliers have also announced EPROM and EEPROM cells. For example, Sierra Semiconductor and NCR have both announced EEPROM cells. Other suppliers are expected to emerge with EEPROM cells that can be used in telecommunications circuits, smart cards, analog-to-digital converters, and voltage regulators.

- Linear cells in combination with digital cells on a single chip are popular for digital signal processing (DSP) applications. Linear cells are surfacing in both CMOS and bipolar libraries. Common linear cells include digital-to-analog converters, operational amplifiers, wideband amplifiers, and voltage comparators.

- CBIC suppliers will round out their libraries with compilable standard products. Most people think that companies such as AMD, Intel, Motorola, and National would have an advantage in this area over current CBIC suppliers because of their broad standard product lines. However, customizing these standard products to the end users' specifications requires very sophisticated CAD tools (cell compilers). Few companies currently offer compilable cells. VLSI Technology Inc. (VTI), the number two CBIC supplier, is a leader in this area. VTI's compilable cells include comparators, counters, flip-flops, multiplexers, PLAs, registers, ROMs, and RAMs. We expect other companies to follow this strategy as the market matures.

HOW WILL THE JAPANESE COMPANIES IMPACT THE CELL-BASED IC MARKET?

During 1985, Fujitsu, NEC, and Toshiba entered the North American CBIC market. It almost goes without saying that most domestic suppliers are paying close attention to their progress after what has happened in the memory market. Historically, large, vertically integrated Japanese companies develop products for internal consumption, move down the learning curve, then offer the device to the merchant market at a reduced price. This was the strategy for memory products and gate arrays. Their advanced memory technology drives their technology in gate arrays and CBIC. Fujitsu, NEC, and Toshiba all offer products that incorporate advanced technology.

During October 1985, Fujitsu announced its 1.8-micron CMOS standard cell family, which produces gate delays typically averaging 1.2 to 1.4 nanoseconds. This family includes automatic place and route with user configuration RAM, ROM, and PLA. Fujitsu's compacted standard cells include macros that are logically equivalent to 4-bit micros (2901), USARTS (8251), internal timers (8254), and 12-bit microprogrammable controllers (2910).

NEC unveiled its standard cell family, which incorporates 1.5-micron CMOS technology. The family includes 130 megacells and can achieve densities up to 17,000 gates.

Toshiba announced a 2-micron CMOS standard cell family with RAM and ROM macros. The family includes approximately 200 megacells, and can achieve device complexities up to 10,000 gates.

Technology is important, but the ASIC market is not driven by technology alone. How will the Japanese companies manage the following important issues?

- Software
- Short production runs
- Service

Today, Japanese companies are known for their production capabilities and not for their software. The merchant market is composed of a wide variety of users' needs and hardware configurations. Developing software that can meet the needs of the diverse merchant market is both costly and time consuming. How will the Japanese companies obtain silicon compiler technology? DATAQUEST believes that they will form alliances with domestic IC CAD companies.

The Japanese companies will also have to adjust to short production runs rather than the high-volume runs that they now dominate. This will require a change in production equipment and production control systems.

Service is one of the most important factors in marketing ASICs. Will Japanese companies be ready with design/support centers where customers can get the technical guidance they require? The cell-based IC market has a wide variety of users with a wide variety of needs which must be attended to in order to capture and maintain business in North America.

WHAT WILL BE THE DOMINANT SINGLE-CHIP SYSTEM DESIGN METHODOLOGY IN THE 1990s?

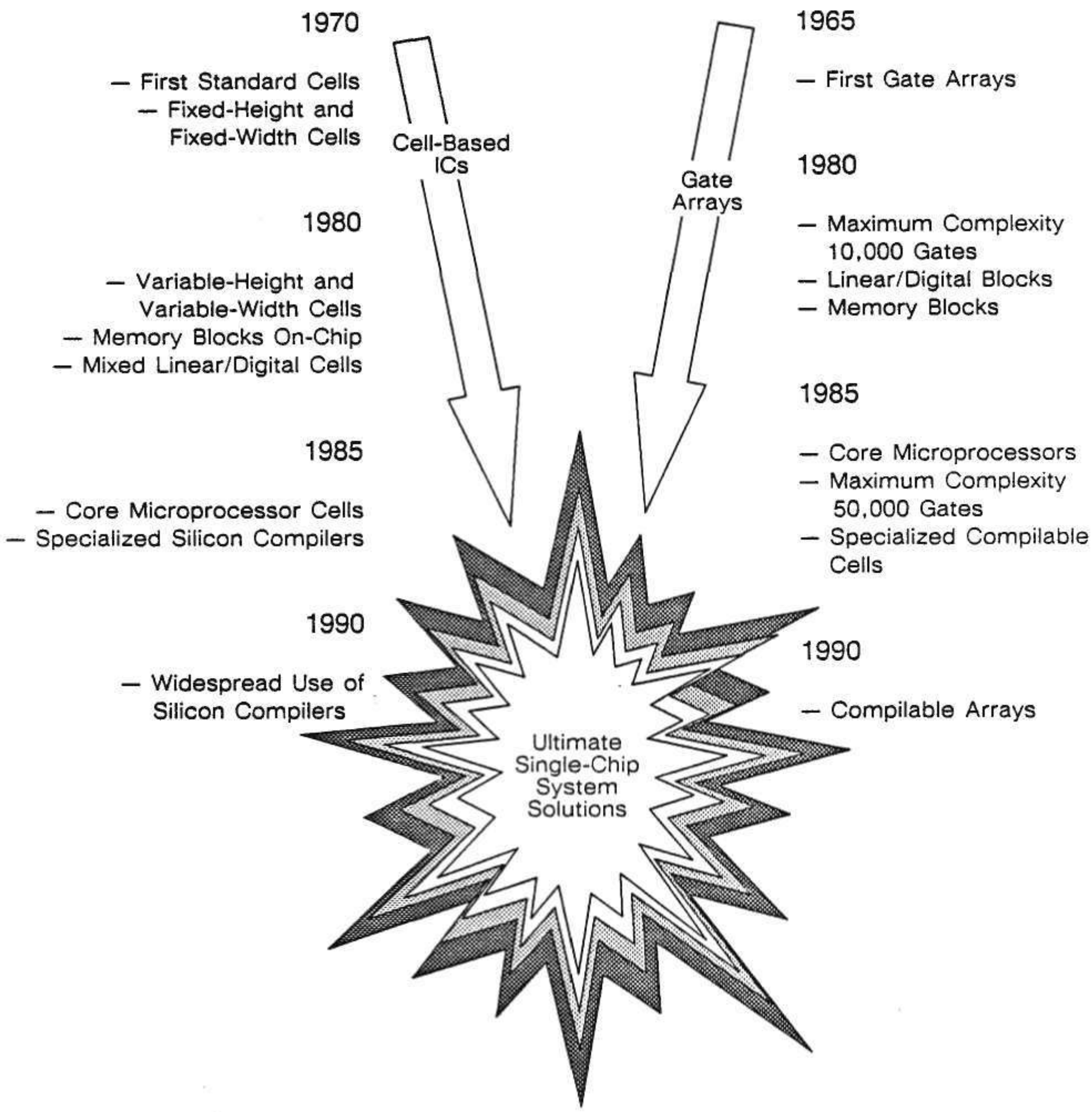
DATAQUEST believes that cell-based ICs will dominate in the 1990s for high-volume applications as well as for applications that require large systems on a chip. However, silicon compilers must get widespread acceptance over the next four years for the CBIC market to reach its potential.

Let's look at the race for the ultimate single-chip system solution. Figure 4 shows the migration path of gate arrays and CBICs on their way to the ultimate single-chip system solution. Keep in mind that gate arrays are customized by the final layers for interconnect while CBICs require a full set of masks.

From a historical perspective, CBICs started with fixed-height and fixed-width cells in the late 1970s and early 1980s, and moved to variable-height and variable-width cells by the mid-1980s. Memory blocks were brought on-chip in 1982, linear/digital in 1984, and core micros in 1985. Silicon compilers started to emerge in the merchant market in 1984.

Figure 4

THE RACE FOR SINGLE-CHIP SYSTEM SOLUTIONS



Source: Dataquest
July 1986

Gate arrays started in the early 1970s. Most gate arrays were used for replacement of standard logic until the early 1980s, when high gate count arrays emerged and made systems on a chip practical. Memory blocks were brought on-chip in 1984. Linear/digital functions were brought on-chip in the early 1980s. Core micros (2901s) emerged in 1985. Gate densities up to 50,000 gates became possible in 1986.

Both design methodologies will ultimately look very similar. Both will offer complex cells, and both will be a solution to single-chip systems. We believe that it will be difficult to tell a CBIC product from a gate array product by the early 1990s. Perhaps it will only be of historical interest how these products evolved.

How Can Semiconductor Suppliers Prepare for Future ASICs?

Suppliers can prepare for future ASICs by:

- Anticipating end-use application
- Exploiting the state of IC CAD tools
- Building cell libraries with the end users in mind
- Providing outstanding service

We expect an IC application explosion to occur over the next three years. Today, device complexity and functionality are far ahead of the designers' abilities to find applications. (For example, what are the applications for a 50,000-gate array?) IC suppliers will not only be selling ICs, they will also be selling insight on applications. We believe that anticipating these future applications and directing the use of IC CAD tools and ASIC products in the end-use markets will be critical success factors.

IC suppliers must exploit the state-of-the-art design tools from the leading IC suppliers and IC CAD vendors. We consider these tools to be vital elements in the design of single-chip systems. The supplier who offers user-friendly integrated design tools directed at end-use applications will win. Today, those tools are widely dispersed and only a few companies have taken steps to link them together to form integrated design systems. How these tools are brought together and made available to the design community is very important. This leads us to conclude that the companies that want integrated IC CAD systems will need to develop or acquire all of the key elements. The right alliances between compiler companies and ASIC manufactures can make the difference between the leaders and the followers.

Building cell libraries that are intended for end-use markets is key. The cell library should bring new specialized functions to a particular market segment. Forming alliances or trading cells will help companies cut the cost of building cell libraries as well as position them to exploit end-use markets.

Service is of critical importance in marketing ASIC products. Providing first-rate service really means two things. First, it means staffing design centers with personnel who are knowledgeable on system solutions as well as on specific end-use markets. Second, it means providing the fastest possible turnaround time during development and prototyping. We believe that the stronger suppliers will invest heavily in resources to provide short turnaround times.

End users' needs and IC applications are driving the cell-based IC market. Probing the end users for possible future IC applications is critical. DATAQUEST believes that the cell-based IC application explosion is creating a wealth of opportunity for both suppliers and users.

Bryan Lewis
Andy Prophet

August

August Newsletters

The following is a list of the newsletters in this section:

Dataquest
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RESEARCH NEWSLETTER

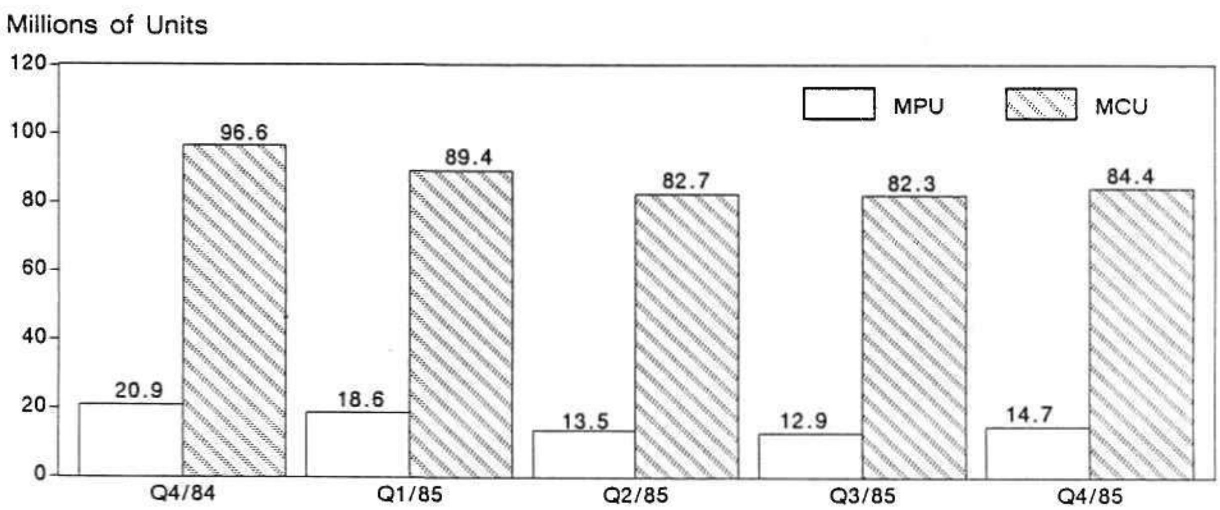
SIS Code: 1986-1987 Newsletters: August
1986-32

FOURTH QUARTER 1985 MICROPROCESSOR AND MICROCONTROLLER UNIT SHIPMENT UPDATE

During the fourth quarter of 1985, worldwide microprocessor and microcontroller unit shipments increased by approximately 4 million units or 4.2 percent from third quarter 1985. Estimated shipments of all microcontroller devices totaled approximately 84.4 million units. Shipments of both 4-bit MCUs and 8-bit MCUs increased slightly. Estimated shipments of all microprocessor devices totaled approximately 14.7 million units. Shipments of 8-bit MPUs and 16-bit MPUs increased in the fourth quarter by 13 percent and 22 percent, respectively, over the prior quarter's shipments. Figure 1 shows MCU and MPU unit shipments from the fourth quarter of 1984 through the fourth quarter of 1985.

Figure 1

**MICROCONTROLLER AND MICROPROCESSOR UNIT SHIPMENTS
FOURTH QUARTER 1984 THROUGH FOURTH QUARTER 1985**



Source: Dataquest
August 1986

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Table 1 shows the quarterly revenue for microcontrollers and microprocessors from the fourth quarter 1984 through the fourth quarter 1985.

Table 1

TOTAL MICROCONTROLLER AND MICROPROCESSOR REVENUE
FOURTH QUARTER 1984 THROUGH FOURTH QUARTER 1985
(Millions of Dollars)

	Q4/84	Q1/85	Q2/85	Q3/85	Q4/85
MCU	$372.2	$293.9	$255.6	$260.0	$300.4
MPU	169.9	131.0	102.0	96.0	104.8
Total	$542.1	$424.9	$357.6	$356.0	$405.2

Source: Dataquest
August 1986

Table 2 shows the change in total microcontroller unit shipments from the third quarter of 1985 through the fourth quarter of 1985.

Table 2

TOTAL MICROCONTROLLER UNIT SHIPMENTS
THIRD QUARTER 1985 THROUGH FOURTH QUARTER 1985
(Thousands of Units)

	Q3/1985		Q4/1985		Percent
MCU	Units	Percent of Shipments	Units	Percent of Shipments	Growth Q3 to Q4
4-Bit	44,187	53.7%	45,635	54.0%	3.3%
8-Bit	38,060	46.2	38,726	45.9	1.7%
16-Bit	56	0.1	71	0.1	26.8%
Total	82,303	100.0%	84,432	100.0%	2.6%

Source: Dataquest
August 1986

Table 3 shows the change in total microprocessor unit shipments from the third quarter of 1985 through the fourth quarter of 1985.

Table 3

TOTAL MICROPROCESSOR UNIT SHIPMENTS
THIRD QUARTER 1985 THROUGH FOURTH QUARTER 1985
(Thousands of Units)

	Q3/1985		Q4/1985		Percent
MPU	Units	Percent of Shipments	Units	Percent of Shipments	Growth Q3 to Q4
8-Bit	11,018	85.7%	12,434	84.6%	12.9%
16-Bit	1,804	14.0	2,199	15.0	21.9%
Others	37	0.3	52	0.4	40.5%
Total	12,859	100.0%	14,685	100.0%	14.2%

Source: Dataquest
August 1986

Table 4 shows the change in the shipments of the leading 8-bit MPUs from the third quarter of 1985 through the fourth quarter of 1985.

Table 4

LEADING 8-BIT MICROPROCESSOR SHIPMENTS
THIRD QUARTER 1985 THROUGH FOURTH QUARTER 1985
(Thousands of Units)

	Q3/1985		Q4/1985		Percent
Device	Units	Percent of Shipments	Units	Percent of Shipments	Growth Q3 to Q4
Z80	4,085	37.1%	4,988	40.1%	22.1%
8085	2,616	23.7	3,200	25.7	22.3%
6802	903	8.2	979	7.9	8.4%
8088	817	7.4	865	7.0	5.9%
6809	638	5.8	680	5.5	6.6%
Others	1,959	17.8	1,722	13.8	(12.1%)
Total	11,018	100.0%	12,434	100.0%	12.9%

Source: Dataquest
August 1986

Table 5 shows the changes in estimated shipments of 16-bit microprocessors from the third quarter of 1985 through the fourth quarter of 1985.

Table 5

16-BIT MICROPROCESSOR SHIPMENTS
THIRD QUARTER 1985 THROUGH FOURTH QUARTER 1985
(Thousands of Units)

	Q3/1985		Q4/1985		Percent
Device	Units	Percent of Shipments	Units	Percent of Shipments	Growth Q3 to Q4
68000	438	24.3%	618	28.1%	41.1%
8086	431	23.9	599	27.2	39.0%
80286	405	22.5	410	18.6	1.2%
80186	210	11.6	228	10.4	8.6%
V30	120	6.7	130	5.9	8.3%
Z8000	89	4.9	85	3.9	(5.0%)
32016	71	3.9	75	3.4	5.6%
Others	40	2.2	54	2.5	35.0%
Total	1,804	100.0%	2,199	100.0%	21.9%

Source: Dataquest
August 1986

Table 6 shows the changes in estimated shipments of 8-bit microcontrollers from the third quarter of 1985 through the fourth quarter of 1985.

Table 6

8-BIT MICROCONTROLLER SHIPMENTS
THIRD QUARTER 1985 THROUGH FOURTH QUARTER 1985
(Thousands of Units)

	Q3/1985		Q4/1985		Percent
Device	Units	Percent of Shipments	Units	Percent of Shipments	Growth Q3 to Q4
6805	5,505	14.5%	6,776	17.5%	23.1%
8049	6,520	17.1	5,902	15.2	(9.5%)
8051	3,931	10.3	3,930	10.2	-
8048	4,241	11.1	3,280	8.5	(22.7%)
Others	17,863	47.0	18,838	48.6	5.5%
Total	38,060	100.0%	38,726	100.0%	1.7%

Source: Dataquest
August 1986

Table 7 shows market share by technology for 8-bit microcontroller and microprocessor devices from the fourth quarter of 1984 through the fourth quarter of 1985, and indicates increased shipments of 8-bit CMOS microcontrollers and microprocessors.

During fourth quarter 1985, approximately 78 percent of all 8-bit CMOS MCU shipments and approximately 64 percent of all 8-bit CMOS MPU shipments were Japanese manufactured and shipped.

Table 7

MARKET SHARE BY TECHNOLOGY FOR MICROCONTROLLERS AND MICROPROCESSORS
FOURTH QUARTER 1984 THROUGH FOURTH QUARTER 1985

Device	Tech.	Q4/84	Q1/85	Q2/85	Q3/85	Q4/85
8-Bit MCU	CMOS	15.3%	16.9%	20.4%	20.4%	21.7%
8-Bit MCU	NMOS	84.7	83.1	79.6	79.6	78.3
Total		100.0%	100.0%	100.0%	100.0%	100.0%
8-Bit MPU	CMOS	11.6%	12.0%	15.2%	17.2%	19.3%
8-Bit MPU	NMOS	88.4	88.0	84.8	82.8	80.7
Total		100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest
August 1986

DATAQUEST ANALYSIS

Dataquest estimates that revenue from microprocessor and microcontroller shipments for fourth quarter 1985 was $405.2 million, an increase of approximately 13.8 percent from the previous quarter. MPU/MCU shipments revenue totaled $1,543.7 million for 1985, which represents a decrease of 23 percent from 1984 MPU/MCU shipments revenue.

Patricia Galligan

September

September Newsletters

The following is a list of the newsletters in this section:

Dataquest
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RESEARCH BULLETIN

SIS Code: 1986-1987 Newsletters: September
1986-41

THE NEC/INTEL TRIAL: THE INDUSTRY WINS A VICTORY--OR DOES IT?

On Monday, September 22, 1986, U.S. District Court Justice William Ingram handed down the first court decision to come out of the NEC/Intel copyright lawsuit. In what has been hailed a landmark event in the protection of intellectual property, Judge Ingram declared that Intel possessed "good, valid, and existing copyrights on its 8086/8088 microcode."

Of greater significance to the semiconductor industry as a whole, and to manufacturers of microdevices in particular, is the court's stated position on the legal nature of that form of intellectual property known as microcode--the implementation of macroinstruction sets in silicon. In accordance with the 1980 amendment to the Copyright Act, which extends protection to computer software, Judge Ingram's decision included the following observations:

- "The loading of an 8086 program into a ROM is accomplished in the same manner as would attend upon the loading of an application program into a ROM."
- "The methodology employed in the creation of microcode is to the court indistinguishable from that employed in the creation of any computer program."

From Intel's point of view, Judge Ingram's decision marks a resounding victory in the war to protect intellectual property. Regardless of the outcome of its infringement suit over the use of 8088/8086 microcode in NEC's V-Series microprocessors (the V-20 through V-50), Intel maintains that the industry may now rest secure that its investments in microcode development are protected, in the words of its General Counsel, against the "predatory practice of copying."

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It is Dataquest's position, however, that 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. In reaching a decision, the court will likely establish a criterion for infringement. This criterion will prove more crucial to the industry than the acknowledgment alone that copyright is applicable to microcode. However, such a decision may still be several months away.

To the semiconductor industry, the court's initial decision comes more as a confirmation than a revelation. Since the 1980 amendment to the Copyright Act and the passage four years later of the Semiconductor Chip Protection Act (SCPA), the semiconductor industry has operated under the assumption that microcode is copyrightable. The landmark nature of Judge Ingram's announcement is that it represents the first real test of this assumption in a court of law.

In the short term, the U.S. District Court's decision makes it unlikely that a microdevice manufacturer will produce a product that is software compatible and pin compatible with a competitor's product without first negotiating a license for that code. Assessment of the long-term effects of the decision await Judge Ingram's verdict on Intel's infringement claims against NEC. Looking at both ends of the possibility spectrum, Dataquest concludes the following:

- 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.

- If the infringement criterion is more loosely interpreted, any degree of similarity, whether the result of plagiarism or independent development, could be enough to constitute an infringement. Such a precedent would give copyright holders much greater influence in their markets through more effective control of alternate sources. With regard to the NEC/Intel trial, Intel would be more likely to win an injunction against the shipment of V-Series microprocessors into the United States, and/or the payment of royalties by NEC for V-Series devices sold.

Michael Boss

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RESEARCH NEWSLETTER

SIS Code: 1986-1987 Newsletters: September
1986-40

PUTTING OUT A FIRE WITH GASOLINE? THE SEMICONDUCTOR INDUSTRY LOOKS AT TAX REFORM

SUMMARY

With the passage of the tax reform bill, Congress will introduce the most significant change in the federal income tax structure since its inauguration in 1913. Once passed, the bill's most important immediate impact will be to end more than a year of uncertainty affecting the financial decisions of businesses and individuals--uncertainty that has been an added drag on domestic investment.

In this newsletter, Dataquest reviews the significance of the tax bill, its broad effects on the business sector, and, more specifically, its effects on the semiconductor industry. In gauging the bill's impact on semiconductor firms, Dataquest has reached a consensus of opinion among its semiconductor clients on the following key points:

- Contrary to initial press coverage, the semiconductor industry will not decrease capital spending as a result of the repeal of investment tax credits.
- Computer equipment manufacturers, who make up the largest end market for semiconductor devices, do not see the new tax bill adversely affecting their business in any significant way.
- The tax bill provides one more reason for semiconductor firms, and manufacturers in general, to make capital goods investments off shore.

EFFECTS AND SIGNIFICANCE

The new bill reverses a trend of nearly four decades during which business has taken on an increasingly smaller share of the federal tax burden. This share diminished from a high of 34 percent in the early

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1950s, to 8.4 percent in 1985. As a result of the tax reform, business contributions should now increase to about 13 percent of collected tax revenue. In addition, tax shelters, which have historically favored high-income earners, will be abolished. By 1988, the bill will also have eliminated a complex schedule of 15 tax rates on individual incomes, which range from 11 percent to 50 percent, replacing it with 2: 15 percent and 28 percent.

Over the next five years, the tax bill's framers hope to add an additional $122 billion to the pockets of U.S. consumers. While the maximum corporate tax rate will drop from 46 percent to 34 percent, business will, nonetheless, pay for the government's largesse to consumers through the elimination of cherished tax credits and the imposition of a minimum tax applied to all corporations. Businesses will feel the effects of the bill most keenly in the following areas:

- Investment tax credit--Companies will lose the 6 percent to 10 percent tax credit for their investments in capital goods. In addition, the repeal of the investment tax credit is retroactive to January 1, 1986. To further aggravate the situation, companies will only be able to apply 65 percent of unused investment tax credits to offset a maximum of 25 percent of their tax liability.

- Minimum tax rate--Tales of corporations paying less in taxes than some of their employees should become the stuff of future lore. All businesses will now be subject to a minimum tax rate of 20 percent. According to the new tax bill, not even the inability to turn a profit will keep companies beyond the long arm of the IRS. With the passage of the bill, net operating losses will only be able to offset 90 percent of minimum taxable income, rather than the 100 percent allowed under current tax law.

- Rate of depreciation--Companies may face a reduction of their depreciation allowances for capital goods, depending on how they file. According to Robert Perlman, director of tax and customs for Intel Corp., filing under the minimum tax provisions could result in a lower depreciation allowance due to differences in the method of calculation.

- Capital gains--Capital gains will no longer be given preferential treatment, but will be taxed at the same rate as regular income. This is expected to shrink available capital for investment in start-up businesses.

- R&D tax credit--Finally, some good news. The tax credit on research and development expenditures, which was to have expired at the end of 1985, has now been granted an additional three-year lease on life. The bad news is that the maximum credit allowed has been reduced from 25 percent to 20 percent, based on R&D costs that exceed average spending for the previous three years.

Overall, the Darwinian effect of the above changes suggests that somehow, capital-intensive companies are not as important as service companies in the eyes of Capitol Hill. Clearly, the companies that stand to benefit most from the tax bill are those that do not invest heavily in plant and equipment, and those whose profitability makes the lowering of the corporate tax rate more advantageous than the tax benefits that they lose. A maximum corporate rate of 34 percent is of little solace to ailing smokestack industries, although the bill's effects on steel producers will be mitigated by sizable "transition" payments to be made by the government over the next year.

Also bearing the brunt of tax reform are banking and real estate firms. While the banking industry may not share General Motor's concern over investment tax credits, banks face the loss of their deductions for bad debt reserves, which could cost them an estimated $4 billion in higher taxes over the next four years. This will no doubt force banks to foreclose more quickly on bad debt accounts in order to take a write-off. The banking industry could be helped, however, by the increased taxes on capital gains and the elimination of tax shelters, which may divert investors from the stock market to bank instruments. On the other side of this coin, America's $68 billion-a-year real estate industry will see a sharp drop in investments due to the elimination of tax shelter partnerships.

Effects on the Semiconductor Industry

Initial press reactions to the new bill have tended to exaggerate its effects on capital spending in the semiconductor industry. The realities of the tax bill do not alter the imperatives of the semiconductor business. In what remains a technology-driven industry, decisions to invest in new products and processes, and in the capital equipment that makes them possible, are not ruled by tax considerations. As a result, none of the semiconductor manufacturing clients surveyed by Dataquest have any intention of altering their capital spending plans. In the semiconductor industry, capital investment decisions are ruled by capacity, product and technology innovation, and manufacturing competitiveness. For the near future, any dampening of capital spending will have more to do with over-capacity and eroded profit margins than with the repeal of the investment tax credit.

For now, the bottom-line effect of investment tax credit repeal is a somewhat moot issue with the semiconductor industry, since the bottom line is red to begin with. During the two difficult years that the industry has been going through, however, this lack of profitability has resulted in the buildup of carry-over investment tax credits. National Semiconductor, for example, estimates its accumulated carry-over at between $40 million and $50 million. Over time, the 35 percent reduction in carry-over credit will cost the semiconductor industry an estimated $300 million.

Start-up semiconductor firms will find initial funding to be more difficult to come by under the new tax bill. By taxing capital gains at the same rate as regular income, venture capitalists may have difficulty in attracting investors to any but the safest investment avenues. To appreciate the possible impact this will have on funding, consider the effects of the 1978 reduction in the capital gains rate, which led to a boom in capital investment. In that year, only $216 million in venture capital was invested. In the seven years following the capital gains rate reduction, $12 billion was invested, for an average annual rate of $1.7 billion. When the new tax goes into effect, in addition to seeing the venture capital pool shrink, start-up companies may find themselves sending a check to the IRS under the minimum 20 percent tax requirement of the new bill, despite operating losses.

Fortunately, the new tax bill provides semiconductor companies with an additional incentive to invest in research and development. Tax credits for R&D, which were to have come to an end in 1985, have been preserved for three more years. In order to utilize these credits, a company will have to show R&D expenses that are higher than the average for the previous three years. If this criterion is met, 20 percent of R&D expenses may be applied against taxable income, as opposed to 25 percent under the old law. This credit is estimated to be worth about $100 million annually to the industry, which spends 10 to 20 percent of sales on R&D.

Future Shock?

At worst, the net effect of the tax bill will be to raise the cost of capital for the semiconductor industry. To its credit, the responses to Dataquest inquiries indicate that the industry is willing to weigh this consequence of the bill against whatever benefits it has on the U.S. economy. Inasmuch as the bill seeks tax burden equity and more productively invested capital, what is good for the economy will certainly benefit the semiconductor industry. If, as the chairman of the Council of Economic Advisers, Beryl Sprinkle, has suggested, shifting more than $120 billion in taxes from individuals to corporations will facilitate the consumer's role in economic expansion, the resulting rise in GNP will manifest itself in renewed capital spending. Historically, this has meant greater consumption of semiconductors. The logic behind this argument is one that the industry would be happy to embrace, except for some reservations gained through the bitter experience of recent years.

What concerns the semiconductor industry, and Dataquest, is the tax bill's seeming disregard for the lesson that semiconductor firms have had to learn the hard way: the U.S. must now effectively participate in a global economy. In this economy, the stimulation and protection of our own domestic market is a futile gesture if we cannot maintain a manufacturing competitiveness worldwide. Not only is the U.S. domestic market no longer solely the plum for our picking, it is not even, in the area of semiconductors, the biggest plum. That honor now goes to Japan. More money in the hands of consumers at the expense of the economy's manufacturing sector will not lead to greater economic growth if consumers simply spend more on Korean autos, Japanese VCRs, and Taiwanese ICs. Ignoring the importance of the U.S. manufacturing sector in reversing the current trade imbalance, in turn ignores the effects of this imbalance on the federal budget deficit.

Increasing the cost of capital will not blunt the semiconductor industry's investment in manufacturing. It will, however, influence where that investment is made. In keeping with a shift in the economic center of gravity toward the Pacific, large capital investments will more likely be made in Penang, Singapore, and Seoul, than in Santa Clara, Austin, and Kokomo. As the imperatives of global competitiveness force U.S. semiconductor firms to become multinational in character, it will ultimately matter less to them where goods are manufactured and who the consumers are. Such considerations, however, will matter very much to the American worker, and to the federal deficit.

During the final stages of the tax bill committee meetings, the House-Senate staff received a harbinger of future peril. A call was received from the Joint Committee on Taxation to report that, based on revised projections for economic growth, tax revenue from the business sector would cover only $114 billion of the originally planned $131 billion cut for individuals. While this $17 billion shortfall was resolved before reaching final agreement on the bill (by raising the maximum tax rate for individuals), a deadly flaw was nonetheless exposed. Under a functioning Gramm-Rudman Act, the effects of any future tax revenue shortfall on the federal deficit will have to be dealt with through budget cuts--that is, unless Congress is willing to commit the heresy of raising taxes in the wake of the landmark bill it is about to pass.

DATAQUEST CONCLUSIONS

The fundamental aims of the new tax bill are simplification, redistribution, and revenue neutrality. There are mixed messages from Washington, however, on the bill's long-term effects. On one hand, the current administration has claimed that tax legislation will no longer be an instrument of societal change or industrial policy. Instead, it will return to its more humble role of raising federal revenue in the most equitable way possible. On the other hand, Beryl Sprinkel, maintains that a redistribution of the tax burden will generate a 10 percent higher growth in productivity than would have occurred under the old tax structure. Thus, the bill is cast in the role of economic spark plug.

Whichever version of the tax bill's intent one chooses to believe, the fact remains that in the absence of an overall industrial policy, the bill's effects on the U.S. manufacturing sector take on a de facto significance. Looked at in this light, Dataquest believes that the tax bill contains the following flaws:

- The bill ignores the fact that the U.S. now competes in a global marketplace.

- The bill creates yet another disincentive for U.S. companies to invest in domestic manufacturing.

- As a result of the above, the bill may fail to raise enough revenue from the business sector to cover the cuts given to individuals--thereby adding to an alarming federal deficit that is the enemy of economic health for consumers and businesses alike.

Michael J. Boss

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RESEARCH NEWSLETTER

SIS Code: 1986-1987 Newsletters: September
1986-39

AMD'S ANNUAL SHAREHOLDERS' MEETING

INTRODUCTION

Advanced Micro Devices' (AMD) annual shareholders' meeting, originally scheduled to take place on September 10 at the Pierre Hotel in New York, was relocated to AMD's office building in the Lawrence Business Park on Lawrence Expressway in Sunnyvale, California. As AMD President and CEO Jerry Sanders set the scene for the semiconductor industry in the United States, it became apparent why the change had occurred--economic pressures. U.S. semiconductor manufacturers' combined losses were approximately $500 million in 1985 and AMD's fiscal year 1986 was the worst in its history. On sales of $576 million in fiscal year 1986, AMD lost $37 million or 65 cents a share. This compares to 1985 earnings of $135 million on sales of $931 million. Revenue for the first two quarters of 1986 was essentially flat at $153 million and $154 million, respectively, with losses of $11 million and $28 million, respectively.

To the question, "Is it too late to save the U.S. semiconductor industry?" Mr. Sanders responds with a firm "No!" How can U.S. semiconductor manufacturers compete in a global market? Innovation, he believes, is the key. In 1986, AMD invested $184 million or 32 percent of sales in R&D and it has spent about 25 percent of total sales on capital investment over the last five years. However, now that excess capacity has reduced the need for capital spending, AMD is now spending at only half of last year's level.

AMD's stated goals are to maintain its R&D expenditure and its commitment to the employees. Although the semiconductor industry is cyclical in nature, which accounts somewhat for the depressed state of the industry, the realities of the marketplace have changed. Fierce international competition and predatory pricing, the overall weak economy and underutilized capacity, and AMD's oversized (in the circumstances) infrastructure and no lay-off policy, have resulted in the worst financial year yet in AMD's history.

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AMD'S STRATEGY

To combat this turn of events, Mr. Sanders outlined AMD's three-part strategy:

- To maintain competitive process technology
- To narrow the cost differential by more efficient manufacturing--a difficult task in today's economy
- To bring innovative new products to market

Process Technology

EPROMs are AMD's technology driver for its process technology. In the fourth quarter of fiscal year 1985, EPROMs accounted for 23 percent of AMD's sales but declined to a low point in third quarter fiscal year 1986 to represent 65 percent of the company's operating losses. Largely due to predatory pricing by foreign suppliers that gained market share in the United States at the expense of domestic suppliers, ASPs for EPROMs declined sharply. Thus, because of the significance of EPROM technology to AMD's long-term well-being, AMD joined with other semiconductor manufacturers in the dumping suit brought against the Japanese in late 1985. Mr. Sanders sees the July 30, 1986, trade agreement as a big step forward to restoring equity to the marketplace, and is heartened by the U.S. government's recognition of the strategic importance of semiconductor technology to the economic health and defense of this country. The trade agreement, Mr. Sanders feels, could herald a new era of "constructive competition" and, if faithfully implemented, could offer a tremendous opportunity to U.S. semiconductor suppliers.

Economy

The current economic environment outlook is poor--the GNP is stagnant, factory utilization is down, ever more U.S. manufacturing is migrating off-shore, and the trade deficit is up, none of which augurs well for the near future. Faced with these conditions, AMD's response has been to drop marginal products, such as DRAMs--which represented less than 1 percent of sales in fiscal 1986, but caused considerable losses--and to increase factory utilization and lower manufacturing costs at its 6-inch wafer fab installation in Austin, Texas. In 1986, 72 percent of AMD's wafer starts were 5-inch and above, as compared to 1984 when 87 percent of wafers used were 4-inch and below. Along with the elimination of marginal products, the Company decided to revoke its "no lay-off policy" in August of this year, a decision which caused Mr. Sanders considerable pain and personal regret but which he recognized as necessary to provide the greatest good for the greatest number. Project reviews are now in progress to discuss which marginal projects should be eliminated, which may result in layoffs in October.

Innovation

R&D spending has been extremely high as a percent of sales and AMD's goal is to reduce it to around $40 million per quarter and to better focus it to leverage spending. The Liberty Chip program (one major new product a week starting in October 1985 through September 1986) has been successful, with 62 new product introductions to date, of which 22 are in CMOS. The most recent introduction was the 8895 hard disk controller. The newest member of the Liberty drive is the Am 29337 Bounds Checker, which deals with placement of data in memory. This product was introduced September 15.

DATAQUEST COMMENTS

The following issues were addressed during the question and answer portion of the meeting:

- AMD is the fourth largest foreign supplier to the Japanese market.
- AMD employment in Japan, now at 50 employees, will double in the near future.
- It was recently announced that the company will open a quality and reliability center, and next year a new sales office in Japan.
- Last quarter, Liberty sales accounted for 6 percent of sales and is growing.
- AMD is targeting early 1987 for renewed profitability, but this depends on many things, including getting costs in line and the actual product mix.
- Mr. Sanders is optimistic about the economy, but considers any further prognostication as too speculative.
- The company's largest customers are ordering more but distributor sales are down.
- AMD has just had its first successful run of a CMOS SRAM using 6-inch wafers.
- The 1Mb EPROM is in CMOS and many more products will be in CMOS.
- By and large, customer-specific ICs will not figure heavily in AMD's product portfolio, although where an opportunity exists to increase revenue in a unique way such an opportunity will be examined--for example, the decision to produce ECL gate arrays.
- Mr. Sanders considers AMD's proprietary chips to be "ASIC" (as opposed to CSIC, customer-specific ICs, such as gate arrays) and the company will continue to participate in the programmable products market with microprocessors, PROMs, and FPLDs.

- AMD's long-term product strategy is reflected in its linkup with Sony, undertaken with a view to defining new products for the consumer market segment where AMD has little experience.

- Investment is being made in ISDN products now, although the market may not be important until the 1988 through 1989 time frame.

- Mr. Sanders is not optimistic about acquiring second-source rights to Intel's 80386, at least in the near term, primarily because Intel is capable of supplying the market demands itself.

- AMD's strength lies partially in the diversity and breadth of its product offerings--no single product represents more than 10 percent of sales.

The new tax law tends to be more punitive to capital-intensive business and the expectation is that it will increase AMD's tax liability over the next several years, although Mr. Sanders wryly commented that he was "looking forward to paying taxes." AMD's cash flow has been positive during the first half of 1986, and the company has no plans to go for bond or equity financing. The outlook for 1987 calls for a modest economic recovery and increased access to the Japanese market, but continuing concern over the worldwide glut. Conditions today are very different from the "good old days of" 1984, and only the "gold medalists" will survive.

Patricia Galligan
Patricia S. Cox
Janet Oncel

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PRICING AND THE MARKET AT ODDS:
REVISED EPROM AND 256K DRAM PRICE ESTIMATES

The semiconductor agreement reached by the United States and Japan on July 31 has had a direct impact on all EPROM and 256K and 1Mb DRAM pricing. As a result of the agreement, the quarterly price estimates for these devices that we had published earlier in July require revision. We are currently conducting our third-quarter price survey, which will constitute a comprehensive pricing estimate for the next five quarters. Until that notebook section is completed, use this bulletin as an update to our July EPROM and DRAM contract price estimates.

Only Japanese manufactured and exported EPROMs and 256K and 1Mb DRAMs are covered by the agreement. Since the Japanese account for more than 80 percent of the 256K DRAM market and close to 50 percent of the EPROM market, Japanese exports greatly influence overall price trends. The price estimates in Tables 1 and 2 reflect information that has been gathered from both users and manufacturers, and they are in line with the Department of Commerce's Foreign Market Values. The price estimates are overall averages that include the prices of both foreign and domestic suppliers of the affected parts.

Although FMV ranges vary by company, on the average, prices initially have risen by a factor of two. Gradual price declines should follow as noted above if the current constructed cost formula used to create the FMVs remains intact. We are currently analyzing cost trends in relation to this agreement and its implications and will publish the results of this research when completed.

Mary Olsson
Mark Giudici

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Table 1

REVISED CONTRACT EPROM PRICE ESTIMATES

Family/Product	Q3/86	Q4/86	Q1/87	Q2/87	Q3/87	Q4/87
64K EPROM	$ 4.85	$ 4.00	$ 3.75	$ 3.50	$ 3.25	$ 3.00
128K EPROM	$ 5.90	$ 5.10	$ 4.85	$ 4.65	$ 4.30	$ 4.00
256K EPROM	$ 9.70	$ 8.00	$ 7.00	$ 6.00	$ 6.15	$ 4.60
512K EPROM	$24.00	$20.00	$17.50	$14.50	$12.00	$ 9.50
1Mb EPROM	$50.00	$35.00	$28.00	$24.00	$20.00	$18.00

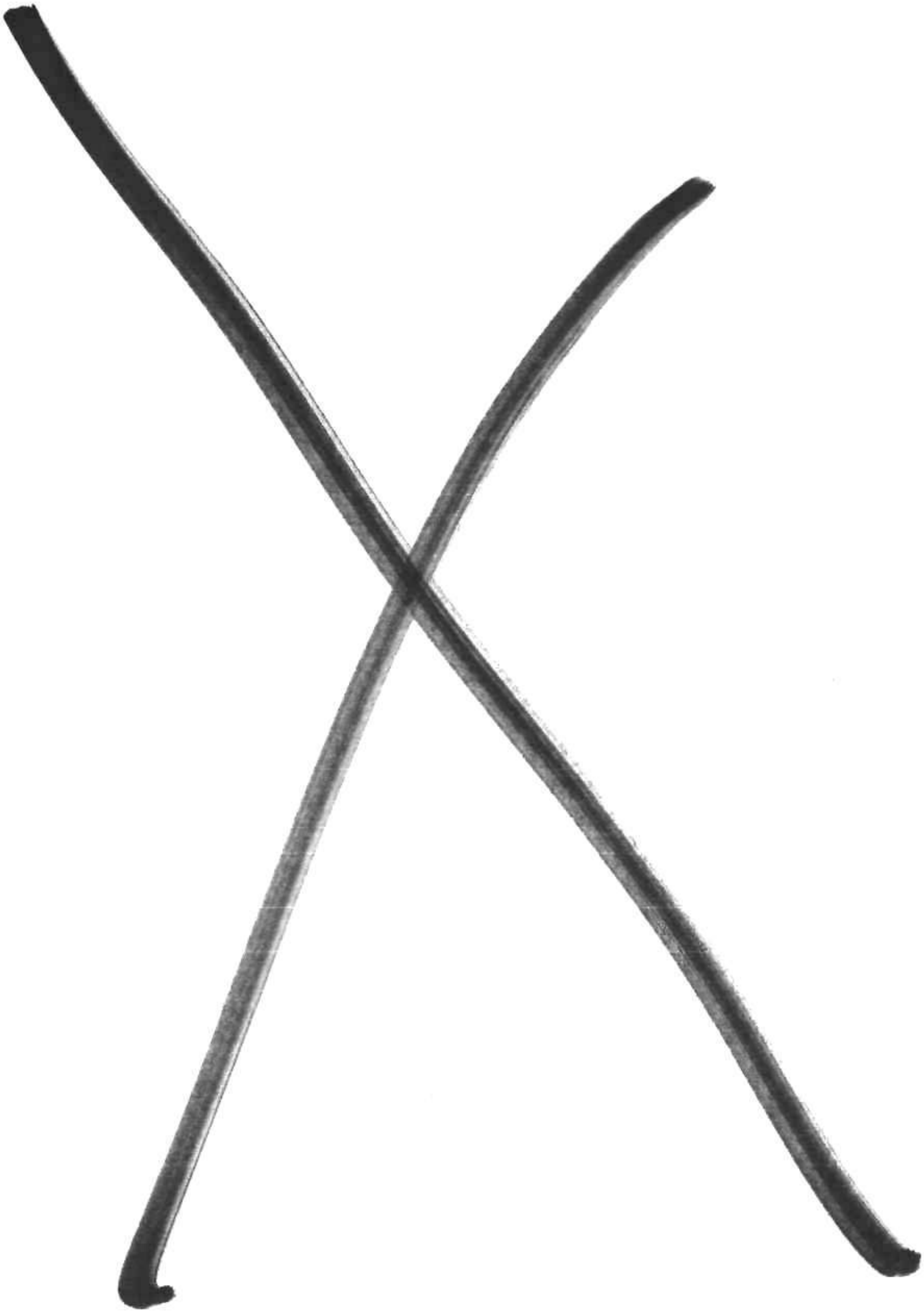
Source: Dataquest
August 1986

Table 2

REVISED CONTRACT DRAM PRICE ESTIMATES

Family/Product	Q3/86	Q4/86	Q1/87	Q2/87	Q3/87	Q4/87
64K DRAM	$ 1.00	$ 1.00	$ 0.95	$ 0.95	$ 0.95	$ 0.95
256K DRAM	$ 5.00	$ 4.50	$ 4.00	$ 3.50	$ 3.00	$ 2.50
1Mb DRAM	$65.00	$55.00	$45.00	$35.00	$24.00	$18.00

Source: Dataquest
August 1986



October Newsletters

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October Newsletters

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RESEARCH BULLETIN

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1986-49

NATIONAL CAPTIVATES ITS REPS

In a dramatic move on Monday, October 13, 1986, National Semiconductor made an offer to purchase its entire force of 150 to 200 U.S. sales representatives. Dataquest believes that this is an excellent move on the part of National and that it is also significant to the industry at large.

Currently, National's U.S. sales are almost exclusively through reps, while its European and Asian sales are handled by company employees. National is well along in its transition from a "jellybean" house to a firm with a broad line of proprietary products. Currently, more than 75 percent of National's new products are proprietary, and 18 of the top-selling 20 products are proprietary. National's component R&D expenditures have grown at a compound rate of 29 percent for the last three fiscal years and now stand at an estimated 19 percent of component revenue.

The acquisition of its North American sales force will permit National to better control its customer relations. This move represents a major push at National, where the corporate mission is to "provide service second to none--resulting in long-term National Semiconductor/customer partnerships." Under National, this sales force should be able to better support the increasing complexity of the company's proprietary products and more effectively work with customers during long design-in cycles. Additionally, this offer is well timed because many reps are currently somewhat disheartened with their businesses. National should be able to acquire a direct sales force for much less than it could recruit and train one.

This action by National is worthy of note by other semiconductor firms since reps that sell National products no longer will sell other firms' products. Dataquest believes that the semiconductor industry is becoming more "globalized," with U.S. firms striving to enter the Japanese market and Japanese and European firms striving to enter the North American market. Given this increasingly competitive situation, access to a captive sales force could be a major advantage.

Howard Z. Bogert
Barbara A. Van

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RESEARCH NEWSLETTER

SIS Code: 1986-1987 Newsletters: October
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PROGRAMMABLE LOGIC DEVICES: THE SYNERGISTIC INTERSECTION

INTRODUCTION

A unique combination of factors have come together in the world of programmable logic devices (PLDs). As application-specific IC (ASIC) users demand shorter and shorter turnaround of their products, more attention has been focused on finding a way to deliver custom ICs in the shortest possible time. Converging with this need is a synergistic combination of new process technologies and sophisticated CAD. The bottom line is that in our opinion, the PLD market is about to experience a growth spurt. With the intersection of these factors, we believe that PLDs will not only expand in diversity of products, but also in diversity of technology.

THE SUPPLIERS AND THE MARKET

Table 1 lists the five top PLD suppliers for 1985. While most of the 1985 revenue for these companies was from bipolar products, all suppliers are now expected to have major product offerings in CMOS, as well. These companies, along with a cadre of start-up companies, are about to change the character of the market. Since the early 1980s, PLDs were made using a bipolar TTL process, but today things have changed. With the emergence of sub-2-micron CMOS technologies, suppliers have started to offer products that compete with some of the more mature TTL products. This repositioning is not to say that the TTL is on its way out, but that we expect products using both bipolar and CMOS technologies to move to speeds that are beyond the reach of today's offerings.

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Table 1

ESTIMATED 1985 REVENUE--TOP FIVE PLD SUPPLIERS
(Millions of Dollars)

Rank	Company	Revenue
1	Monolithic Memories	$123
2	Signetics	44
3	Advanced Micro Devices	23
4	National Semiconductor	22
5	Texas Instruments	12
Total		$224

Source: Dataquest
October 1986

Table 2 shows our estimated consumption forecast by technology for PLDs. We have divided the markets into one-time programmable (OTP) and reprogrammable products. Under each of these categories, we have estimated growth by process technology and by programming technology. It is important to note that all CMOS technologies, whether OTP or reprogrammable, are forecast to experience strong growth for the balance of the decade. In the bipolar segment, where speed is critical, we believe that there will be small but growing demand for ECL PLDs. While the majority of the demand is for OTP products, we believe that reprogrammable parts will reach consumption levels in the $350 million range by 1991.

This means that we will see a rapid expansion of new, very diverse products. As suppliers rush to introduce products, users can expect a variety of products that will:

- Increase speed
- Increase density
- Provide flexible architecture
- Lower power

Table 2

ESTIMATED WORLDWIDE CONSUMPTION OF PROGRAMMABLE LOGIC DEVICES BY PRODUCT
(Millions of Dollars)

	1984	1985	1986	1991
Total Programmable Logic	$219.9	$234.4	$353.5	$1,263.8
MOS (CMOS)	2.7	9.4	58.5	665.2
Bipolar	217.2	225.0	295.1	598.6
One-Time Programmable (OTP)	$219.7	$230.3	$317.0	$ 914.9
MOS (CMOS)	2.5	5.3	21.9	316.3
EPLD	0	1.2	16.2	293.4
Fuse Link	2.5	3.1	4.5	15.0
Mask	0	1.0	1.2	7.9
Bipolar	$217.2	$225.0	$295.1	$ 598.6
TTL	217.2	225.0	291.4	525.4
Fuse Link	210.2	218.0	283.4	508.4
Mask	7.0	7.0	8.0	17.0
ECL	0	0	3.7	73.2
Fuse Link	0	0	3.6	70.0
Mask	0	0	0.1	3.2
Reprogrammable	$ 0.2	$ 4.1	$ 36.6	$ 348.9
MOS (CMOS)	0.2	4.1	36.6	348.9
EPLD	0.2	3.1	23.3	82.5
EEPLD	0	0.7	7.2	115.2
Cell Array	0	0.3	6.2	115.1

Source: Dataquest
October 1986

THE QUICKEST TURNAROUND

With the proliferation of new products, we expect more engineers to seek ways to customize products using PLDs. Our surveys of the engineering community show that many users are frustrated by the long development times encountered with gate arrays, cell-based ICs, and full custom. They see PLDs as a way to tailor ASICs at their desks. With the growing diversity of PLDs and the ability of the users to customize the products, we believe that demand for PLDs will be stimulated.

NEW CAD TOOLS

History has shown that first-rate CAD tools have fueled the growth of ASICs. In PLDs it is no different. Since the founding days, PLD suppliers have developed and refined CAD systems that have streamlined engineers' tasks. While most suppliers would prefer to leave the design of PLD-CAD to third-party companies, PLD manufacturers have often been the leaders in developing innovative systems to support their products. We believe that this trend will continue. As new products proliferate, we expect the PLD suppliers to offer the first PLD-CAD tools.

FAT CATALOGS

All of the above point to an exciting synergistic mix of factors that should make PLDs experience robust growth. Over the next five years, Dataquest believes that the intersection of technologies, CAD tools, and the need for quicker ASICs will drive the growth of PLDs. The industry can expect to see a sharp increase in the number and diversity of products available.

Before the end of the decade, Dataquest expects to see PLD suppliers' catalogs that are as large as today's LS TTL catalogs.

Andrew M. Prophet

Dataquest

Conference Schedule

1986

Semiconductor	October 20-22	Hotel Inter-Continental San Diego, California
Technical Computer	November 3-5	Silverado Country Club Napa, California
Asian Peripherals	November 5-7	Hotel Okura Tokyo, Japan
Semiconductor Users/ Semiconductor Application Markets	November 10	Sheraton Harbor Island San Diego, California
Electronic Publishing	November 17-18	Westin Copley Place Boston, Massachusetts
CAD/CAM EDA	December 4-5	Santa Clara Marriott Santa Clara, California

1987

Semiconductor Users/ Semiconductor Application Markets	February 4-6	Saddlebrook Resort Tampa, Florida
Copying and Duplicating	February 23-25	San Diego Hilton Resort San Diego, California
Electronic Printer	March 23-25	Silverado Country Club Napa, California
Japanese Semiconductor	April 13-14	The Miyako Kyoto, Japan
Telecommunications	April 13-15	Silverado Country Club Napa, California
CAD/CAM	May 14-15	Hyatt Regency Monterey Monterey, California
Display Terminals	May 20-22	San Diego Hilton Resort San Diego, California
European Semiconductor	June 4-5	Palace Hotel Madrid, Spain
European Copying and Duplicating	June 25-26	The Ritz Hotel Lisbon, Portugal
Financial Services	August 17-18	Silverado Country Club Napa, California
Western European Printer	September 9-11	Palace Hotel Madrid, Spain
European Telecommunications	October 1-2	Monte Carlo, Monaco
Semiconductor	October 19-21	The Pointe Resort Phoenix, Arizona
Office Equipment Dealers	November 5-6	Hyatt Regency Monterey, California
Electronic Publishing	November 16-17	Stouffer Hotel Bedford, Massachusetts
CAD/CAM EDA	December 10-11	Santa Clara Marriott Santa Clara, California

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Product Offerings

Industry Services

Business Computer Systems

CAD/CAM

Computer Storage—Rigid Disks

Computer Storage—Flexible Disks

Computer Storage—Tape Drives

Copying and Duplicating

Display Terminal

Electronic Printer

Electronic Publishing

Electronic Typewriter

Electronic Whiteboard

European Semiconductor*

European Telecommunications

Gallium Arsenide

Graphics

Imaging Supplies

Japanese Semiconductor*

Office Systems

Personal Computer

Personal Computer—Worldwide Shipments and Forecasts

Robotics

Semiconductor*

Semiconductor Application Markets*

Semiconductor Equipment and Materials*

Semiconductor User Information*

Software—Artificial Intelligence

Software—Personal Computer

Software—UNIX

Technical Computer Systems

Technical Computer Systems—Minisupercomputers

Telecommunications

Western European Printer

Executive and Financial Programs

Corporate Alliance Program

Coporate Technology Program

Financial Services Program

Strategic Executive Service

Newsletters

European PC Monitor

First Copy

Home Row

I.C. ASIA

I.C. USA

Focus Reports

The European PC Market 1985–1992

European PC Retail Pricing

PC Distribution in Europe

PC Software Markets in Europe

PC Local Area Networking Markets in Europe

The Education Market for PCs in Europe

Japanese Corporations in the European PC Markets

Home Markets for PCs in Europe

Integrated Office Systems—The Market and Its Requirements

European Market for Text Processing

Image Processing in the Office

Work Group Computing

Translation Systems

Vendor Support

The IBM 3270 Market: 1986 and Beyond

Korean Semiconductor Industry Analysis

Diskettes—The Market and Its Requirements

Directory Products

I.C. Start-Ups—1987

SpecCheck—Competitive Copier Guide

SpecCheck—Competitive Electronic Typewriter Guide

SpecCheck—Competitive Whiteboard Guide

Who's Who in CAD/CAM 1986

Future Products

- Industry Services
  - Manufacturing Automation
  - Computer Storage—Optical
  - Computer Storage—Subsystems
- Focus Reports
  - Japanese Printer Strategy
  - Japanese Telecommunications Strategy
  - Canon CX Laser—User Survey
  - Digital Signal Processing
  - PC-based Publishing
  - Taiwan Semiconductor Industry Analysis
  - China Semiconductor Industry Analysis
  - PC Distribution Channels
- Directory Products
  - SpecCheck—Competitive Facsimile Guide
  - SpecCheck—Competitive Electronic Printer Guide

*On-line delivery option available

For further information about these products, please contact your Dataquest sales representative or the Direct Marketing Group at (408) 971-9661.

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RESEARCH NEWSLETTER

SIS Code: 1986-1987 Newsletters, October
1986-47

THE SEMICONDUCTOR AGREEMENT: INTENTIONS AND REALITY

SUMMARY

This newsletter concerns the near- and long-term pricing repercussions of the U.S.-Japan semiconductor agreement reached on July 31, 1986. It reviews the agreement's main points and the potential effects and resulting strategies for semiconductor manufacturers and users. It analyzes the agreement's intentions and potential near- and long-term effects and concludes with specific suggestions for how the situation can best be managed.

AGREEMENT OVERVIEW

The semiconductor agreement between the United States and Japan revolves around two key issues:

- Cost/price monitoring of semiconductor devices to insure that prices of semiconductors exported into the United States do not fall below costs

- Increased Japanese market access by U.S. semiconductor manufacturers

Cost/Price Monitoring

The agreement resulted in the suspension of dumping charges on all EPROMs and 256K and 1Mb DRAMs by the U.S. Department of Commerce (DOC). Instead, the DOC will monitor on a quarterly basis the prices and costs of certain Japanese-manufactured and exported semiconductor products.

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The DOC uses a formula to construct the quarterly Foreign Market Values (FMVs). This formula (A + B + C + D = Foreign Market Value) is made up of the following four parts:

- Material costs, including some R&D
- Fabrication costs
- General sales and administration expenses, including some R&D (not less than 10 percent of the above two costs)
- Profit (not less than 8 percent of the above three costs)

The formula is applied on a company-by-company basis using proprietary cost information to determine the minimum price of each company's products. This method uses real-time fabrication cost data in determining FMVs. The capacity utilization of a given company at a given time will determine in large part what that company's FMV will be. A company running at 80 percent capacity will have lower fabrication costs per unit than a company running at 50 percent capacity. The initial capacity utilization rate used can determine which companies will be continually competitive and which will continue to be uncompetitive, since a profit always has to be added to a higher manufacturing cost. Using these same guidelines, Japan's Ministry of International Trade and Industry (MITI) has agreed to monitor the following volume Japanese-exported semiconductors:

- MOS SRAMs
- ECL RAMs
- 8- and 16-bit microprocessors
- 8-bit microcontrollers
- ECL logic
- Gate arrays
- Standard cells

<u>Market Access</u>

The second part of the agreement facilitates greater access by U.S. semiconductor manufacturers to the Japanese market, which a Japanese governmental organization has been formed to support. The organization will:

- Provide sales assistance for foreign semiconductor producers as they attempt to penetrate the Japanese market
- Make quality assessments of foreign semiconductor products, upon request, and organize such things as research fellowship programs, seminars, and exhibitions for foreign firms

- Promote long-term relationships between Japanese semiconductor purchasers and foreign producers, including joint product development with Japanese customers

AGREEMENT EFFECTS

The effect of capacity utilization on price is illustrated by the cost model shown in Table 1.

The first round of FMVs created significant problems for Japanese semiconductor companies and for users in the United States. Larger users appeared to have managed to source product from U.S.-based suppliers or to be prebuying before the September 15, 1986, deadline. Many smaller users got caught in the crossfire.

Table 1

CONSTRUCTED PRICES FOR 256K DRAM

	Capacity			
	100%	75%	50%	25%
Processed-Wafer Cost	$178.00	$220.00	$280.00	$500.00
Cost/Chip	$ .27	$ .33	$ .42	$ .75
Test Cost/Hour	$ 27.00	$ 34.00	$ 54.00	$100.00
Wafer Probe Cost/Chip	$ .07	$ .10	$ .15	$ .28
Wafer Probe Yield	70%	70%	70%	70%
Cost/Good Chip	$ .49	$ .61	$ .81	$ 1.47
Assembly Cost	$ .14	$ .19	$ .24	$ .36
Assembly Yield	85%	85%	85%	85%
Assembly Chip Cost	$ .74	$ .94	$ 1.24	$ 2.15
Test Cost/Pkg.	$ .25	$ .36	$ .54	$ 1.01
Test Yield	90%	90%	90%	90%
Tested Device Cost	$ 1.10	$ 1.44	$ 1.98	$ 3.51
Mark, Pack, Ship	$ .20	$ .20	$ .20	$ .20
Total Mfg. Cost/Unit	$ 1.30	$ 1.64	$ 2.18	$ 3.71
R&D Expense (15%)	$ .20	$ .25	$ .33	$ .56
SG&A Expense (10%)	$ .15	$ .19	$ .25	$ .43
Profit (8%)	$ .13	$ .17	$ .22	$ .38
Foreign Market Value	$ 1.78	$ 2.25	$ 2.98	$ 5.08

Source: Dataquest
October 1986

Japan-based semiconductor companies have seen their exports to the United States decrease as prices based on yen have continued to drop in Japan, impacting company profits. The price for 256K DRAMs was ¥450 in 1985. Today the price is ¥289. The agreement has helped yen-based average selling prices increase to ¥375 or higher for sales made into the U.S. market.

It appears that the new FMVs that will become effective on October 15 will be much more palatable to customers. We expect 256K DRAMs to range in price from $2.50 to $4.00, and we expect 1Mb DRAMs to be in the $20 to $25 range for the lowest-cost suppliers. EPROM prices are outlined in our recent Research Newsletter number 1986-28, "Pricing and the Market at Odds: Revised EPROM and 256K DRAM Estimates."

Dataquest believes that the new FMVs will make life easier for U.S. buyers. The new prices indicate that buyers may expect prices to continue to decrease throughout 1987. By the end of 1987 we expect 256K DRAM prices to be close to $2.20, as shown below:

	1986		1987			
	Q3	Q4	Q1	Q2	Q3	Q4
256K DRAMs	$2.85	$2.85	$2.85	$2.50	$2.35	$2.20

We also expect 1Mb DRAMs to return to more competitive pricing than we had previously expected. We now believe that they will approach the crossover point by the end of 1987.

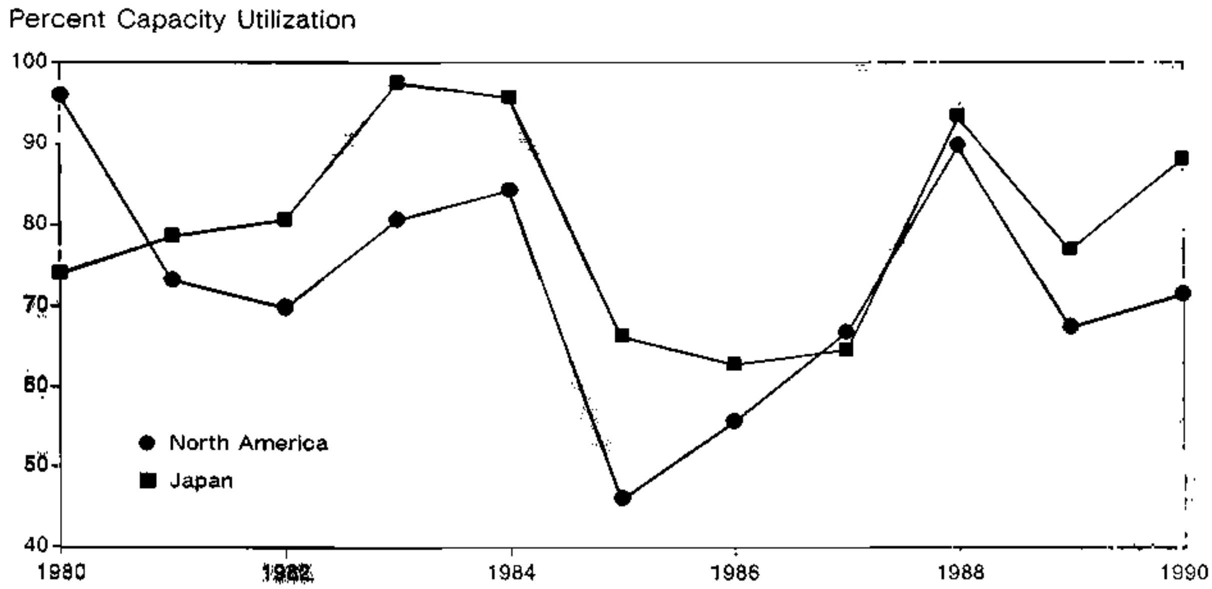
As prices in the United States reach more stable levels, the focus of the program is expected to move to other regions. We expect the Department of Commerce to take up this issue with MITI in the near future. Dataquest surveys prices in Europe, Japan, and Taiwan every two weeks, and prices in Europe and Taiwan have remained at $2.00 or less during the last month. However, our European research indicates that prices in Europe will increase from current levels in the next two quarters.

LONG-TERM IMPLICATIONS OF THE AGREEMENT

This agreement presents interesting opportunities for users and semiconductor manufacturers. Because the models used to determine the FMVs are based on capacity utilization, FMVs will decrease during market growth periods and increase during recessions when capacity utilization drops. Figure 1 shows our projection of capacity utilization for the industry for the next five years. By combining this with the data shown in Table 1, we can analyze the impact of the business cycle on FMVs. As capacity utilization drops, FMVs will tend to increase; this will effectively remove uneconomic foreign capacity from the U.S. market as demand declines and will direct more business toward U.S.-based suppliers who are not affected by the FMVs. Our current forecasts project that this will occur in 1989.

Figure 1

CAPACITY UTILIZATION--NORTH AMERICA VERSUS JAPAN



Source: Dataquest
October 1986

Another concern arising from the first round of FMVs was the price of new technologies--in this case, the 1Mb DRAM. Third quarter FMVs were double the prior market price. This had the impact of delaying the introduction of the latest technology into U.S.-manufactured equipment, giving Japanese companies a lead in this area. The long-term implications of this are far more important than any other action resulting from the agreement.

New technology has far greater impact on system cost than declining prices. Figure 2 shows how this works. Cost per function can decline by a factor of five or more for a much smaller decrease in price. Figure 3 shows how it works for memories. Each new level of cost occurs when the next generation of memory enters the market. Each new generation decreases the cost from the previous generation by a factor of five. A one-year lag in pricing causes a one-year lag in system technology. The anticipated 1Mb FMVs will prevent a near-term U.S. versus Japan system technology dichotomy.

The new FMVs of $20 to $25 for 1Mb DRAMs should correct this situation, but the impact on future generations of DRAMs remains to be seen. This is not a problem with EPROMs, however, because U.S. companies are leaders in introducing next-generation EPROMs.

Figure 2

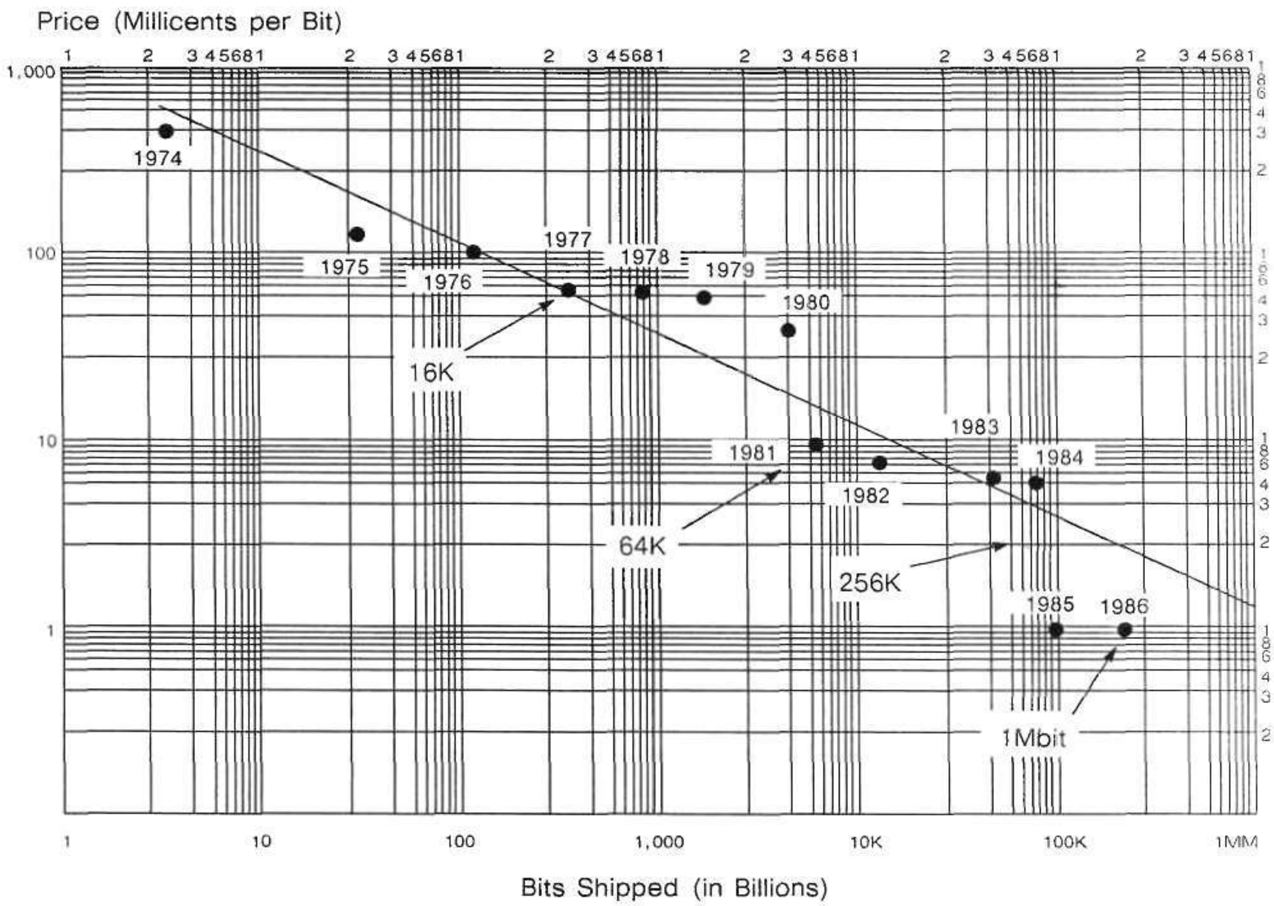
HYPOTHETICAL CHIP COST MODEL

	1984	1986
Minimum dimension	3 microns	2 microns
Wafer size	4 in.	6 in.
Processing cost	$140	$220
Chip size (mils per side)	200	250
Yield	30%	50%
Chip cost to product cost	4X	4X
Good chips	100	200
Finished chip cost	$1.49	$1.10
Finished package cost	$5.96	$4.40
Transistors/chip	50,000	211,000
Cost/transistor	9.9m¢	2.1m¢

Source: Dataquest
October 1986

Figure 3

DRAM EXPERIENCE CURVE



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STRATEGIES FOR THE TRADE-AGREEMENT ENVIRONMENT

The trade agreement has precipitated a number of responses by semiconductor users. These responses and their implications are discussed in the following paragraphs.

Some U.S. companies are considering having memory PC boards manufactured in Japan and exported to the United States. Through this transformation of product, the FMVs are avoided. This is a good plan, but the government could close this loophole if it becomes a serious impediment to making the agreement work.

A number of users have benefited from agreements with NEC, which has manufacturing capacity in both the United States and Japan. The short-term effect obviously has been to lower prices. This will not appear to be so important with the new FMVs, but we believe that all users should develop a balanced U.S./Japanese supply base. It will enable them to shift sourcing during recessionary periods, when we expect the FMVs to increase as capacity utilization decreases. This will minimize the price impact on customers during down markets.

Moving to offshore manufacturing is another possible strategy. However, we believe that companies should be very careful with this, as the agreement could equalize prices worldwide (except in Japan) if it works as intended.

Korean suppliers offer another opportunity for lower prices, but this should be considered a short-term strategy. Korea currently supplies a small part of the market. If the U.S. government becomes interested in controlling Korean suppliers as a major source of DRAMs, we believe that Korean FMVs would be substantially higher than current prices.

DATAQUEST CONCLUSIONS

Procurement strategies under the trade agreement should remain extremely flexible. Companies should balance U.S. sources with foreign sources to be able to adjust to changes in the current business environment. Any actions taken to get around the agreement could be affected by government actions to close loopholes that could affect the intent of the agreement. We believe that the major negative effects of the agreement will subside when the new FMVs are released on October 15. The groundwork has to be done now for dealing with the long-term effects of the agreement.

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RESEARCH NEWSLETTER

SIS Code: 1986-1987 Newsletters: October
1986-46

GALLIUM ARSENIDE ICs--FACT OR FANCY?

It has been said that the quantity of paper published on gallium arsenide (GaAs) technology outweighs the shipments of chips, and this certainly holds true for GaAs ICs. Dataquest recently analyzed the industry to determine the extent of activity in this field and to gain insight into the reality of the emerging markets for GaAs semiconductors.

A CRITICAL MASS OF PLAYERS AND INVESTMENTS

Dataquest estimates the number of participants in the GaAs industry to be:

- 28 merchant market suppliers of GaAs ICs
- 26 additional companies supplying discretes
- 21 captive-only producers of GaAs chips
- More than 20 merchant suppliers of GaAs wafers, plus 10 or more suppliers of other III-V compound wafers such as InP
- 10 merchant foundries
- 11 IC start-ups not included above, with planned shipments starting in 1986 or 1987
- 30 Japanese companies in MITI-supported projects funded at $348 million

Additionally, more than 60 universities in the free world are involved in III-V compound semiconductor R&D, many with fabrication facilities. The number of professionals with degrees in this field is rapidly approaching 10,000. Analog GaAs ICs for TVRO applications are now available at ASPs

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of less than $20. Vitesse Electronics Corporation has announced a 2900-type bit slice family of digital ICs that includes a 1Kx4 SRAM and are based on a 1.2u E/D MESFET process. Dataquest estimates that capital infusion into the GaAs IC field exceeded $330 million in 1985.

WHAT IS THE FUTURE OF THE GaAs IC INDUSTRY?

A recent Dataquest analysis of available high-speed ICs shows that silicon technology is evolving rapidly on several fronts. CMOS processes are now pushing critical dimensions (CDs) to less than 1.5 and, in some cases, below 1.0 , resulting in subnanosecond gate delays. ECL gate arrays based on sub-u CDs are now in limited volume production and feature gate delays of less than 300 picoseconds. This progress, coupled with product schedule slippages at several major GaAs digital houses, has raised some doubt as to the viability of using GaAs digital ICs in new systems now being developed, especially at bottom-line-sensitive U.S. computer houses. This situation has also inspired many U.S.-based silicon IC suppliers to maintain the status quo of evolutionary progress in silicon as opposed to extending themselves by risking investment in GaAs.

Dataquest observed during this analysis that all of the Japanese GaAs IC suppliers are vertically integrated, supplying communications and EDP equipment; many also produce their own wafers. This contrasts sharply with the typical U.S. GaAs IC start-up, which is a "chips-only" company.

Despite the number of players in the GaAs arena, wafer defect densities are still excessive with respect to LSI chip fab requirements. This problem and the problem of gate threshold control have, to date, prevented the introduction of cost-effective GaAs chips into commercial systems. However, these problems are resolvable with the appropriate application of presently understood technology. The GaAs IC situation today is not unlike the Si NMOS situation in 1971, when the industry struggled to produce the standard 1K DRAM, the 1103. At that time, Burroughs, NCR, and others took leadership positions by designing the 1103 into systems and pressuring the U.S. industry to rise to the occasion, which it did. Today, to Dataquest's knowledge, only one U.S. systems house is applying similar pressure to potential GaAs RAM suppliers. If history is any indicator, the GaAs IC industry needs several more courageous champions within systems houses demanding tens of millions of GaAs LSI chips and backing their demands with purchase orders and multiyear schedules. It now appears that if such a situation evolves, it will do so in Japan, leading to a further demise of U.S. EDP houses in the world marketplace.

DATAQUEST CONCLUSIONS

While the U.S. Department of Defense appears to be pushing the U.S. industry very hard for viable merchant GaAs IC sourcing, many potential suppliers are limited by the lack of adequate additional demand from the commercial sector. This shortfall in demand is preventing a sufficiently rapid buildup of volume, making it difficult, if not impossible, to achieve the minimum efficiency of scale required for the success of the GaAs IC industry. The MITI-backed effort at vertically integrated Japanese firms does not face the same limitation; the net effect may be the eventual domination of the emerging worldwide GaAs IC market by Japanese firms. However, the race has just started, with only two Japanese suppliers of merchant GaAs ICs at present; a few courageous "drivers" in U.S. systems houses could have a major impact on the outcome.

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RESEARCH NEWSLETTER

SIS Code: 1986-1987 Newsletters: October
1986-45

FMVs: "FOREIGN MARKET VICISSITUDES"

OVERVIEW

For the last several years, the semiconductor industry has experienced significant market shifts. Figure 1 shows that the Japanese have continued to gain market share at the expense of their U.S. and European competitors. This issue is of vital importance to U.S. manufacturers, who do not want to see their business migrate offshore. However, following the recent trade agreement with Japan, there is some optimism on the part of U.S. chip suppliers that they may be able to increase their market share in Japan above the 1985 level of 9 percent. Some American suppliers would even like to push their market share in Japan up to 20 percent over the next five years, and they tried unsuccessfully to have this stipulation included in the final agreement. The stakes are high. Dataquest estimates that $6,232 million in cumulative additional revenue could be generated if U.S. suppliers achieved a 20 percent share of the Japanese market by 1991 (see Figure 2).

CHALLENGE

There is, understandably, resistance among the Japanese suppliers to handing over market share to competitors; they are also resistant to supplying guarantees of market share level. The Japanese will provide some support for foreign companies attempting to do business in Japan through forums designed to teach them about Japanese business practices. Access to government-funded R&D programs will be facilitated, and MITI seems to be intent on encouraging compliance with the spirit of the law. However, it will not be easy for U.S. suppliers to increase their share of the business in Japan. The cultural barriers still exist, and these will take time to break down. Some Japanese companies already purchase 20 percent of their semiconductor requirements from U.S. vendors and are unlikely to increase that amount. Other companies will claim that the U.S. suppliers cannot provide the parts they need, particularly in the consumer field.

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On the other hand, pricing should now be less of a barrier to the American suppliers, since the yen appreciation is making parts imported from America more competitive. Other areas of concern are quality and service. There are many American companies that are on a par with their Japanese counterparts in terms of quality. The areas where the U.S. vendors could really make some headway are in service and support, which constitute an integral part of any strategy to increase market share in Japan.

One strategy for entering the market quickly and without large capital outlay is the approach recently taken by National Semiconductor Corporation. National has signed an agreement with NMB Semiconductor whereby NMB will supply the foundry capacity while National provides the design and marketing expertise to supply SRAMs to the Japanese market.

AMD is planning to double its work force in Japan from the current level of approximately 50. A quality-assurance center will be opened this year, to be followed by a design center next year. In this context, AMD's wide-ranging strategic alliance signed in February of this year with Sony Corporation may be significant. In terms of access to the Japanese market, Sony's expertise in the consumer realm could pay off for AMD in long-term product strategy; Sony will benefit from AMD's experience in telecommunications and microdevices.

DATAQUEST CONCLUSIONS

Given the difficulties ahead, it is somewhat problematic to foresee the U.S. suppliers actually attaining the goal of 20 percent market share over the next five years. Japanese companies may realign their organizations to place more focus on the end-use equipment area, where they possess certain key advantages over the competition; in doing so, they would move the battle to another field. This is a concern voiced by several U.S. equipment manufacturers, who fear that the problems experienced by the U.S. semiconductor industry are merely being transferred to their business. The FMVs (foreign market values) assessed for certain key components might have a detrimental affect on the ability of U.S. equipment manufacturers to compete in pricing with their Japanese counterparts. This could have long-term implications for America's participation in the equipment market.

As Figures 3 and 4 illustrate, the U.S. manufacturers have been hit with a double whammy. Although Japanese semiconductor consumption has increased and is expected to overtake U.S. consumption in the near future, the U.S. share of the Japanese market has remained flat or declined, while Japanese suppliers have continued to steadily increase their share of the U.S. market (with the exception of the dip in 1985 due primarily to the collapse of the commodity memory market). Unless some progress is forthcoming, it is probable that the concerns that originally led to the trade agreement may reemerge even more forcefully before the five-year period is over. Nonetheless, there is considerable optimism that some measure of success will be achieved; for example, recently we saw Micron Technology, Inc., drop its antitrust suit against certain

Japanese chip makers to show good faith in light of the trade agreement. From the U.S. perspective, the trade agreement represents both a challenge and an opportunity. The industry will watch with keen interest how market share rankings shape up over the next few years.

Patricia A. Galligan

Figure 1

WORLDWIDE SEMICONDUCTOR MARKET SHARE

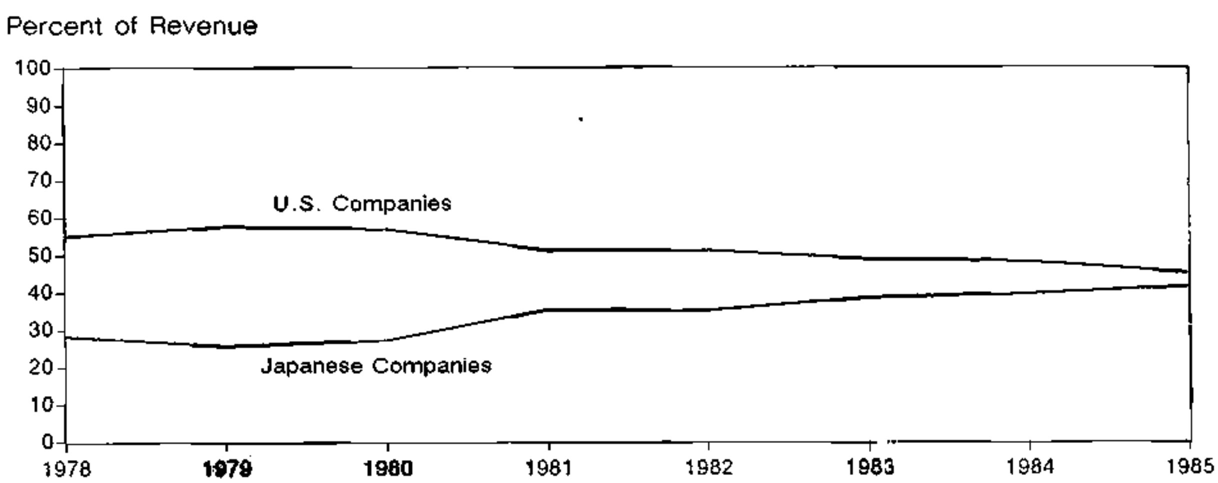

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Figure 2

ESTIMATED U.S. SALES IN THE JAPANESE SEMICONDUCTOR MARKET

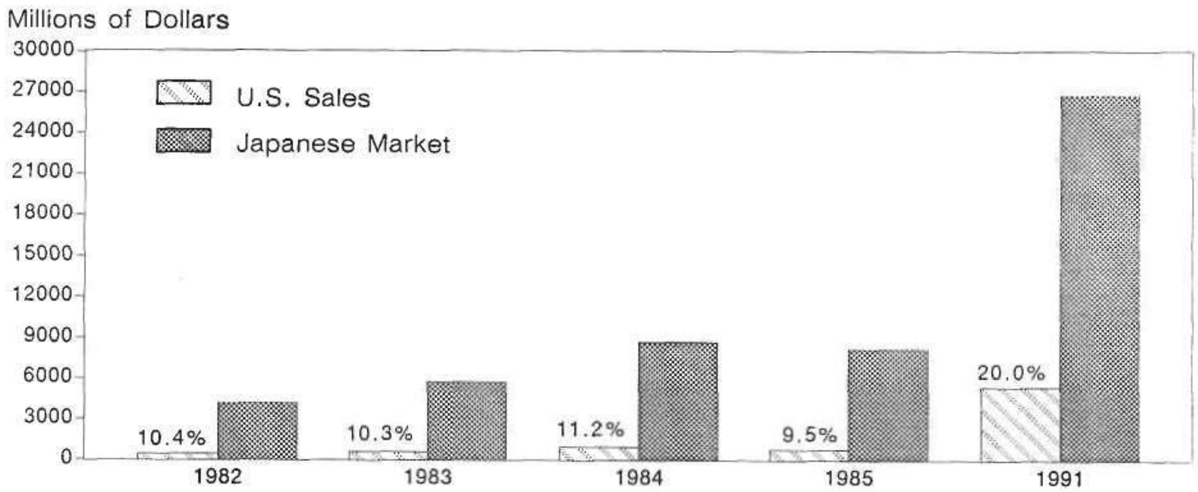

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Figure 3

ESTIMATED END MARKET COMPARISONS

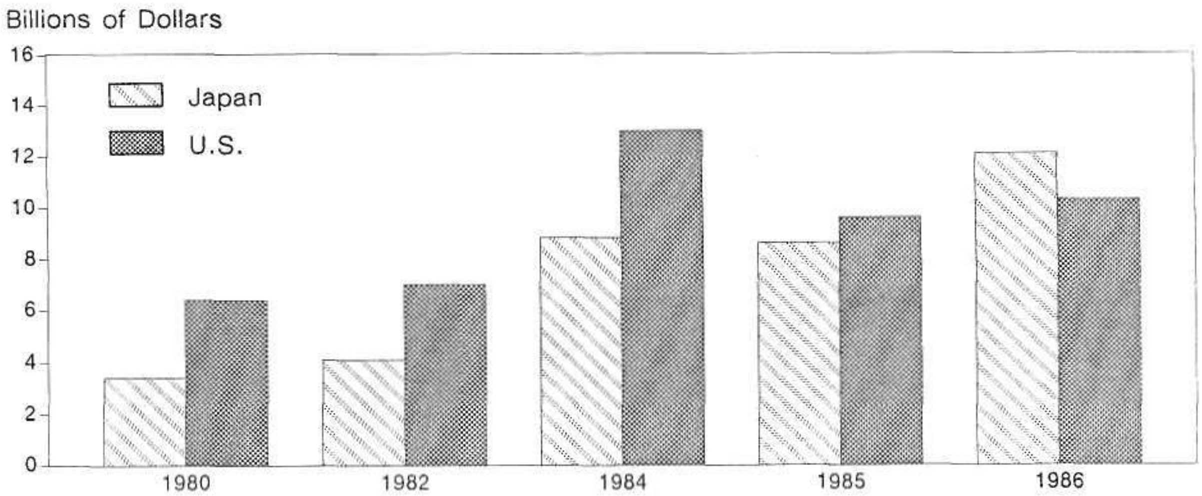

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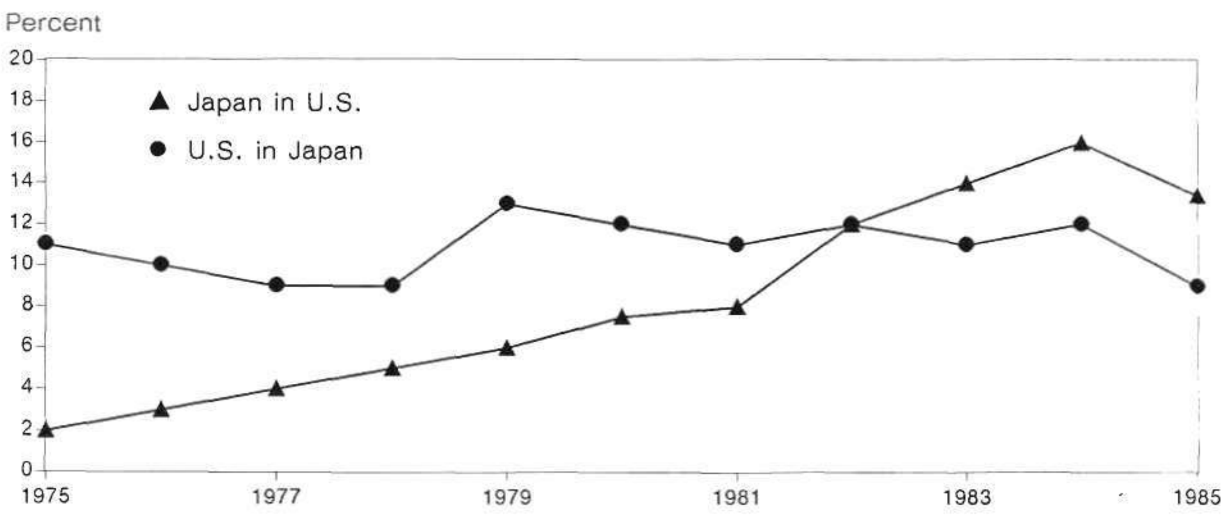
Figure 4

U.S. SHARE OF JAPANESE MARKET VERSUS
JAPANESE SHARE OF U.S. MARKET



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October 1986

SIS Code: 1986-1987 Newsletters: October 1986-44

THE DATAQUEST SEMICONDUCTOR MEGATRENDS

SUMMARY

In his influential best-seller, Megatrends, analyst John Naisbitt outlined ten societal transformations taking place in the United States. Mr. Naisbitt characterized these megatrends as:

- The shift from an industrial to an information society
- The combining of high-technology with "high touch"
- The shift from a national to a world economy
- The shift in perspective from short-term to long-term
- The shift from centralization to decentralization
- The shift from institutional help to self-help
- The shift from representative to participatory democracy
- The shift from hierarchical structures to networking
- The shift in regional importance from north to south
- The shift from either/or options to multiple options

The Dataquest Semiconductor Industry Service has summarized the ten trends that we believe are currently transforming the semiconductor industry. These megatrends have been defined by key Dataquest analysts from not only the semiconductor service, but from many other Dataquest high-technology groups as well. Dataquest's "Semiconductor Megatrends" are characterized as:

- The system is the chip
- The dawn of application-specific logic products

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- Universal CAD/technology-specific CAD
- Service: The next high-technology battleground
- Hardware design versus software design
- The "commodization" of the computer industry
- The protection of intellectual property
- The new Japanese strategy
- The shifting of the electronic center of gravity to the Pacific Basin
- The growing importance of strategic alliances

This newsletter briefly describes each of these megatrends and weighs their impact on the semiconductor industry. A thorough understanding of these trends and their implications for the industry is certainly in order at this time.

THE SYSTEM IS THE CHIP

As standard cell libraries grow to include powerful microprocessors, the translation of systems-level architectures into silicon will become increasingly practical. More and more, therefore, the system is the chip. An intriguing question then arises: Who dictates the system, the IC designer or the systems engineer? Computer-aided design (CAD) tools are just now becoming sophisticated enough for engineers to translate systems designs directly to silicon. This is fortunate for the industry, since IC designers are not normally trained at a systems level. Until more sophisticated silicon compilation tools are joined to expanded cell libraries, however, a significant opportunity exists for IC start-ups, not unlike the opportunity seized by value-added resellers (VARs) in the computer industry.

Consider the following analogy. As desktop computers proliferated, software firms initially concentrated on developing products for high-volume applications. This created a need for companies dedicated to servicing application niches not addressed by the makers of "horizontal" products (general data processing, word processing, etc.). By tailoring systems and software to meet more highly specialized applications, value-added resellers became a force in the computer industry. What VARs lost in economies of scale could be made up through greater applications knowledge and correspondingly higher profit margins, given an effective means of distribution. The situation in the IC industry follows a similar script--engineers with their feet in both the systems and IC design worlds have the opportunity to become "VADs" (value-added designers). As with VARs in the computer business, the major commodity for sale-by-chip companies following the VAD route is applications know-how, with manufacturing handled through associations with wafer foundries or through joint ventures and licensing agreements with existing IC manufacturers.

APPLICATION-SPECIFIC LOGIC PRODUCTS

In 1985, the semiconductor industry witnessed the introduction of core microprocessors and specialized compilable cells in both gate arrays and cell-based ICs. Dataquest believes that in the 1990s the widespread use of high-performance CAD systems will blur the distinction between full-custom solutions and standard logic products. As a result, a growing number of IC products that address specific applications will emerge, but, unlike typical application-specific integrated circuits (ASICs), the new products will be sold to more than one customer as catalog logic products. Dataquest has recently observed the growth of products that apply ASIC design technology to end-market applications, giving rise to what we term ASLPs (application-specific logic products).

The economic force behind ASLPs is that they solve a current design dilemma for companies that seek larger markets for their chips even though the application windows are narrowing. As suppliers attempt to differentiate their products, they continually search for unique niches where they can have a dominant position. Meanwhile, design costs escalate because of complexity and the decreasing number of units over which the design costs can be amortized. The advent of ASICs has led to a design technology aimed directly at solving this problem. The application of this technology to end-market segments rather than single customers will both feed and drive product growth in areas such as telecommunications, digital signal processing, graphics, and voice and pattern recognition. Semiconductor suppliers can best prepare for success in these markets by anticipating end-use applications and exploiting state-of-the-art IC-CAD tools. ASLPs offer great opportunities to those companies that best combine the skills of the traditional catalog product and ASIC design.

UNIVERSAL CAD/TECHNOLOGY-SPECIFIC CAD

The successful penetration of ASIC and ASLP products is directly linked to a revolution in the computer-aided design of integrated circuits (IC-CAD). "CAD for the masses" will require systems that are both universal in design capture and technology-specific/manufacturer-specific in their implementations. These CAD tools will have the following characteristics:

- Highly automated design steps linking design, testing, and manufacturing

- Utilization of expert systems that understand what it is they are designing and perform layouts that optimize designed performance

- High-level architectures capable of design-in and layout of components from a conceptual systems level

- Emphasis not only on the management of design data, but also on design creativity from a systems level

- Incorporation of multivendor cell families into universal design processes

In achieving these characteristics, CAD tools will successfully encompass a design process spectrum that may be diagrammed as:

architectural concept→logic component specification→simulation of logic design→layout→test

At present, existing CAD products address single components of this process--most notably schematic capture and simulation. No systems as yet integrate the entire design gamut, nor are they process-independent.

The semiconductor industry will see a profound transformation when CAD technology arrives at design capture systems that are capable of handling any cell library and are translatable into any specified process technology. An important step in this direction will be taken when the semiconductor industry fully endorses silicon compilation and is willing to release physical libraries and layout programs to IC-CAD vendors.

SERVICE: THE NEXT HIGH-TECHNOLOGY BATTLEGROUND

In the past, seizing the competitive high ground in the semiconductor industry was achieved largely through dominance in technology, price, and quality. The application-specific IC (ASIC) market, however, demands that companies structure themselves as providers of service as well. A number of forces pushing the industry toward a higher degree of service orientation, such as:

- The erosion of profit margins in the commodities arena

- The growing market for ASIC solutions

- Lower inventory levels typical of "just-in-time" manufacturing

While many semiconductor companies will remain in the MOS memory market in order to maintain a technological edge in IC manufacture, profit margins and return on investment in this sector will continue to face the specter of overcapacity as newly industrialized countries enter the competitive crush. As technology advances, the confluence of systems and chips will require companies to preserve profit margins by addressing the more lucrative custom and semicustom needs of their clients.

The ASIC market, which Dataquest predicts will account for 26 percent of worldwide IC shipments in four years' time, is a service business with an estimated annual sales potential of more than $11.6 billion in 1990. As such, it requires an operating style that differs significantly from that of the standard products business. At the design level, ASIC suppliers will have to structure their customer interface to minimize engineering efforts on both sides of the customer/vendor relationship. Accomplishing this will require large investments in IC-CAD, allowing engineers to implement systems-level architectures directly into silicon.

At the marketing level, ASIC suppliers will need to work closely with customers to identify applications for high-integration ASIC devices. This will require personnel who are knowledgeable in applying systems solutions to specific end-use markets. The necessity for customers to entrust their suppliers with more highly proprietary information will forge significantly closer relationships than typically exist between customers and vendors in a price-driven marketplace.

Greater automation will be crucial to customer service regardless of whether a supplier's orientation is commodities or custom. ASIC manufacturers will demand higher yield predictability in order to reduce testing bottlenecks and improve cost effectiveness. Effective telecommunications links between design centers and foundries and computer control of wafer processes will be necessary as well. Commodities suppliers will rely on automation not only to service clients on the basis of pricing and quality, but in response to the changing manufacturing environment brought on by just-in-time delivery.

HARDWARE DESIGN VERSUS SOFTWARE DESIGN

In years past, the massive data processing tasks typical of computers in the corporate MIS environment justified the building of general-purpose, sequential-processing computing engines. Computer manufacturers or value-added resellers could then adapt these engines to specific applications through software development. This often resulted in software budgets that equaled the development costs of the hardware itself.

More recently, computer processing needs have changed dramatically. This change was brought about primarily by the explosive growth in technical computing systems, which in 1985 represented 38 percent of the total computer market. The fastest growing segment of the technical computing business has been technical workstations. Between 1981 and 1985, technical workstations proliferated at an astounding 226 percent compound annual growth rate (CAGR). Nor is this phenomenon short-lived: Dataquest forecasts continued growth in the technical workstation market at a 32 percent CAGR between 1986 and 1990. With its emphasis on graphics and simulations, the technical workstation is creating a greater demand for parallel processing. This growth in parallel processing applications will in turn result in more hardware-intensive computer design--for the simple reason that stored programs do not work as well in a parallel processing world as they do in a sequential one.

For technical computer designers, meeting the needs of specialized applications in parallel processing more often means finding solutions in hardware rather than software. Not only is the hardware approach more cost-effective in terms of development time, but it yields greater gains in performance as well. Certain technical applications that could take a Cray supercomputer up to two hours to perform (such as three-dimensional image processing) can be handled by a pair of specialized ICs in two minutes. In comparing the price of a Cray with that of a desktop workstation, the difference in price/performance can be measured in orders of magnitude. The significance of this trend to the semiconductor industry is quickly appreciated: the fastest-growing segment of the computer industry, which as a whole remains the largest end user of semiconductors, will be defining systems increasingly in transistors rather than lines of code.

Advances in "systems on a chip" will be both a driver and beneficiary of the trend toward application-oriented technical workstations. ASIC manufacturers will not be the only ones to benefit from the boom in technical computers. In 1986, memory devices made up 40 percent of the ICs consumed by technical computers, while microdevices accounted for 23 percent. Dataquest believes that the next wave in technical systems will be minisupercomputers, a market that will approach $2 billion in 1990. Following the current input/output ratios for semiconductor consumption by this market segment, growth in sales of minisupercomputers will result in the consumption of $180 million worth of ICs.

"COMMODIZATION" OF THE COMPUTER INDUSTRY

Much to its chagrin, IBM helped make the personal computer a commodity item through its open architecture design approach to the PC. Foreign and domestic clone manufacturers quickly discovered that duplicating IBM's PC success was no more mysterious than duplicating the machine itself. IBM's loss has, as a result of the clone wars, been the consumer's gain. Lower prices, the banner under which most clones do battle, have proliferated the spread of personal computers beyond even IBM's considerable marketing clout, while add-on memory products give each PC owner the potential for incredible desktop computing power. This proliferation comes at a time when the profile of the average computer user has metamorphosed from hobbyist, to early innovator, to everybody.

The confluence of systems and chips and the commodization of the personal computer are highly complementary trends. To maintain price competitiveness, computer manufacturers must reduce costs through the use of more highly integrated ICs. To increase performance and maintain product differentiation, manufacturers must also implement proprietary features through the use of custom chips. These trends bode well for the semiconductor industry as a whole, but there are some impediments to a rate of growth at anywhere near that of the past. One major obstacle is the absorption in the marketplace of the kind of memory and performance of which microcomputers are capable. Overcapacity in semiconductor MOS memories finds its equivalent at the systems level in a glut of memory bits that far exceed functional demand.

Some manufacturers believe that market growth for 32-bit MPUs will be spurred as these devices replace minicomputers and that future MPUs will have microcoded instruction sets that can emulate minicomputer instruction sets--systems on a chip. These devices will profoundly affect the industry by destroying the distinction between computer companies, thus raising the level of competition. While soaking up a glut of memory bits can be easily accomplished by more powerful machines, what the industry now requires is the software to justify purchasing the new products. Next-generation MPUs, such as Intel's 80386, will involve a major software development effort to take advantage of the new microprocessing technology.

PROTECTION OF INTELLECTUAL PROPERTY

On July 31, 1978, the National Commission on New Technological Uses of Copyrighted Works recommended that the Copyright Act be amended to "make it explicit that computer programs, to the extent that they embody an author's original creation, are proper subject matter of copyright." The Commission's report was relied upon by Congress in enacting the 1980 software amendment to the United States Copyright Act. Critics of the Commission's recommendation included the Commissioner himself, John Hersey, who argued that the inclusion of software "would mark the first time copyright had ever covered a means of communication, not with the human mind and senses, but with machines."

Mr. Hersey's misgivings underscore a problem that high-technology firms and our legal system must resolve. As we move from an industrial to an information society, the distinction between information and function becomes blurred, challenging the current dualisms of patent and copyright. While copyright law encourages abundant expression, patent law encourages substantial technological improvement.

As the recent copyright infringement lawsuit between NEC and Intel has demonstrated, this distinction begins to break down when an expression such as "microcode" can be argued to be functionally constrained. Here the industry faces a double-edged sword. On one hand, judges do not give functional works as broad a range of protection as expressive works. Thus, in weighing whether or not a copyright has been infringed upon, the courts tend to limit the criteria for infringement to literal or close to literal copies of the copyrighted work. This may leave the intellectual property investments of companies open to greater vulnerability. On the other hand, the danger of applying copyright to functional expressions is that in protecting against too wide a range of equivalents, copyright may monopolize all expression of the underlying function itself.

The application of copyright to intellectual property will face a challenge in areas where product differentiation is achieved through nonhardware customization. This would certainly include products such as gate arrays, PLDs, and ROMs. We expect to see infringement cases over device similarities begin to involve the users, suppliers, and licensors of cell libraries. As intellectual property increasingly accounts for the uniqueness of a device, litigation over such property will become more commonplace.

THE NEW JAPANESE STRATEGY

Surprising as it may seem, in 14 of the 20 years beginning in 1955, the value of Japan's imports exceeded that of its exports. Through the touchstone of high-quality, low-cost manufacturing, Japan has displayed a genius for leveraging borrowed innovation into successful consumer products. In 1985, this genius resulted in exports accounting for an impressive 3.5 percent of Japan's GNP. Japan's highly successful manufacturing strategy is epitomized by the rapidity with which it dominated the world market for MOS memories. Dataquest, however, sees a fundamental shift in Japan's strategy toward greater technological innovation and less reliance on the export-driven manufacture of lower-end commodities. A number of forces are compelling the Japanese to change direction, including:

- Competitive pressure from newly developed Pacific Basin countries in the commodity bastions of steel, automobiles, and low-end electronics

- The appreciation of the yen versus the dollar

- The Japanese government's move toward becoming less dependent on exports as an economic mainstay

- Technological parity with the West in a growing number of fields

Just as the semiconductor industry in Japan has always reflected the nation's export aggressiveness, it is now also reflecting the shift in strategy. Japanese semiconductor manufacturers now, in effect, own the markets in which they participate. Therefore, they no longer have to scramble to build market share through adding capacity. This is borne out by changes in the capital spending outlook for Japanese semiconductor firms. Measured in yen, 1986 Japanese capital spending is expected to decline approximately 30 percent from 1985. This steep decline represents the beginning of a fundamental restructuring of the Japanese semiconductor industry as it turns away from increasing manufacturing capacity and toward productivity-enhancing equipment and leading-edge technologies.

Between 1984 and 1988, Japanese electronics manufacturers will have opened at least 80 basic research laboratories. These R&D centers will oversee 25 IC-related projects in such leading-edge technologies as 4Mb and 16Mb DRAMs, 32-bit microprocessors, standard cells, three-dimensional CAD systems, VLSI design expert systems, automotive electronics, telecom ICs, optoelectronics, gallium arsenide, bioelectronics, voice recognition/synthesis, ceramic packaging, diamond substrates, and new materials. Assuming an average investment of $25 million to $33 million each, these laboratories collectively represent an estimated total investment of approximately $2.0 billion.

In addition to corporate R&D projects, Japan's Ministry of International Trade and Industry (MITI) has been working on its "Technopolis Project" since 1980. Combining urban and economic planning with Japan's desire for technological leadership, the technopolis strategy involves no less than the creation of Silicon Valley-like communities in more than 25 different locations in Japan--at a cost of between $1 billion and $2 billion each over the next two decades. These highly planned communities will combine academic centers, foreign and domestic corporations, public transportation systems, venture capital concerns--in short, all the necessary infrastructure for high-technology entrepreneurial activity.

Ironically, the short-term discomfiture that many of Japan's leading semiconductor exporters are now feeling as a result of the higher yen and the recent U.S./Japan trade agreement may well yield a long-term benefit. While the resulting price increases have a negative effect on the competitiveness of Japanese MOS memory devices, their positive effect on the corporate bottom line will likely help fund a transition to more value-added products. In part as a response to the MOS memory dumping suits and in part due to shifting strategies, the Japanese are already becoming more aggressive in the gate array market. Along with other Asian suppliers, some Japanese companies may be giving away nonrecurring engineering (NRE) costs to win designs. The impact is being felt: last year, CMOS gate arrays fabricated with 3-micron, double metal sold for approximately $0.01 per gate. Today's pricing is now down to $0.003 per gate.

ELECTRONIC CENTER OF GRAVITY SHIFTING TO THE PACIFIC

Winds of change from both the East and the West are propelling exports from the Pacific Basin's newly industrialized "Five Tigers": South Korea, Taiwan, Hong Kong, Malaysia, and Singapore. To begin with, a higher yen combined with the effects of the semiconductor trade agreement's Fair Market Values (FMVs) on MOS memory prices are forcing the Japanese to locate manufacturing in other Asian countries. Furthermore, since the currencies of the Pacific Basin countries are more or less pegged to the U.S. dollar, their goods and services become increasingly attractive as Japan's become more expensive. U.S. companies, which have already turned to Asia for low-cost manufacturing, have further incentive to invest brick and mortar in the region as a result of the new tax bill, which repeals investment tax credits for capital spending.

Dataquest estimates that because of increased off-shore manufacturing, $700 million in semiconductor devices that otherwise would have been consumed in Japan and the United States were instead consumed by the Five Tigers during the first half of 1986. This is further supported by the figures for rest-of-world (ROW) semiconductor consumption, which appear in the most recent Dataquest Quarterly Industry Forecast. While North American consumption of semiconductors for 1986 will increase less than 10 percent over 1985, ROW consumption will increase more than 50 percent, with a 60 percent increase in integrated circuits. The Pacific Basin markets have also grown stronger due to increased domestic demand for television sets, VCRs, and telecommunications products.

The U.S. trade deficit with Taiwan reached a record $13.1 billion in 1985, but this figure is somewhat misleading. The Five Tigers have become a manufacturing hinterland for both Japan and the United States. The economies of countries like Taiwan and Malaysia rest on the existence of large multinational corporations and thousands of cottage industries. Malaysia's leadership in chip assembly, for example, is due to the establishment of plants by Motorola, National Semiconductor, Texas Instruments, and Hewlett-Packard. As a result, exports from the Five Tigers are pulled from the United States and Japan more than they are pushed by the Pacific Basin countries themselves.

As Japan pursues its Technopolis strategy, it will increasingly relinquish low-end portions of its cherished commodity markets to the Five Tigers. Taiwan and South Korea have already emerged as leading personal computer producers, pulling off a feat that has as yet eluded their Japanese neighbors. Taiwan will export $730 million in kits and finished PC clones by year end, with 70 percent of these going to the United States. South Korea's Daewoo Telecom set the pace for Asian clone manufacturers with the successful Leading Edge Model D and expects sales of $400 million this year. While continuing in their roles as manufacturing hinterlands, we can expect to see the Pacific Basin countries follow the same value-added migration that the Japanese so successfully embarked on previously. The industrial and social changes that accompany this transformation may then draw new regions into the low end of high technology--countries such as India and China.

STRATEGIC ALLIANCES

High-technology firms have long found compelling reasons to form strategic alliances among themselves. As technologies advance, new commercial applications for technology abound. No one company, even in a well-defined area of expertise, can call all the new trends or exploit all the new product possibilities with equal proficiency. In a recent study of licensing agreements and joint ventures, Dataquest has observed the following trends:

- Alliances are increasing in number.
- Alliances are increasing in complexity.
- In alliances between U.S. and foreign firms that involve a transfer of technology, the technology is usually supplied by the U.S. company.
- An increasing number of alliances involve the sharing of fab capacity.

Dataquest has observed that from 1982 to the present, more than 60 licensing agreements and joint ventures have taken place in the United States in the MOS memory area alone--over 40 of which have occurred in the last 18 months. Many of these agreements have involved start-up companies unable to attract additional rounds of funding from venture capital sources.

Overall, the Japanese and Korean firms have weathered the current semiconductor slump better than their U.S. competitors. In Japan's case, this can be attributed to the association of semiconductor manufacturers with large, vertically integrated parent companies. In the case of Korea, government subsidies of exports have been a contributing factor. These advantages have given Asian electronics firms the cash to invest in new technologies. The prime targets of such investment have very often been cash-hungry U.S. start-up companies.

With technology as a bargaining chip, U.S. companies are trading innovation for capital, manufacturing capability, and market access. This trend has shown up most strongly in the area of MOS memories, where more than 80 percent of agreements have involved technology transfers by U.S. firms in return for cash or fab capacity. At the same time this trend in license agreements is occurring, U.S. companies are slowing their rate of R&D investment in response to the fiscal realities of the current industry slowdown. Unless the trend in R&D spending changes, U.S. firms may find themselves at the bargaining table with little to bid.

To avoid trading away tomorrow's competitive advantage for today's capital requirements, American firms must look to one another for the kinds of strategic alliances that provide the most effective sharing of resources. Given today's situation of overcapacity, there exists a logical opportunity for the pairing of companies possessing innovative design and technology with firms possessing the manufacturing capacity and marketing resources to carry them forward.

It is very likely that the industry will see increasing joint ventures and acquisitions among the larger merchant semiconductor firms in an attempt to consolidate market share in the face of low-cost suppliers from the Pacific Basin on the one hand, and to protect themselves from the deep-pocket clout of the NECs and AT&Ts of the world on the other. The imposition of price structures and the monitoring of Japanese manufacturers to prevent the precipitous erosion of IC prices may buy the critical time U.S. chip manufacturers need to make these kinds of accommodations.

DATAQUEST CONCLUSIONS

In reviewing the semiconductor megatrends under discussion, it becomes apparent that none are isolated phenomena. In actuality, each hints at the inevitability of another. Commodization of the computer is most certainly influenced by the ability to place a system on a chip. Advances in CAD technology are a critical factor in the advance of ASICs--the production of which will transform the industry into a more service-oriented business. The concentration on value-added products is further propelled by the shift in low-end manufacturing to the Pacific Basin, which in turn will drive the Japanese into competition with the United States in the value-added market and increase the concern of all players over the protection of valuable intellectual property.

The implications of all this are that the semiconductor industry is not only going through a recession, but through a restructuring as well. The nature of this restructuring very closely follows a megatrend pointed to by Mr. Naisbitt: the movement from centralization toward decentralization. To successfully compete in the ASIC world, the corporate structure of semiconductor firms increasingly will focus on the identification of application niches, particularly in transferring systems solutions to silicon. In so doing, these firms will stress customer support over internal fabrication capabilities. This will create a clear delineation between those firms that manufacture and those that supply. Future strategic alliance will recognize this distinction, bringing together the suppliers of applications know-how with the manufacturers and marketers of application-specific products. Such alliances will make possible the profitable servicing of market niches that the large, multinational semiconductor firms will not find economical to address.

Unquestionably, recognizing the directions and implications of change is important. Of greater ultimate importance, however, is how individuals and businesses structure themselves in response. In his book, Mr. Naisbitt challenges managers to continually ask the simple yet powerful question, "What business am I in?" Answering this question without assessing the forces that shape one's business does not augur well for a bright future. During the year to come, Dataquest will continue to focus on the semiconductor megatrends summarized in this newsletter. In so doing, we hope to both challenge our clients' assessments of their businesses, and to provide information and analysis in support of this process.

Michael Boss

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RESEARCH BULLETIN

SIS Code: 1986-1987 Newsletters: October
1986-43

PRELIMINARY DRAM FMV PRICES RELEASED

The U.S. Department of Commerce has provided Japan-based manufacturers with a new set of preliminary FMV (fair market value) prices for DRAMs. These FMV prices are in keeping with the U.S.-Japan semiconductor trade arrangement in which dumping tariffs were suspended in exchange for a commitment by Japanese manufacturers to provide access to Japanese markets and monitor prices. The Japan-based manufacturers have the opportunity of commenting and appealing before the prices are finalized on October 11 and put into effect on October 16.

INDICATIONS OF THE NEW PRELIMINARY FMVs

Indications are that the new FMV prices will fall within the range of $2.50 to $4.00 for a 256Kx1 NMOS DRAM in a dual-in-line package. Current FMV prices for this product range from approximately $2.80 to $8.00. This decrease will lower the average FMV by more than 30 percent and narrow the price differences among the manufacturers.

For the 1Mb DRAM, the price differences among manufacturers are expected to remain wide, although the low point of the range of new FMV prices is anticipated to drop to between $20 and $25 from the current $50 to $60.

FMV prices will be different for each manufacturer. They will also differ by package (such as PLCC and SOJ) and by organization (such as x1 and x4). FMV prices will also include standard DRAM modules such as SIPs and SIMMs and one specialty memory, the video RAM.

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DATAQUEST ANALYSIS

Dataquest believes that the potential impact of the new FMVs includes the following:

- We expect the trend toward offshore manufacturing and purchasing to continue, but at a more tempered rate. For users who have not yet done this, offshore manufacturing will remain a clear and viable option. Although the new round of FMV prices will narrow the gap between U.S. prices and those of Japan and Southeast Asia, the differences will still be significant.

- We expect purchasers to resume placing orders with more Japan-based manufacturers starting this month, but for more short-term requirements. Many buyers have been holding back orders because of the high FMV prices, in anticipation of new, lower FMVs in October.

- The 1Mb DRAM market is expected to resume its normal rate of development and should continue if future FMV prices follow the learning curve. Dataquest believes that the FMVs may result in diminishing the lead of the Japanese manufacturers over domestic and Korean suppliers. The current high 1Mb DRAM FMVs are a major concern of OEMs that have designed in the device. There are no viable commercial 1Mb DRAM suppliers other than the Japanese manufacturers.

Victor de Dios

Dataquest
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RESEARCH NEWSLETTER

SIS Code: 1986-1987 Newsletters: October
1986-42

SMART POWER ICs: TECHNOLOGICAL EVOLUTION WILL CREATE $2 BILLION OPPORTUNITY BY 1990

OVERVIEW

The stream of new product announcements and trade articles about smart power ICs reflects the early results of a technology and processing race that began around 1982 as discrete semiconductor manufacturers, linear IC houses, and start-up companies first sought to establish long-term positions in this nascent market. These firms and other recent entrants are eagerly and aggressively tapping into a total available market for smart power ICs that stands, excluding hybrid packages, at $0.9 billion in 1986 (although actual sales will be far less because all possible applications will not be immediately achieved), and that should grow to $1.95 billion by 1990 (again, actual sales will be less, but closer to the full target market). As we will discuss, including hybrids would enlarge the total available market by $300 million in 1986 and $500 million in 1990.

Although actual consumption will fall short of the total available market for sales, the raw magnitude of the business makes the smart power IC a key element in strategic plans for companies ranging from start-ups like Integrated Power Semiconductor and Maxim Integrated Products to industry giants like General Electric, Motorola, and Texas Instruments. Smart power chips will be an impact product for semiconductor manufacturers as well as for users (like us) of equipment that incorporate these chips, both at home and in industry. Although smart power represents more of an evolution than a revolution in semiconductor technology, the stakes are huge because the winners in this competition will earn millions of dollars in revenue during the next decade and, in the process, virtually assure themselves of a continuing role in an expanding segment of the semiconductor industry well into the 1990s.

Manufacturers continue to disagree about the definition of a smart power IC. As a working definition, Dataquest defines a smart power IC as a device that combines logic and/or analog circuitry with power-handling capabilities on a monolithic chip. We realize that no definition is as

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yet perfect in this young market: voltage regulators meet the strict definition of a smart power IC, and, in fact, smart power devices have been available in hybrid packages for years. The focus on the monolithic chip, however, spotlights an economic reality that in turn affects engineering design decisions: monolithic ICs lend themselves to low-cost volume production (compared with the more expensive hybrid packages), and the availability of less expensive parts typically accelerates new product design-ins and thus the rate of growth in consumption (as in the case of power MOSFETs).

The smart power IC business is not for all companies, and many successful semiconductor manufacturers of the next decade will not produce these chips. Even so, smart power ICs represent a genuine opportunity for merchant suppliers of discrete semiconductors and linear integrated circuits, for certain captive producers of semiconductors, and for start-ups that can devise specialized products or unique technologies. Semiconductor manufacturers interested in smart power technology face a host of tough strategic issues. For those thoroughly committed to the smart power market, strategic plans must be carefully reexamined with an eye to issues like the continuing vitality of the original product/technology choices, the impact of competitors' advances (or delays), growth prospects in application markets, newly discovered opportunities in terms of both specific products and broad business segments, and joint venture arrangements. As for those that have not yet entered the smart power IC business, the obvious "market entry" question becomes a matter of determining which segments or niches can support new entrants, how long the windows of opportunity will remain open (if not already closed), and whether the would-be entrant should develop its technology and products alone or else by way of a joint venture, technology transfer, or similar route.

For consumers as well as industrial producers, the smart power products made possible by these ICs will change the way we work just as microcomputers changed our ways of thinking and computing. Smart power ICs are going to have tremendous impact on personal life as well as commercial industry. Right now, microprocessor-based systems process information for us, but smart power chips extend the computer revolution a big step by enabling these systems to perform actual work. Smart power marks a fundamental change in the control and operation of electrical power. The impact of these power chips will be seen first in the home, automobile, and factory during the next two years as products like smart home appliances, automotive systems, and robotic factory controls move from the drawing board to end-market applications. The smart power chip market is still quite young, however, and the full impact of these ICs will not be felt until the 1990s, when the smart car, smart house, and smart factory become firmly integrated into our way of life.

To gauge demand for a given chip, smart power IC vendors need to know not only the magnitude of this market and its segments but also the consumption forecasts for a variety of application markets. Dataquest segments the smart power IC market on the basis of IC electronic characteristics (i.e., voltage and current) and then analyzes the forecasts for growth in relevant application markets. This approach provides a framework of analysis for companies already participating in or considering entry into the smart power IC business.

This newsletter addresses primarily the first issue--the overall magnitude of the smart power IC market--based on the prospects for growth in the critical end markets (i.e., application markets). This newsletter does not present a forecast of smart power IC consumption, but rather a measurement of the potential market (total available market) for these chips. Again, the focus will be on monolithic smart power ICs, with a separate discussion of the hybrid segment.

SMART POWER IC SUBMARKETS

To begin, Tables 1 and 2 summarize the two segments of the emerging market that most readily lend themselves to monolithic chip production. Based on industry discussions, Dataquest refers to these submarkets as "medium-power ICs" and "high-power ICs." The lists of product applications and competitors should be considered as representative, and not exhaustive.

Tables 1 and 2 also provide estimates in dollars of the total available market for smart power ICs in 1986 and 1990--which includes portions of the discrete semiconductor and linear IC markets vulnerable to displacement by smart power chips.

Medium-Power ICs

The first submarket for smart power applications is the medium-power segment. As can be seen from Table 1, all applications for medium-power ICs used to be served by discrete components. However, as the demand for digital switching technology for telephone systems and data transmission became more prevalent, digital chip engineers began devoting effort to these smart power ICs. The ICs needed for these telecommunication applications require voltages in excess of 100 volts and low currents of less than 100 milliamperes. Similarly, flat-panel display developers were looking desperately for lower-cost electronic row-and-column driver ICs. The same electrical environment existed for these display driver ICs as for telecommunications switches, so the developers of high-voltage, low-current switches also worked to develop display driver ICs. Much of the attention to smart power ICs has focused on the medium-power segment of the market.

High-Power ICs

The second submarket for smart power applications is the high-power IC segment. High-power ICs are needed to provide high currents of up to 10 amperes to drive small motors, operate power supplies, and regulate power. Closely tied to growth in the factory automation, industrial, and transportation markets, the high-power IC segment should become the mainstream of the smart power market by 1990, although few products exist as of 1986. Because these high-power chips do not lend themselves easily to commodity production, niche market opportunities will be available for producers in this segment. Table 2 describes the high-power IC market.

Table 1

ESTIMATED MEDIUM-POWER IC SUBMARKET

Total Available Market*	Application	Electronic Characteristics	Competitors
1986--$400M 1990--$750M CAGR 17%	Display drives Telecom switches High-voltage SLIC Very small DC-DC converters	To 200 volts To 100 milliamps output To 5 watts dissipation	Siliconix Sprague Texas Instruments Maxim Motorola

Table 2

ESTIMATED HIGH-POWER IC SUBMARKET

Total Available Market*	Application	Electronic Characteristics	Competitors
1986--$500M 1990--$1.2B CAGR 24%	DC motor drives in computer/office peripherals, automobiles AC motor control in robotics, industrial controls Power regulation Power supervision	To 400 volts To 10 amperes output To 50 watts dissipation	Integrated Power SGS Sprague Hitachi Unitrode Silicon General

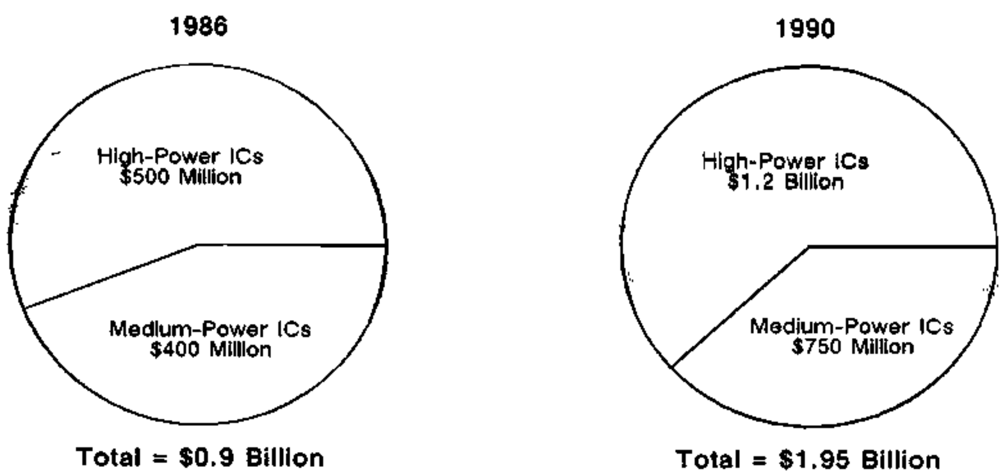
*Represents linear and discrete semiconductor markets vulnerable to displacement by smart power products, not necessarily the total market that will be served.

Source: Dataquest
October 1986

Figure 1 describes the 1986 and 1990 total available markets for smart power ICs (excluding hybrids).

Figure 1

ESTIMATED TOTAL AVAILABLE MARKET FOR SMART POWER ICs (Excludes Hybrids)



Source: Dataquest
October 1986

Our analysis of the total available market for smart power ICs shows that the basis exists for booming sales, but a host of problems must be solved before the $10-million market of 1985 can become the billion-dollar market of the 1990s. As of yet, few smart power chips are available in the marketplace, and only then at very high prices. General Electric is a major consumer of smart power ICs, but most of its needs are supplied internally. Design engineers need time to become familiar with the new ICs before demand will grow. The process by which engineers take a new chip and adapt it for commercial, industrial, and military use involves the kind of experimentation that eventually leads to a series of both anticipated and unforeseen product applications.

Technological limitations--such as the constraints faced in combining so much power in such close proximity to sensitive logic functions, or the fact that high-current capability means a sacrifice in chip space (except for the expensive hybrid package approach)--could thwart the development of monolithic smart power ICs for very high power applications. At the present time, with several exceptions, only hybrids can meet the demand for applications requiring more than 400 volts, more than 10 amps, and more than 50 watts of dissipation. Unless the challenging technical barriers are overcome, no monolithic smart power ICs will be developed to serve this potential niche of the market.

Very High Power Discretes

A third potential submarket for smart power applications is that of discrete power transistors. Table 3 provides an estimate of the total available market for very high power smart power chips should the technological barriers be overcome regarding monolithic chip products. Some manufacturers of discrete components have participated in the smart power motor-drive market by marketing their discretes in hybrid form with four or more separate chips inside the package. Such hybrids are too expensive, however, for motor-drive applications in computer peripherals, office products, and automobiles. Table 4 describes the very high power discrete market.

Vendors of smart power ICs must deal with tremendous pricing pressures. Some of the targeted end markets (e.g., computer peripherals and automotive electronics) are analogous to the consumer electronics market, and the typically aggressive pricing in those markets foretells low average selling prices for many smart power IC suppliers, especially those in the medium-power segment. Except for the huge volume producers like Hitachi or Motorola, producers will be hard pressed to recover the high costs of new IC development, and it will certainly not happen over a short period of time.

Table 3

ESTIMATED VERY HIGH-POWER DISCRETE MARKET

Total Available Market*	Application	Electronic Characteristics	Competitors
1986--$300M 1990--$500M CAGR 14%	Large DC motor drives Large AC motor drives Power supply outputs	To 100 amps output To 1,500 volts To 100 watts dissipation	Motorola General Electric RCA Toshiba Ixys Siemens General Instrument Siliconix Texas Instruments Int'l Rectifier

*Represents linear and discrete semiconductor markets vulnerable to displacement by smart power products, not necessarily the total market that will be served.

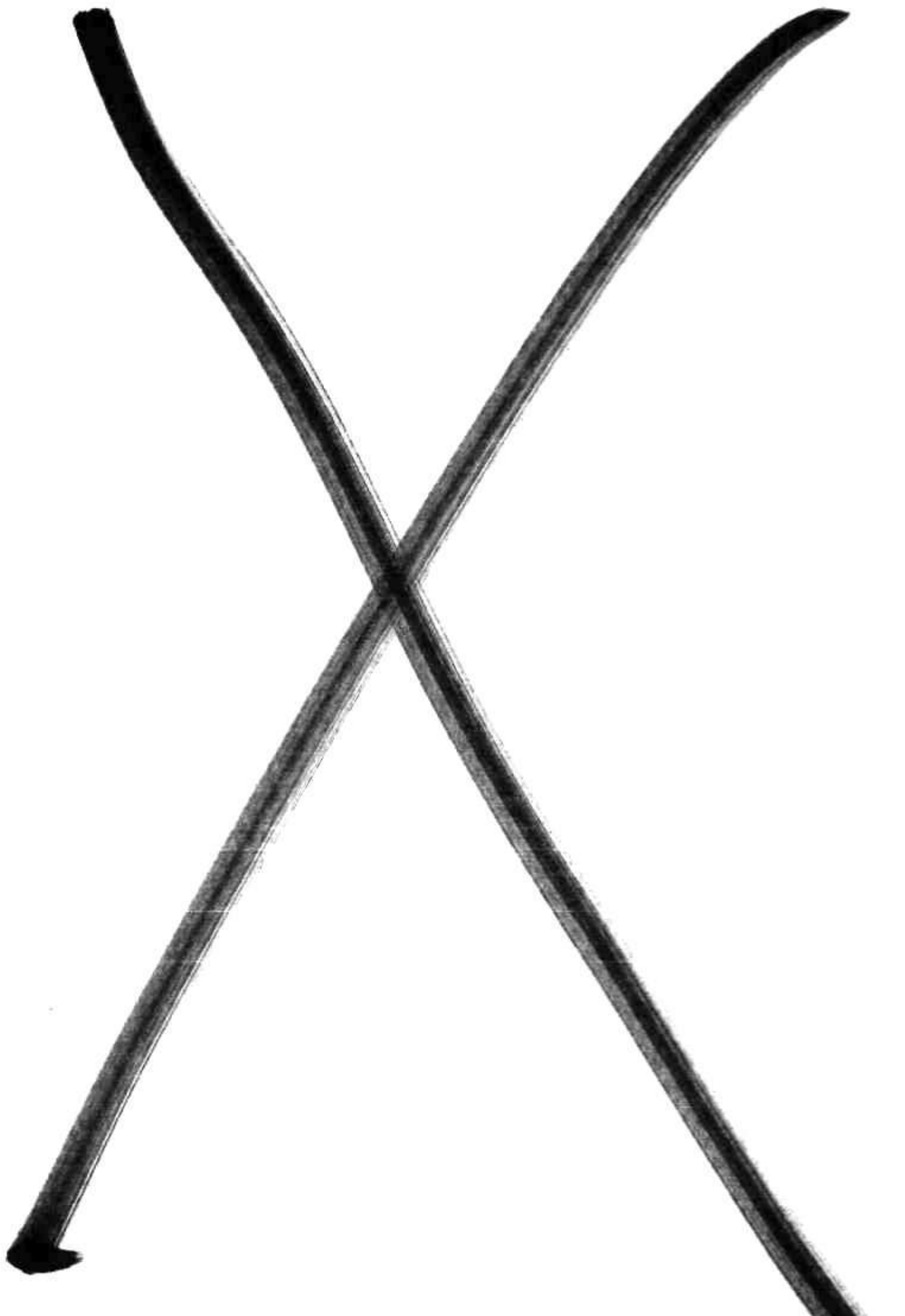
Source: Dataquest
October 1986

DATAQUEST CONCLUSIONS

Beyond the considerations discussed above, there is always the risk of unexpectedly slow growth in application markets. Part of the 1986 spotlight on the smart power market stems from a somewhat misguided belief that there already waits an application for each smart power chip in the same way that there does seem to be an existing or soon-to-be-discovered application for every power MOSFET. The critical, unresolved question becomes a high-tech version of the "chicken or the egg" puzzle: which comes first--the egg (the smart power IC) or the chicken (the product application, such as a flat-panel display)? That is, will the availability of a smart power chip lead to a boom in sales of a given smart product (e.g., high-voltage subscriber line interface circuits), or will the demand for the smart power IC remain strictly keyed to growth in the application markets? In the early growth stages of this marketplace, demand for smart power ICs will be closely linked to end-market demand, and only over time will the chips themselves lead to new applications and growth opportunities. In other words, for the short term, smart power IC manufacturers must know their targeted end markets as well as they know the semiconductor business.

Producers of smart power ICs confront a total available market of $0.9 billion in 1986 that will more than double to $2 billion by 1990 (excluding hybrids). But they will capture only a small portion of this year's total available market. Today's efforts by producers like General Electric, Integrated Power Semiconductors, Maxim, Motorola, Siliconix, and Texas Instruments puts those firms in a good position to capture a healthy share of the total available market in the future. A host of would-be suppliers will face more constrained opportunities, but the supplier base is far from settled. Strategic planning will focus as much on application market analysis as on assessments of the smart power IC market. As noted, over the long-term, new product applications will spring forth for smart power ICs, especially as prices decline. But in the short haul, vendors of smart power chips must closely track developments in the end markets.

Ron Bohn



November Newsletters

The following is a list of the newsletters in this section:

Dataquest
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RESEARCH BULLETIN

SIS Code: 1986-1987 Newsletters: November
1986-56

PRELIMINARY THIRD-QUARTER 1986 MICROCOMPONENTS UPDATE

The stagnation evidenced in semiconductor bookings toward the end of the first half of 1986 became very pronounced during the third quarter of this year. The third quarter is traditionally a weak period, and in the current flat business environment, it is not surprising that demand for products continued to be weak. Thus, bookings in Q3 1986 were essentially flat compared with the previous quarter. Some semiconductor manufacturers claim that order rates from domestic OEMs are showing strength, although distribution orders are flat and likely to remain so through the fourth quarter of 1986. High-end microcomponents are showing some strength, and this should benefit participants in the 32-bit microprocessor and 16-bit microcontroller markets. The European market remains stable if flat, while the Japanese market is weak with fierce price competition continuing. ROW is experiencing strong growth.

Although we expect that the industry may see some modest growth in bookings in 1986 over 1985, resulting primarily from activity in the first half of the year, no significant improvement is yet in sight. Dataquest does not anticipate any real recovery until sometime in the first half of 1987. The problem of excess capacity continues to plague the large semiconductor manufacturing companies, and the hopeful signs that some companies are seeing are unlikely to result in strong positive growth until the computer industry segment starts showing improvement.

In the microcomponent area, as can be seen from Table 1, Dataquest is currently forecasting marginal revenue growth in the fourth quarter over the third quarter. However, billings in October were lower than expected, so unless November and December are better than anticipated, the annual growth that was projected at approximately 27 percent over 1985 may have to be revised slightly downward.

Patricia A. Galligan

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Table 1

WORLDWIDE QUARTERLY MICROCOMPONENTS FORECAST
(Millions of Dollars)

	1986				
	Q1	Q2	Q3	Q4 (Est.)	Year
MCU	$321	$358	$317	$308	$1,304
MPU	122	136	143	144	545
MPR	378	400	417	443	1,638
Total	$821	$894	$877	$895	$3,487

Source: Dataquest
November 1986

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RESEARCH BULLETIN

SIS Code: 1986-1987 Newsletters: November
1986-55

MARKETING STRATEGY HIGHLIGHTS 80386 AT COMDEX

To the uninitiated observer at Comdex 1986 in Las Vegas, Nevada (held November 10 through 14), it might have seemed that the world's first 32-bit microprocessor was about to be unveiled. One year and one month after the introduction of the 80386 in San Francisco, it appeared that Intel was using Comdex as the medium to announce some significant design-ins of its promising young star 32-bit microprocessor--the 80386--and to present its graphics product offering--the 82786. National Semiconductor claims the distinction of having been first to the market with a 32-bit microprocessor--the 32032--which is second sourced by Texas Instruments, whereas Motorola with its 68020 has been the volume shipper over the last two years. Both National and Motorola have extensive lists of design-wins based on their 32-bit microprocessors, with many products already available and on display at Comdex. At Intel's November 11 press conference, Dave House, vice president and general manager of Intel's Microcomputer Group, stated that design-wins for the 80386 currently stand at 200. Mr. House recognized some of the 25 or more companies previewing 80386-based products at Comdex.

A substantial base of existing application software designed for the IBM PC is a major incentive toward fostering the PC as a standard platform while offering higher performance and connectivity through the 80386. By achieving for the desktop computer the features currently associated only with workstations (e.g., multitasking, multiuser capability, speed, enhanced graphics, and access to application software available under alternative operating systems), the new generation of 80386-based PCs promises increased performance and productivity at a fraction of today's cost. However, until an 80386 protected-mode operating system is made available by Microsoft and IBM, the first product offerings will primarily be faster ATs.

A myriad of products, including 80386-based computers, accelerator boards, replacement and coprocessor boards, and support tools, were on display at Comdex. Convergent announced its Series 386 NGEN--a desktop workstation that provides concurrent access to application bases developed for multiple operating systems, multitasking, and networking capabilities. Desktop 80386-based PCs were being displayed by such

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vendors as Kaypro, Multitech, Rexon Business Machines, and Zenith. Board-level products were displayed by Applied Reasoning, Intel, Orchid, and Quadram. Several ISVs were previewing multiuser/multitasking support for 80386-based products such as Locus Computing's simultaneous and transparent execution of UNIX and MS-DOS operating systems or Softguard's multiuser DOS operating system.

One notable product announcement concerned MAD Intelligent Systems' "AI adaptive" workstation--the D3000--which is the first to incorporate both the 80386 and the 82786 graphics chip to bridge AI technology with information-processing applications in a PC AT-compatible environment. In fact, Intel is placing considerable emphasis on the 80386 as the engine of choice for AI and expert-type systems. Common LISP products for the 80386 are being supplied by such companies as Franz, Inc., Gold Hill, and Lucid Inc.

Activity involving the 80386 really became noticeable in the couple of months preceding Comdex, during which time Compaq introduced its DESKPRO 386, Microsoft offered the Xenix System V/386 operating system, and Chips and Technologies launched its seven-chip 386-CHIPSet. Perhaps most significantly, the recent IBM-Intel agreement to exchange IBM's gate array and packaging technology for rights to Intel's 80386 supports speculation that IBM will offer an 80386-based product in the 1987 time frame.

Speakers at Intel's press conference continually referred to the 80386 as a flagship product. If Intel intended to use Comdex to promote the 80386, it succeeded in generating considerable anticipation about the product, despite the fact that real systems using the full capabilities of the 80386 microprocessor are still in the development stages. Speculation about yet to be discovered next-generation applications that will use the chip's power and will fuel renewed growth in the computer market remains just speculation. Meanwhile, 32-bit microprocessor applications such as technical workstations are being supported by Motorola, and National has successfully targeted embedded and military applications with its family of 32-bit microprocessors.

Trish Galligan

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RESEARCH
NEWSLETTER

SIS Code: 1986-1987 Newsletters: November
1986-52

THE 1Mb DRAM: AN ENVIRONMENTAL ANALYSIS

As the leading edge DRAM, the 1Mb DRAM has assumed a very visible role in the semiconductor arena. This environmental analysis will discuss the major environmental areas related to the 1Mb DRAM and the issues involved. These areas are: market size and growth, influence of FMV prices, growing product diversity, and the changing supplier base.

MARKET OUTLOOK

Currently, Dataquest expects the 1986 1Mb DRAM market to hit $126 million, with shipments of 3.5 million units. During the last quarter of 1985, expectations for growth of this market were much higher. With the depressed prices of the 256K DRAM, many manufacturers were looking to the 1Mb DRAM as a profitable alternative.

But reality set in. Most manufacturers did not hit their targeted production schedules. The intended price decrease, toward an early price-per-bit crossover, was interrupted by tariff penalties for Japan-made devices and subsequently, by the U.S.-Japan semiconductor trade arrangement. Major OEMs were not as quick to use the part because of the new pinout and package.

Nevertheless, 1Mb DRAM prospects remain bright, as shown in Table 1. Dataquest expects the 1Mb DRAM market to grow to more than $2 billion by 1990, with total shipments of 900 million units. We believe that the 1Mb DRAM market will differ from that of the 256K in certain aspects.

- CMOS DRAMs will dominate from the beginning, accounting for 95 percent of total 1Mb DRAM revenue in 1990. Although many manufacturers have introduced NMOS 1Mb DRAMs, they have indicated that they will produce CMOS versions within 1987.
- Surface-mount package and ZIP usage is anticipated to be larger than DIP in 1989.

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- The 1Mbx1 DRAM is expected to be only 67 percent of the total 1Mb DRAM market in the peak year, 1990, while the 256Kx1 DRAM is expected to be 80 percent of the total 256K DRAM market in the peak year, 1987. The change is due to an anticipated preference for the 256Kx4. Many 256Kx1 and 64Kx4 users are expected to upgrade to the 256Kx4 for better flexibility in configuring their system memories.

Table 1

1Mb DRAM FORECAST

	1986	1987	1990
Total 1Mb Units (Millions)	3.5	40	900
ASP ($)	$36.00	$17.14	$ 2.43
Dollars (Millions)	$ 126	$ 685	$ 2,183
Units (Millions)			
1Mbx1	3.5	36	666
256Kx4		3.6	207
Others		0.4	27
NMOS	0.6	4	45
CMOS	2.9	36	855
DIP	3.4	25	396
SOJ/ZIP/Others	0.1	15	504

Source: Dataquest
November 1986

PRICES AND THE INFLUENCE OF FMVs

Dataquest expects the FMV prices determined by the U.S. Department of Commerce as part of the U.S.-Japan semiconductor trade arrangement to play a significant role in the development of the 1Mb DRAM market and its competitive profile. Future FMV prices can change the forecast given above, since they affect the Japan-based companies that are expected to account for 91 percent of 1Mb DRAM supply by the end of 1986.

Two factors have already influenced the market:

- The first round of FMV prices raised preagreement price quotes by more than 100 percent--from $20-to-$30 to $50-to-$60--between mid-July and mid-October. The price-per-bit crossover schedule has shifted by about six months and is now expected to occur in the beginning of 1988.

- Since the FMV prices are released every quarter, forward pricing beyond a quarter has been made more difficult. Forward pricing is an industry tool to encourage users to design in and purchase a new device early by showing them the projected decrease in price until a per-bit crossover occurs. This has worked well in helping markets ramp for new densities. Japan-based suppliers no longer possess control of actual prices that they can give in the future.

The FMV price determination is also likely to influence the competitive makeup of the 1Mb DRAM market. Except for Toshiba, which is ahead by far in the learning curve, the six-month lead of other Japan-based manufacturers may diminish vis-a-vis the Korean, U.S., and European suppliers that are not constrained by the agreement.

PRODUCT DIVERSITY

The 1Mb DRAM market will have a proliferation of versions. These versions parallel those of the 256K DRAM. However, unlike the 256K DRAM market, they will be available early in the 1Mb DRAM product life, standards have been defined, and OEMs are familiar with them. The versions will be different combinations of packaging, mode, organization, process technology, and specialty features, as shown in Table 2. This product diversity will segment customer needs further and alter the nature of competition.

Table 2

1Mb DRAM VERSIONS

By Process	By Organization	By Package	By Mode	By Features
CMOS	1Mbx1	DIP	Page	Dual Port
NMOS	256Kx4	SOJ	Nibble	FIFO
	128Kx8	ZIP	Static Column	
		SIP		
		SIMM		

Source: Dataquest
November 1986

THE MARKET PLAYERS

The number of 1Mb DRAM suppliers is expected to be just as high as that of the 256K DRAMs. Including those currently in production, 16 manufacturers have already indicated that they will be producing 1Mb DRAMs in 1987. One-half of the 16 suppliers are Japanese companies. Of the companies already in production, only one company, AT&T, is not a Japanese firm.

It will be interesting to note the performance of a few relatively new entrants into the 256K DRAM market who hope to penetrate the 1Mb DRAM field early. These companies include Hyundai, NMB Semiconductors, Samsung, Siemens, and Vitelic.

The relative positions of 1Mb DRAM suppliers have changed compared with those of the 64K and 256K DRAMs, which have been dominated by Hitachi, NEC, and Fujitsu. Toshiba has gained a firm lead in 1Mb volume production and its position in the cost curve. Its licensing agreement with Siemens has helped defray development costs. The FMV price determination has so far been advantageous to Toshiba because of the company's cost lead and because it prevents other Japan-based companies from matching Toshiba's price to ramp volume. Contrast that with Toshiba's number four position in 256K DRAMs and number twelve position in 64K DRAMs at the end of 1985.

DATAQUEST CONCLUSIONS

Dataquest believes that:

- The race for 1Mb DRAM leadership is not yet clear. The true test will be in bringing up and sustaining high-volume production at the lowest cost. Japan-based suppliers have to also consider capacity utilization as an important element in gaining leadership, since the FMV price determination is closely tied to it. Several manufacturers, including those already in production, seem to still be coping with the complexities of 1-micron geometries.

- The product diversity of the 1Mb DRAM will allow relatively smaller manufacturers to compete effectively in the market. Large OEMs will be hard pressed to efficiently manufacture every version for everyone.

The 1Mb DRAM market is still unfolding. This product, its suppliers, and its users have to contend with factors that were not present in the same stage of the 256K DRAM's product life: the growing influence of both U.S. and Japanese governments, the changing supplier base, and the diversity of product versions. DRAM manufacturers now have to observe the transforming market environment more closely than ever.

Victor G. de Dios

Dataquest

Conference Schedule

1986

Semiconductor	October 20–22	Hotel Inter-Continental San Diego, California
Technical Computer	November 3–5	Silverado Country Club Napa, California
Asian Peripherals	November 5–7	Hotel Okura Tokyo, Japan
Semiconductor Users/ Semiconductor Application Markets	November 10	Sheraton Harbor Island San Diego, California
Electronic Publishing	November 17–18	Westin Copley Place Boston, Massachusetts
CAD/CAM EDA	December 4–5	Santa Clara Marriott Santa Clara, California

1987

Semiconductor Users/ Semiconductor Application Markets	February 4–6	Saddlebrook Resort Tampa, Florida
Copying and Duplicating	February 23–25	San Diego Hilton Resort San Diego, California
Electronic Printer	March 23–25	Silverado Country Club Napa, California
Japanese Semiconductor	April 13–14	The Miyako Kyoto, Japan
Telecommunications	April 13–15	Silverado Country Club Napa, California
CAD/CAM	May 14–15	Hyatt Regency Monterey Monterey, California
Display Terminals	May 20–22	San Diego Hilton Resort San Diego, California
European Semiconductor	June 4–5	Palace Hotel Madrid, Spain
European Copying and Duplicating	June 25–26	The Ritz Hotel Lisbon, Portugal
Financial Services	August 17–18	Silverado Country Club Napa, California
Western European Printer	September 9–11	Palace Hotel Madrid, Spain
European Telecommunications	October 1–2	Monte Carlo, Monaco
Semiconductor	October 19–21	The Pointe Resort Phoenix, Arizona
Office Equipment Dealers	November 5–6	Hyatt Regency Monterey, California
Electronic Publishing	November 16–17	Stouffer Hotel Bedford, Massachusetts
CAD/CAM EDA	December 10–11	Santa Clara Marriott Santa Clara, California

Dataquest

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The IBM 3270 Market: 1986 and Beyond

Korean Semiconductor Industry Analysis

Diskettes—The Market and Its Requirements

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  - Computer Storage—Optical
  - Computer Storage—Subsystems
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  - Japanese Printer Strategy
  - Japanese Telecommunications Strategy
  - Canon CX Laser—User Survey
  - Digital Signal Processing
  - PC-based Publishing
  - Taiwan Semiconductor Industry Analysis
  - China Semiconductor Industry Analysis
  - PC Distribution Channels
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*On-line delivery option available

For further information about these products, please contact your Dataquest sales representative or the Direct Marketing Group at (408) 971-9661.

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RESEARCH NEWSLETTER

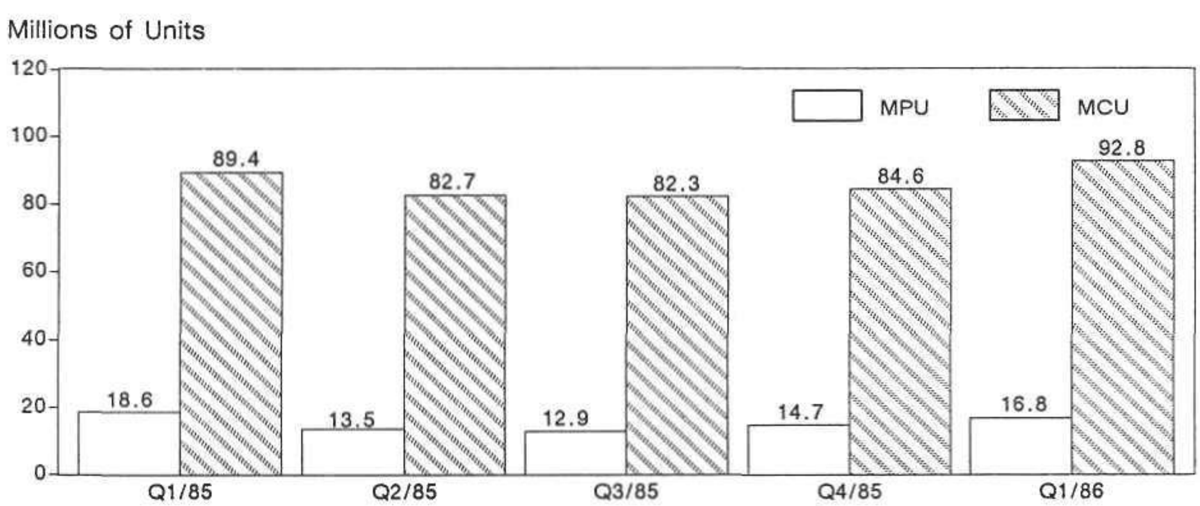
SIS Code: 1986-1987 Newsletters: October
1986-51

FIRST QUARTER 1986 MICROPROCESSOR AND MICROCONTROLLER UNIT SHIPMENT UPDATE

During the first quarter of 1986, worldwide microprocessor and microcontroller unit shipments increased by approximately 10.2 million units, or 10.3 percent, from fourth quarter 1985. Estimated shipments of all microcontroller devices totaled approximately 92.8 million units. Shipments of all MCU categories increased. Estimated shipments of all microprocessor devices totaled approximately 16.8 million units. Shipments of 8-bit MPUs and 16-bit MPUs increased in the first quarter by 12 percent and 17 percent, respectively, over the prior quarter's shipments. Figure 1 shows MCU and MPU unit shipments from the first quarter of 1985 through the first quarter of 1986.

Figure 1

MICROCONTROLLER AND MICROPROCESSOR UNIT SHIPMENTS FIRST QUARTER 1985 THROUGH FIRST QUARTER 1986 (Millions of Units)



Source: Dataquest
October 1986

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Table 1 shows the quarterly revenue for microcontrollers and microprocessors from the first quarter 1985 through the first quarter 1986.

Table 1

TOTAL MICROCONTROLLER AND MICROPROCESSOR REVENUE
FIRST QUARTER 1985 THROUGH FIRST QUARTER 1986
(Millions of Dollars)

	Q1/85	Q2/85	Q3/85	Q4/85	Q1/86
MCU	$293.9	$255.6	$260.0	$300.0	$322.0
MPU	131.0	102.0	96.0	104.8	99.0
Total	$424.9	$357.6	$356.0	$404.8	$421.0

Source: Dataquest
October 1986

Table 2 shows the change in total microcontroller unit shipments from the fourth quarter of 1985 through the first quarter of 1986.

Table 2

TOTAL MICROCONTROLLER UNIT SHIPMENTS
FOURTH QUARTER 1985 THROUGH FIRST QUARTER 1986
(Thousands of Units)

	Q4/1985		Q1/1986		Percent Growth
MCU	Units	Percent of Shipments	Units	Percent of Shipments	Q4 to Q1
4-Bit	45,635	53.9%	51,130	55.1%	12.0%
8-Bit	38,883	46.0	41,587	44.8	7.0%
16-Bit	71	0.1	75	0.1	5.6%
Total	84,589	100.0%	92,792	100.0%	9.7%

Source: Dataquest
October 1986

Table 3 shows the change in total microprocessor unit shipments from the fourth quarter of 1985 through the first quarter of 1986.

Table 3

TOTAL MICROPROCESSOR UNIT SHIPMENTS
FOURTH QUARTER 1985 THROUGH FIRST QUARTER 1986
(Thousands of Units)

	Q4/1985		Q1/1986		Percent
MPU	Units	Percent of Shipments	Units	Percent of Shipments	Growth Q4 to Q1
8-Bit	12,442	84.4%	14,069	83.9%	13.1%
16-Bit	2,234	15.2	2,623	15.6	17.4%
Others	59	0.4	80	0.5	35.6%
Total	14,735	100.0%	16,772	100.0%	13.8%

Source: Dataquest
October 1986

Table 4 shows the change in the shipments of the leading 8-bit MPUs from the fourth quarter of 1985 through the first quarter of 1986.

Table 4

LEADING 8-BIT MICROPROCESSOR SHIPMENTS
FOURTH QUARTER 1985 THROUGH FIRST QUARTER 1986
(Thousands of Units)

	Q4/1985		Q1/1986		Percent
Device	Units	Percent of Shipments	Units	Percent of Shipments	Growth Q4 to Q1
Z80	4,988	40.0%	5,585	39.7%	12.0%
8085	3,200	25.7	3,007	21.4	(6.0%)
6802	865	7.0	1,675	11.9	93.6%
8088	979	7.9	895	6.3	(8.6%)
6809	680	5.5	686	4.9	0.1%
Others	1,730	13.9	2,221	15.8	(28.4%)
Total	12,442	100.0%	14,069	100.0%	13.1%

Source: Dataquest
October 1986

Table 5 shows the changes in estimated shipments of 16-bit microprocessors from the fourth quarter of 1985 through the first quarter of 1986.

Table 5

16-BIT MICROPROCESSOR SHIPMENTS
FOURTH QUARTER 1985 THROUGH FIRST QUARTER 1986
(Thousands of Units)

	Q4/1985		Q1/1986		Percent
		Percent of		Percent of	Growth
Device	Units	Shipments	Units	Shipments	Q4 to Q1
8086	599	26.8%	675	25.7%	12.7%
68000	618	27.7	629	24.0	1.8%
80286	445	19.9	507	19.3	13.9%
V30	130	5.8	310	11.8	138.5%
80186	228	10.2	272	10.4	19.3%
Z8000	85	3.8	91	3.5	7.1%
32016	75	3.4	81	3.1	8.0%
Others	54	2.4	58	2.2	7.4%
Total	2,234	100.0%	2,623	100.0%	17.4%

Source: Dataquest
October 1986

Table 6 shows the changes in estimated shipments of 8-bit microcontrollers from the fourth quarter of 1985 through the first quarter of 1986.

Table 6

8-BIT MICROCONTROLLER SHIPMENTS
FOURTH QUARTER 1985 THROUGH FIRST QUARTER 1986
(Thousands of Units)

	Q4/1985		Q1/1986		Percent
		Percent of		Percent of	Growth
Device	Units	Shipments	Units	Shipments	Q4 to Q1
6805	6,776	14.5%	6,393	17.5%	(5.7%)
8049	5,999	17.1	6,491	15.2	8.2%
8051	4,155	10.3	3,692	10.2	(11.1%)
8048	3,110	11.1	3,415	8.5	9.8%
Others	18,843	47.0	21,596	48.6	14.6%
Total	38,883	100.0%	41,587	100.0%	7.0%

Source: Dataquest
October 1986

Table 7 shows market share by technology for 8-bit microcontroller and microprocessor devices from the first quarter of 1985 through the first quarter of 1986, and indicates increased shipments of 8-bit CMOS microprocessors.

During first quarter 1986, approximately 79 percent of all 8-bit CMOS MCU shipments and approximately 66 percent of all 8-bit CMOS MPU shipments were Japanese manufactured and shipped.

Table 7

**MARKET SHARE BY TECHNOLOGY FOR MICROCONTROLLERS AND MICROPROCESSORS
FIRST QUARTER 1985 THROUGH FIRST QUARTER 1986**

Device	Tech.	Q1/85	Q2/85	Q3/85	Q4/85	Q1/86
8-Bit MCU	CMOS	16.9%	20.4%	20.4%	21.6%	21.3%
8-Bit MCU	NMOS	83.1	79.6	79.6	78.4	78.7
Total		100.0%	100.0%	100.0%	100.0%	100.0%
8-Bit MPU	CMOS	12.0%	15.2%	17.2%	19.3%	24.5%
8-Bit MPU	NMOS	88.0	84.8	82.8	80.7	75.5
Total		100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest
October 1986

DATAQUEST ANALYSIS

Dataquest estimates that revenue from microprocessor and microcontroller shipments for first quarter 1986 was $421 million, an increase of approximately 4 percent from the previous quarter.

Patricia Galligan

Dataquest
a company of The Dun & Bradstreet Corporation

RESEARCH NEWSLETTER

SIS Code: 1986-1987 Newsletters: November
1986-50

AT&T: A COMPANY IN TRANSITION

SUMMARY

AT&T has gone through many changes over the past five years. Among them was the government's divesting AT&T from its communications empire. The company broadened its international focus through acquisition and strategic alliances, and decided to enter the merchant semiconductor industry. This newsletter will discuss the nature of this electronics giant while focusing on the semiconductor segment of its business.

BACKGROUND

AT&T's history began in electronics. Bell Laboratories, which was founded in 1925, is responsible for many of the most important technological developments in electronics today--the transistor, the laser, and the solar cell. The following are some of AT&T's historical landmarks:

- 1947--The transistor invented
- 1954--Solar cell technology invented
- 1958--Principles of laser technology conceived
- 1960s--Lightwave communication work began
- 1970s--Research work of 32-bit microprocessor conducted
- 1980--Digital signal processor introduced
- 1981--WE 32000, the first 32-bit microprocessor introduced
- 1982--The first manufacturable 256K DRAM announced

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- 1984--The smallest-ever one-dimensional transistor introduced; second-generation 32-bit microprocessor, the 32100, announced

- 1985--Manufacturable 1Mb DRAM chip announced

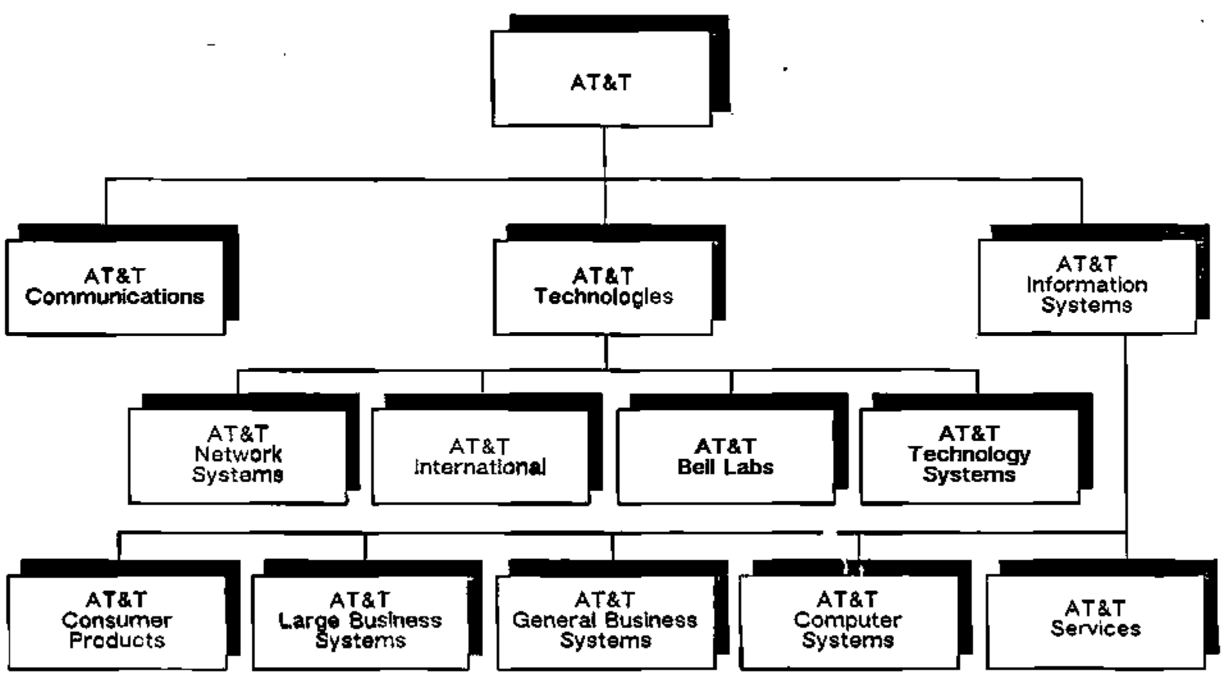
AT&T is an international corporation that participates in numerous product markets. The key markets are the telecommunication networks, information systems, telephone products, and related electronic components for high-technology products. AT&T manufactures equipment and services equipment in the telecommunications area.

COMPANY ORGANIZATION

AT&T is structured to service the various elements of its business. Figure 1 shows the AT&T organization chart. AT&T Communications focuses on long-distance communications. AT&T Network Systems is a supplier of central office equipment. AT&T International services communication systems worldwide. AT&T Bell Laboratories continues its renowned research and development work. AT&T Information Systems offers computers and information systems for business and home use. And AT&T Technology Systems supports systems products with components for internal and external sales.

Figure 1

AT&T ORGANIZATION CHART



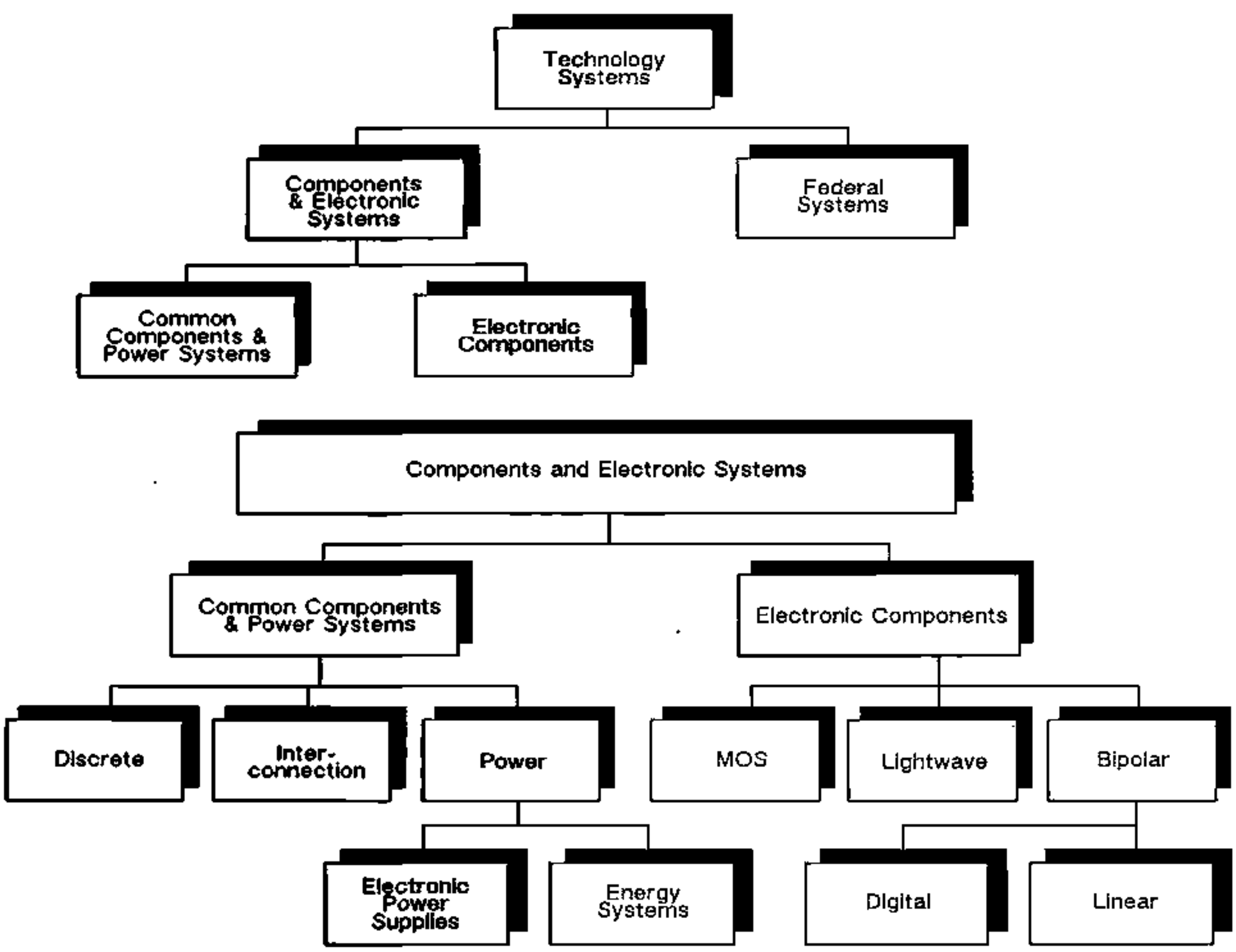
Source: AT&T

AT&T Technology Systems

AT&T Technology Systems is divided into two segments: Federal Systems, and Components and Electronic Systems, as shown in Figure 2. Components and Electronic Systems is further segmented into Common Components/Power Systems and Electronic Components. Common components and power systems include discrete devices; interconnection products, such as connectors and hybrid ICs; and power systems, such as converters and power modules. Electronic components encompass technologies of MOS, bipolar, and lightwave. MOS products include the 256K and 1Mb DRAM chips, modem chips, and the WE 32100 chip set, a 32-bit microprocessor family. Bipolar digital and analog circuit offerings are mainly components for data and voice communications. Lightwave products are fiber optics that transmit data over long distances.

Figure 2

AT&T TECHNOLOGY SYSTEMS ORGANIZATION CHART



Source: AT&T

International Operations

Over the past ten years, AT&T has substantially increased its international presence. There are 24 offices worldwide that sell to 90 countries. In 1985, more headway was made by AT&T in its mission to become a world competitor. Through direct sales, acquisitions, joint ventures, and comarketing agreements, AT&T added strength to its international presence. The following is a list of strategic alliances:

- AT&T and Philips--Joint venture to manufacture and market network transmission systems in Europe and other regional markets
- Olivetti--Equity interest in Olivetti purchased in 1984; joint effort to develop and market office automation products primarily in Europe
- SGS--Cooperative five-year marketing agreement under which SGS will market and sell AT&T's linear bipolar and high-voltage ICs previously used only in AT&T equipment; design support to SGS customers to be provided by AT&T
- UNIX Europe--A wholly owned subsidiary, based in London, that markets and licenses the UNIX system throughout Europe
- AT&T Microelectronica Espana--Joint venture with the Spanish telephone company to produce custom integrated circuits for the European market
- Gold Star Semiconductor--Joint venture with Lucky-GoldStar of Korea to manufacture switching machines and to distribute a family of computers in Korea
- Gold Star Fiber Optic--Joint venture with Lucky-GoldStar to manufacture fiber optic cable for the Korean market
- AT&T Taiwan Telecommunications, Inc.--Four-way venture with AT&T, Directorate General of Telecommunications of Taiwan, the Bank of Communications, and the Yao-Hua Glass Company to manufacture the 5ESS switch in the Taiwan market
- Western Electric Saudi Arabia--Joint venture with A.S. Bugshan Bros. to install, operate, and maintain the telecommunications operations in Saudi Arabia
- UNIX Pacific--Wholly owned company, based in Tokyo, that markets and licenses the UNIX System in Asia
- Synertek Facilities--Honeywell's Synertek facilities in Singapore, Thailand, West Germany, and California that AT&T purchased to design and manufacture electronic components

AT&T has manufacturing, sales, and design facilities worldwide, as shown by Table 1. Its strongest presence is in the United States. Within the last decade, AT&T has significantly increased its world position by adding more facilities.

Table 1

AT&T MANUFACTURING PLANTS AND DESIGN CENTERS

Location	Products	Comments
Santa Cruz, CA	Memory	Currently closed; acquired from Synertek
Sunnyvale, CA	ASIC	Fully staffed design center
Los Angeles, CA	ASIC	Future regional design center
Minneapolis, MN	ASIC	Future regional design center
Kansas City, MO	Transistor diodes	Small line
	1-Megabit DRAM	MOS technology
Allentown, PA	DRAMs, MPU, logic	CMOS and NMOS technology
	Logic	Bipolar technology
	ASIC	MOS technology
	ASIC	Fully staffed design center
Reading, PA	Switches, telecom	Bipolar technology
	Linear	Bipolar technology
Boston, MA	ASIC	Future regional design center
Orlando, FL	ASIC, 32-bit MPU	CMOS technology
London, United Kingdom	ASIC	Design center
Munich, West Germany	ASIC	Design center
Paris, France	ASIC	Future design center
Madrid, Spain	ASIC	Design center
	Custom	Future CMOS manufacturing, planned for 1987
Bangkok		Assembly and test
Singapore		Assembly and test
	ASIC	Design center planned for 1986
Japan	ASIC	Future design center

Source: Dataquest
November 1986

INVESTMENT

AT&T spends large sums of money on corporate capital spending and research and development to remain a leader in the industry. When the company entered the merchant semiconductor market in 1984, it spent about $400 million in the integrated circuit area. In 1985, AT&T as a whole spent a total of more than $4.5 billion, a 27 percent increase over 1984.

Research and development activities include private work and joint research. AT&T spent more than $2.2 billion on corporate-sponsored research in 1985. This work primarily included activities performed by Bell Telephone Laboratories, AT&T's wholly owned subsidiary. Bell Telephone works with many research organizations including the Microelectronics and Computer Technology Corporation and Bell Communications Research. The Microelectronics and Computer Technology Corporation focuses its research on advance computer architectures, semiconductor packaging/interconnect, software, VLSI, and computer-aided design. Bell Communications Research works with telephone and computer network technologies. AT&T Technologies, the semiconductor division, also participates in the joint research work of the Semiconductor Research Corporation (SRC), which pursues the development of the semiconductor industry.

AT&T MERCHANT SEMICONDUCTOR PRODUCT OFFERINGS

Beyond its well-publicized 1Mb DRAM, AT&T offers a variety of semiconductor products developed from its telecommunications and computer needs, as shown by Table 2. AT&T produced about $600 million worth of products in 1985, down from an estimated $1 billion in 1984. Approximately 10 to 15 percent of the products produced are sold to the merchant market. Table 3 shows the estimated technology and product split for 1985.

Table 2

AT&T's COMPONENTS AND ELECTRONICS SYSTEMS PRODUCT LINE

AC Plasma Displays

Cable and Wire

- Electronic wire
- Exchange and toll cable
- Mechanical and electrical protection
- Cross connection
- Building entrance terminal
- Network interface

Energy Systems

- DC/DC converters
- AC/DC electronic power supplies
- DC/DC power modules
- Uninterruptible power systems
- Power line conditioners
- Battery plants
- AC reserve

(Continued)

Table 2 (Continued)

AT&T's COMPONENTS AND ELECTRONICS SYSTEMS PRODUCT LINE

Interconnection Products

- Flexible printed wiring
- Multilayer PWBs
- Hybrid ICs

Lightwave Products

- ODL data links
- Data interfaces
- Long-haul transmission subassemblies
- Optical components
- Passive components

Lightguide Products

- Connectors and jumpers
- Connectorized cable
- Single-mode and multimode fibers/cables
- Splices
- Cabinets
- Installation service
- Hardware

Linear Integrated Circuits

- High-voltage
- Bipolar

MOS Integrated Circuits

- Memory
    - Dynamic RAMs (DRAMs)
        - Commercial
        - Military
    - Dual-port RAMs
    - Video RAM (RARAM memory)
- Communications
    - Modems
    - Protocol controllers & formatters
    - Digital encryption devices including random number generator

(Continued)

Table 2 (Continued)

AT&T's COMPONENTS AND ELECTRONICS SYSTEMS PRODUCT LINE

MOS Integrated Circuits (Continued)

- Application-Specific ICs
  - Gate arrays
  - Standard cells
- Digital signal processors

Optoisolators

- Autopolarity
- Unipolarity

Piezoelectric Devices

- Voltage-controlled crystal oscillators

Premise Distribution Products

- Cable and wire
- Lightguide products

Transformers and Inductors

- Audio/Voice
- Pulse
- Wideband
- Hybrid

Turnkey Systems

The UNIX Microsystem

- Central processor unit (CPU)
- Clocks
- Direct memory access controller (DMAC)
- Dynamic random access memory controller (DRAMC)
- Math acceleration unit (MAU)
- Memory management unit (MMU)
- Microprocessor development system
- Microprocessor evaluation board
- Software generation program
- System interface unit (SIU)
- Training

(Continued)

Table 2 (Continued)

AT&T's COMPONENTS AND ELECTRONICS SYSTEMS PRODUCT LINE

Wound Film Capacitors

- Metallized miniature
- Metallized standard
- Related products

Source: AT&T Corporation

Table 3

AT&T PRODUCTION REVENUE
1985
(Millions of Dollars)

Total Semiconductor	$600
Total IC	$400
Bipolar	$ 65
ECL gate arrays	37
Other	28
MOS	$220
Memory	52
Micros (32-bit)	33
Logic	135
Linear	$115
Total Discrete/Opto	$200

Source: Dataquest
November 1986

AT&T has sold semiconductors to the merchant market since 1983, the year in which the 256K DRAM was introduced. The 256K DRAM ramped in production at a rate of about 100 percent quarterly between the fourth quarter of 1983 and the fourth quarter of 1985. During this time, the 1Mb DRAM also was introduced. Of the six major semiconductor suppliers of 1Mb DRAMs, AT&T is now ranked as the fourth largest producer. This total production figure includes internal use. Dataquest estimates AT&T's total MOS memory production for 1985 at $50 million.

In 1985, the WE 32100, a 32-bit microprocessor chip set, was introduced to the merchant market. This particular design has twice the processing capability of the earlier 32000. A third-generation design is currently in progress. It is expected to be twice as powerful as the existing version. Dataquest believes that the 32-bit device is used internally. Merchant sales are currently light but are expected to increase. AT&T also has recently teamed up with Zilog as a second source on the 32-bit family.

AT&T is the first to develop ICs from standard cells and is very advanced in standard cell technology. The company has more than 1,000 circuits in its library at 1.25-, 1.75-, and 2.5-micron design rules, all built using CMOS technology. AT&T has a network of design centers scheduled to open in the near future, and with its increasing international exposure and sophisticated technology, the company expects to capture a great deal of design activity.

DATAQUEST CONCLUSIONS

AT&T did not enter the merchant market at the best time. After entering in 1983, AT&T encountered an anxious market bustling with activity in the computer segment. Continued computer activity caused the boom-bust phenomenon of 1984-1985. During that time, AT&T's commitment to the merchant market surprisingly did not waver in enthusiasm. Market commitment was high in the boom year of 1984 when profits were high, but it was low in 1985 when profits disappeared. We believe that AT&T is more active in the merchant market now that its costs have declined and market pricing has stabilized.

The structure of the new merchant environment also has proven difficult for AT&T. Captive environments typically do not operate at the fast pace required in the merchant arena. Bureaucracy seems to be inhibiting opportunities that would otherwise prove lucrative, specifically in the semicustom product areas. There is a great need for speed in quotations and flexibility. We believe that AT&T must overcome existing problems like this and provide strong service support to effectively penetrate the merchant market.

Barbara A. Van

Dataquest

Conference Schedule

1986

Semiconductor	October 20–22	Hotel Inter-Continental San Diego, California
Technical Computer	November 3–5	Silverado Country Club Napa, California
Asian Peripherals	November 5–7	Hotel Okura Tokyo, Japan
Semiconductor Users/ Semiconductor Application Markets	November 10	Sheraton Harbor Island San Diego, California
Electronic Publishing	November 17–18	Westin Copley Place Boston, Massachusetts
CAD/CAM EDA	December 4–5	Santa Clara Marriott Santa Clara, California

1987

Semiconductor Users/ Semiconductor Application Markets	February 4–6	Saddlebrook Resort Tampa, Florida
Copying and Duplicating	February 23–25	San Diego Hilton Resort San Diego, California
Electronic Printer	March 23–25	Silverado Country Club Napa, California
Japanese Semiconductor	April 13–14	The Miyako Kyoto, Japan
Telecommunications	April 13–15	Silverado Country Club Napa, California
CAD/CAM	May 14–15	Hyatt Regency Monterey Monterey, California
Display Terminals	May 20–22	San Diego Hilton Resort San Diego, California
European Semiconductor	June 4–5	Palace Hotel Madrid, Spain
European Copying and Duplicating	June 25–26	The Ritz Hotel Lisbon, Portugal
Financial Services	August 17–18	Silverado Country Club Napa, California
Western European Printer	September 9–11	Palace Hotel Madrid, Spain
European Telecommunications	October 1–2	Monte Carlo, Monaco
Semiconductor	October 19–21	The Pointe Resort Phoenix, Arizona
Office Equipment Dealers	November 5–6	Hyatt Regency Monterey, California
Electronic Publishing	November 16–17	Stouffer Hotel Bedford, Massachusetts
CAD/CAM EDA	December 10–11	Santa Clara Marriott Santa Clara, California

Dataquest

Product Offerings

Industry Services

Business Computer Systems

CAD/CAM

Computer Storage—Rigid Disks

Computer Storage—Flexible Disks

Computer Storage—Tape Drives

Copying and Duplicating

Display Terminal

Electronic Printer

Electronic Publishing

Electronic Typewriter

Electronic Whiteboard

European Semiconductor*

European Telecommunications

Gallium Arsenide

Graphics

Imaging Supplies

Japanese Semiconductor*

Office Systems

Personal Computer

Personal Computer—Worldwide Shipments and Forecasts

Robotics

Semiconductor*

Semiconductor Application Markets*

Semiconductor Equipment and Materials*

Semiconductor User Information*

Software—Artificial Intelligence

Software—Personal Computer

Software—UNIX

Technical Computer Systems

Technical Computer Systems—Minisupercomputers

Telecommunications

Western European Printer

Executive and Financial Programs

Corporate Alliance Program

Coporate Technology Program

Financial Services Program

Strategic Executive Service

Newsletters

European PC Monitor

First Copy

Home Row

I.C. ASIA

I.C. USA

Focus Reports

The European PC Market 1985-1992

European PC Retail Pricing

PC Distribution in Europe

PC Software Markets in Europe

PC Local Area Networking Markets in Europe

The Education Market for PCs in Europe

Japanese Corporations in the European PC Markets

Home Markets for PCs in Europe

Integrated Office Systems—The Market and Its Requirements

European Market for Text Processing

Image Processing in the Office

Work Group Computing

Translation Systems

Vendor Support

The IBM 3270 Market: 1986 and Beyond

Korean Semiconductor Industry Analysis

Diskettes—The Market and Its Requirements

Directory Products

I.C. Start-Ups—1987

SpecCheck—Competitive Copier Guide

SpecCheck—Competitive Electronic Typewriter Guide

SpecCheck—Competitive Whiteboard Guide

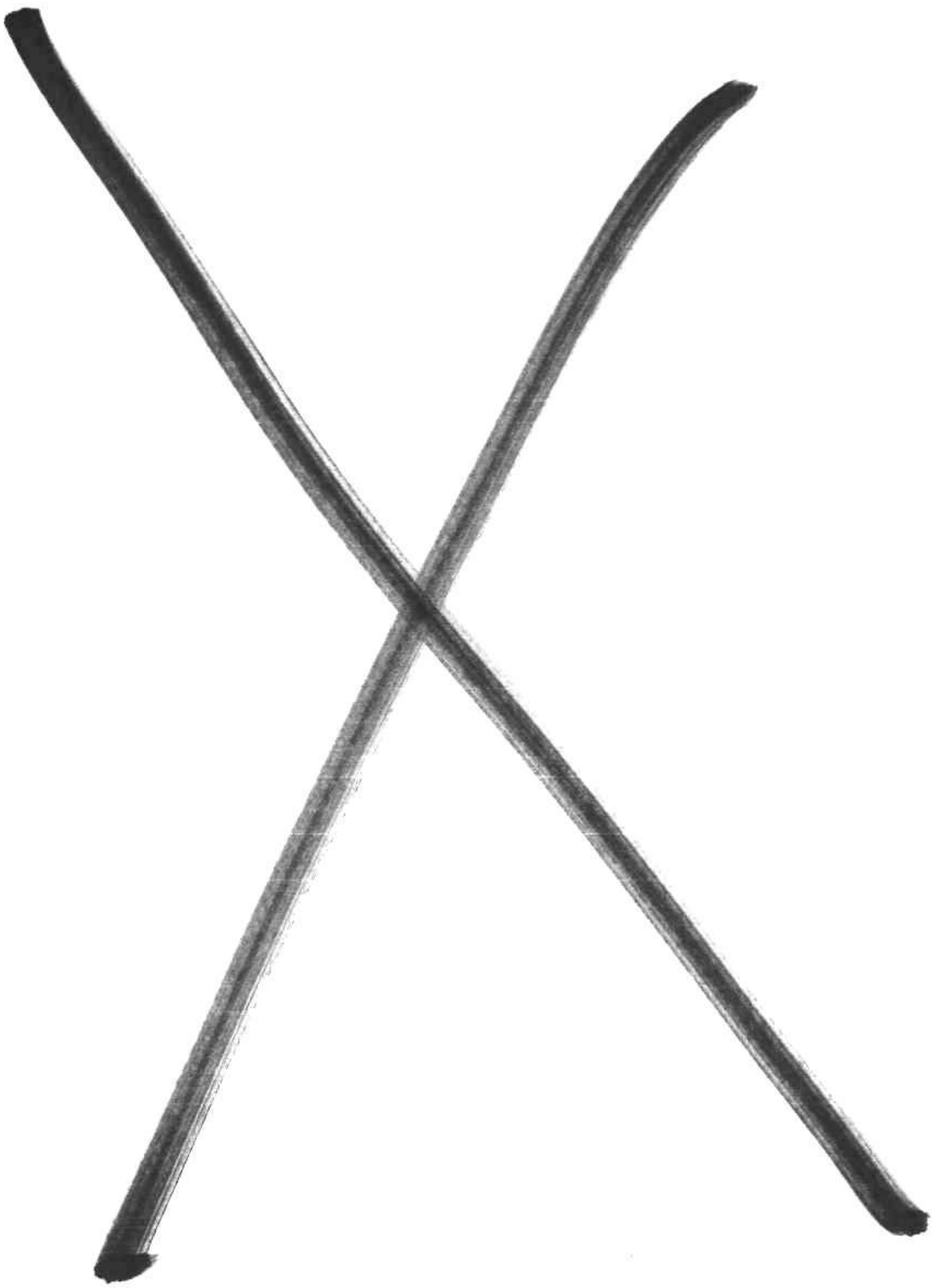
Who's Who in CAD/CAM 1986

Future Products

- Industry Services
  - Manufacturing Automation
  - Computer Storage—Optical
  - Computer Storage—Subsystems
- Focus Reports
  - Japanese Printer Strategy
  - Japanese Telecommunications Strategy
  - Canon CX Laser—User Survey
  - Digital Signal Processing
  - PC-based Publishing
  - Taiwan Semiconductor Industry Analysis
  - China Semiconductor Industry Analysis
  - PC Distribution Channels
- Directory Products
  - SpecCheck—Competitive Facsimile Guide
  - SpecCheck—Competitive Electronic Printer Guide

*On-line delivery option available

For further information about these products, please contact your Dataquest sales representative or the Direct Marketing Group at (408) 971-9661.



December Newsletters

The following is a list of the newsletters in this section:

Dataquest
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RESEARCH NEWSLETTER

SIS Code: 1986-1987 Newsletters: December
1986-58

THE 1986 DATAQUEST SEMICONDUCTOR INDUSTRY CONFERENCE: FACING THE NEW INDUSTRY STRUCTURE

SUMMARY

The 1986 Dataquest Semiconductor Industry Conference, held October 20 to 22 in San Diego, was a gathering not of celebrants but of determined survivors. While 1986 began with heightened expectations of an industry-wide upturn, the persistence of the current slump has caused a serious assessment of the directions in which the industry is heading. The mood of the Dataquest conference reflected a thoughtful effort to define both the changing structure of the semiconductor business and the strategies required to succeed in it. To quote conference speaker Jon Cornell, senior vice president of Harris Corporation's semiconductor sector, "The only way to deal with reality is to be realistic."

In this newsletter, Dataquest looks at the following aspects of the new semiconductor industry structure as highlighted by the San Diego conference:

- The era of applications
- The role of intellectual property
- Service as a value-added commodity
- Vertical integration through cooperative alliances
- Manufacturing automation
- Global competitiveness

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The Age of Realism

Given the sobering state of the industry, the Dataquest semiconductor consumption forecast, unveiled by vice president Howard Bogert on day one of the conference, came as no surprise to attendees: the North American semiconductor market in 1986 will see only 6.4 percent growth over 1985, with 1987 growth predicted to increase by 12 percent. Dataquest further anticipates that before the U.S. industry sees an upturn, it will experience two more quarters of sluggish growth.

The ravages of 1986 have not spared Japan either. Measured in dollars, the Japanese semiconductor market shows an impressive 40.6 percent growth over 1985. The appreciation of the yen against the dollar, however, masks the fact that Japan's semiconductor market remained flat in terms of local currency. The European market showed greater vitality in 1986, with an increase of 14.8 percent over the previous year.

The real story in regional semiconductor growth for 1986 was in that area collectively referred to as "Rest of World" (ROW). From 1975 to 1984, the compound annual growth rate (CAGR) for ROW was 28 percent. In 1986, however, ROW consumption of semiconductors increased nearly 54 percent over 1985--accelerating in the space of one year from a $1.9 billion to a $2.9 billion market.

Dataquest forecasts that over the next 10 years, the newly developed countries of the Pacific rim will continue to enjoy market growth well above that of the semiconductor industry as a whole. Not only are these countries expanding as manufacturers of steel, automobiles, and consumer electronics products, but they are also the beneficiaries of manufacturing capacity shifted to them by developed countries seeking market access and lower costs for labor and materials.

While Dataquest forecasts 12 percent growth in the U.S. semiconductor market in 1987, and a robust 30 percent increase in 1988, the industry's long-term rate of growth will slow from a CAGR of 18 percent to 13 percent. This decline in the rate of growth reflects an industry that has gone from creating high-growth, high-volume markets, to one that services these markets as they mature in a global marketplace.

As in the calculator market of the 70s, growing saturation in the personal computer market has coincided with vastly diminished average selling prices (ASPs) for semiconductor memories. To quote conference speaker Wilf Corrigan, president of LSI Logic, "As the computer becomes a standard, it becomes a commodity . . . . mayhem then ensues." Added to this current mayhem is a new and more insidious twist: the global nature of the commodity IC business has created overcapacity on a global scale. According to Dataquest's Semiconductor Equipment and Materials Service (SEMS), average capacity utilization in the semiconductor industry reached a worldwide low of 50 percent in 1985. With surplus computer power available for some years to come, semiconductor industry leaders will be more concerned about capacity management than identifying the next PC or calculator market.

As a result of this current industry down cycle, semiconductor manufacturers are not the only ones appraising their businesses with a more critical eye. In his conference presentation, Greg Smith, president of Prudential-Bache Securities Investment Management Group, offered the financial community's perspective on the semiconductor industry: "We no longer see the semiconductors as a 'growth' industry, but as a 'growth cyclical' industry. We have a shorter horizon at Wall Street given the volatility of the trading market."

To protect itself from market volatility, and to respond to changing end-user expectations and a global shift in manufacturing, the semiconductor industry is restructuring as follows:

The Era of Applications

"Manufacturing with standard products may be suicide in a one-world market."--Wilf Corrigan, President, LSI Logic

"Application drives specification."--Jim Smaha, Executive Vice President and General Manager, National Semiconductor

To the more cynical, it may seem that the trend toward ASIC manufacture is simply a new ride on the high-tech bandwagon. Viewed from this perspective, the ASIC phenomenon represents a U.S. retreat from the commodity chip business in the face of competition from Japan's semiconductor monoliths. During a speech delivered at Tuesday night's conference dinner, Jerry Sanders of AMD raised the specter of a U.S. semiconductor industry doomed to the anonymity of niche markets, while Japan completes its gutting of the U.S. manufacturing sector.

From the point of view of chip manufacturers, whether U.S. or Japanese, global forces compel, if not necessitate, an entry into the ASIC arena. As summarized during the San Diego conference, these forces include:

- The shift in commodities manufacturing to the Pacific
- The emergence of new markets with specialized needs
- The pervasiveness of digital technology
- The need to achieve higher ASPs on smaller production runs

To look at the ASIC business as purely a tactical shift in the industry, however, is to ignore the role of the end user in defining the new industry structure. The business of ASICs is, in reality, an evolutionary step for the semiconductor industry--a step toward placing the value-added process closer to the customer. Jim Smaha of National Semiconductor characterized the new semiconductor market as a "customer driven market demanding more complex devices, more systems solutions, and more customer partnership." The key to addressing this market lies in the successful combination of existing process technologies with emerging design automation. The benefit to the industry is increased pervasiveness.

The entrepreneurial climate of the United States has led to an explosive growth in computer, telecom, and CAD/CAM related companies designing for the ASIC environment, and as a result, ASICs are raising the customer's level of expectation. The customer-driven aspect of the ASIC business is exemplified by Dataquest's projections for future sales of programmable logic devices (PLDs). Frustration with long development times encountered with gate arrays, cell-based ICs, and full custom, has poised the PLD market for rapid growth. Dataquest forecasts that by 1991, annual PLD sales will be in excess of $1 billion--nearly 360 percent greater than the 1986 market! Among the rapid growth segments of the overall PLD market will be CMOS one-time programmable (OTP) devices, ECL PLDs, and reprogrammable PLDs.

Intellectual Property

For all its supply/demand volatility, the business of manufacturing commodity ICs has had a certain predictability about it. Competitive advantages have been enjoyed by those manufacturers who could squeeze ever more functionality out of a piece of silicon. Since the device architectures themselves were largely in the public domain, intellectual property was less a concern than process technology.

For ASIC manufacturers, however, the world looks very different. The ASIC business is experiencing increased competitive intensity. Existing and emerging companies are continually jockeying for market position based on how their customers will view the trade-offs between cost, performance, flexibility, and turnaround time. In many cases the differences between competing products have more to do with incremental changes to an architecture than with radical design differences. As a result, the ability to protect an architecture as broadly as possible represents significant control over market entry by would-be competitors.

The problem, of course, is to identify those architectural changes that are merely "tweaks" to a patentable innovation--and therefore subject to license by the patent holder--and those changes that clearly differentiate the product from others. As the controversy behind the Intel/NEC trial illustrates, too broad an extension of intellectual property rights stifles the proliferation of technology in its application to consumer needs, while too loose an application may destroy the incentive to invest in innovation. Given increased competition in the ASIC market, there will no doubt be greater temptation to use intellectual property law as a means of erecting market barriers. In short, the industry will become more litigious.

Service as a Value-Added Commodity

"Silicon will only be the packaging through which device designers deliver the value added."--Dr. Wilmer Bottoms, General Partner, Allan Patricoff Associates

"Service should be thought of as features, acts, or information which increases the value of a product."--Dr. William Davidow, Mohr, Davidow Ventures

In the "era of applications," the above two quotes are highly complementary. As the semiconductor industry looks to ASIC technology as a value-added approach to increasing ASPs in lower-volume applications, the industry finds that the value it is increasingly required to add is service.

The basic nature of ASIC development implies the kind of all-encompassing approach to service that Dr. Davidow's definition suggests. The following characteristics of ASICs, as emphasized repeatedly during the conference, demand the creation of a service-oriented infrastructure:

- ASIC products are produced in close proximity to customers.

- Design automation tools must increasingly migrate to the customer, and must respect the customer's architectural needs at a systems level.

- Turnaround time is a driving force for the achievement of adequate profit margins.

In the new semiconductor industry structure, service is not only the function of manufacturing quality product at a competitive price, by now a given in the industry, but of closer identification with the customer's products and processes, and ultimately with the customer's customer. The infrastructure necessary to operate with such an orientation demands a pervasive service culture that is sensitive to the customer's concerns with effective design tools, product differentiation, time to market, and inventory management. For many companies, creating this infrastructure may be more of a challenge than producing products. As Dr. Davidow observes, "Delivering service will be tougher than finding new technology in the future."

Vertical Integration through Cooperative Alliances

"Cooperative alliances between our major companies are forming . . . by 1991 our domestic semiconductor industry will be strong."--Dr. Robert Noyce, Vice Chairman and Vice President, Intel Corporation

"I'd suggest that a lot of the craziness in the marketplace during the last three years would have been eased by having more committed relationships."--James A. Norling, Executive Vice President and General Manager, Semiconductor Products Sector, Motorola, Inc.

Success in the age of applications requires transferring design capability to the end user, which means tremendous investments in design tools. As William Davidow suggests, developing a true service infrastructure requires major investments as well. In addition to the increasing emphasis on service, success in the semiconductor industry is still predicated on advancements in process technology. Existing semiconductor firms, as well as start-up companies, will find it difficult to serve two masters. The nature of the new industry structure tends to separate the processes of design and manufacturing to a degree unparalleled in the industry's history, making equal investments in service and manufacturing capability cost prohibitive.

Integration of design and manufacturing is no less important than ever--witness the success of Japan Inc. If achieving this integration on a vertical basis becomes too costly in an era of niche market identification, then the only alternative is to achieve it through cooperative alliances. The proliferation of corporate alliances during the past two years has been propelled by several factors.

For one thing, the optimum market size necessary to support an efficient wafer fab is increasing. Aside from the current cost of building a fab (approximately $30 million to $35 million at the least for state-of-the-art CMOS), current manufacturing trends indicate that by the year 2000, such a facility will be capable of producing nearly $500,000 worth of devices a year. The kind of market share required to justify a fab may well be at odds with the niche market thrust of ASIC suppliers.

And overcapacity continues to make the investment in manufacturing facilities difficult to justify, particularly at a time when Wall Street has entered a "revisionist" period in its outlook on the semiconductor industry. Exchanges involving technology transfer for manufacturing capability make more sense domestically and internationally.

Also, the growth of the Japanese semiconductor market, and the increase in ROW consumption, make it necessary for semiconductor firms to establish a presence in those marketplaces. Alliances provide a vehicle for market access, as illustrated by the recently announced Toshiba-Motorola agreement.

Automation

"If you look at productivity since the beginning of the semiconductor industry, it has fallen like a shot."--Bob McGeary, Director, Dataquest Semiconductor Equipment and Materials Service (SEMS)

"The U.S. has an opportunity to leapfrog in manufacturing technology--an opportunity to do it right."--Susan Powell-Billat, Manager, Microelectronics Group, Bechtel National Incorporated

The issue of automation in the manufacturing of semiconductors is often associated simplistically with global competitiveness, or "How can the U.S. out-manufacture the Japanese?" In reality, both Japan and the United States face a more insidious manufacturing nemesis than one another: the declining ratio of revenue to capital investment. In 1985, this ratio reached an all-time low for both the Japanese and U.S. industries--on an average, the U.S. chipmakers did slightly better than trade dollars, while the Japanese dropped below the 1:1 ratio.

While part of the decline can be laid at the doorstep of overcapacity, silicon throughput has simply not kept pace with equipment costs. Process productivity, while on the rise, will still be well below the 1971 level by 1991. Global competition aside, the merchant semiconductor industry will find continued investment in R&D impossible if yields and productivity are not increased. Given today's level of return on investment dollar, future industry growth can be guaranteed only by deep-pocket resources, either governmental or commercial. Since the U.S. merchant business enjoys neither governmental subsidy nor captive security, automation is a basic issue of survival.

At present, as Dataquest's Semiconductor Equipment and Materials Service (SEMS) points out, some two-thirds of Japan's fabs are capable of manufacturing in the sub-2-micron range, as opposed to one-half of all U.S. fabs. While this may seem further confirmation that the United States has lost "the manufacturing war," conference speaker Susan Powell-Billat spoke of an opportunity for the United States to leapfrog the Japanese through the use of computer-aided design and drafting (CADD) tools, as well as through computer-integrated manufacturing (CIM).

While Japanese manufacturing is often referred to as "automated," it may be more accurate to call it "mechanized." Japan's wafer-processing lines are typically product dedicated, and therefore have little or no flexibility. Ms. Powell-Billat envisions designed-in productivity for both existing and future wafer fabs by means of dynamic simulation models that three-dimensionally illustrate the effect of any capital expenditure on a wafer-processing line. Three-dimensional representation of a manufacturing process has been a reality in the petroleum industry for many years. Such a simulation allows one to view products moving through a fab, and models the effects on production resulting from changes in layout and specific process equipment--including variables such as mean time between failure, mean time to repair, and utilization rates.

Ironically, the success of CIM in the semiconductor industry will probably depend more on changes to corporate hierarchy than on the evolution of CIM tools themselves. Closer cooperation between engineering groups, information services, and manufacturing and facilities managers will also have to be a designed-in feature of future fabs if process automation is to be a reality.

Global Competitiveness

"Overnight, the Japanese are losing their competitiveness. Most Japanese companies are now on a five-track recovery plan."--Sheridan Tatsuno, Industry Analyst, Dataquest Japanese Semiconductor Industry Service (JSIS)

"We find ourselves at a point in history where our ideas and technology have become more of a resource than our natural materials. The ability to employ those ideas and technology in our society will ultimately determine the future of our economic well-being."--Dr. Robert N. Noyce, Vice Chairman of the Board of Directors and cofounder, Intel Corporation

The issue of "global competitiveness" has, in recent years, been another way of saying "United States versus Japan." The polarized nature of global competition in the semiconductor business is rapidly changing. As Dataquest's consumption forecast reveals, 1986 will prove to be the worst year the Japanese semiconductor industry has yet experienced. Appreciation of the yen and the impact of the U.S.-Japan trade agreement have coincided with the emergence of Korean and Taiwanese semiconductor manufacturers as global suppliers of commodity devices. Looked at in this light, Japan's technopolis strategy, which Dataquest analyst Sheridan Tatsuno spoke of during his conference presentation, is not so much directed at dominating new markets as it is directed at future survival.

Competitive pressures from newly industrialized countries of the Pacific rim will profoundly affect the basic structure of Japan's electronics industry. Dataquest's Tokyo office reports that between 1987 and 1991 the compound annual growth rate (CAGR) for Japan's electronics industry is expected to decline by nearly 8 percent from the previous four-year period. The presence of Pacific rim newly industrialized countries (NICs) is felt most keenly in consumer electronics, where Japan's CAGR over the next four years will decline from 12.3 percent to 3.3 percent!

What we are now witnessing is the beginning of the end for the traditional low-risk, low-cost approach that Japanese companies have successfully exploited in the past. Coming in second with massive volume and forward pricing, after others have primed a market, will no longer lead to increased Japanese market share in the new industry structure. In moving from Japan Inc. to Japan Tech, the Japanese will now have to take the same technological risks, and pay the same financial penalties, as their entrepreneurially inclined competitors in the United States. In this sense, the Japanese will be playing the game according to U.S. rules, and they will be playing as though their lives depend on it. With the buying power of the yen at an all-time high, shopping for technology and manufacturing presence in the United States will have a high priority. Japan simply does not have the time to wait for its far-reaching R&D schemes to pay off.

Neither Japan's shift to creative research nor the ASIC thrust of U.S. semiconductor firms represents a retreat from the business of volume manufacturing--Jerry Sander's warnings notwithstanding. Japan's goals for future megabit DRAM products will continue to push the limits of process technology well below the submicron range, keeping Japan in the high end of the memories business. Major U.S. semiconductor companies in turn see their ASIC investments as a means of defining new standard products in cooperation with the end user. Japan needs to move immediately into value-added products, as a result of pressure from the Pacific rim and the strong yen, and the United States needs to regain the manufacturing strength it lost with the memories business. The new industry structure suggests that U.S. and Japanese companies have more to gain from cooperative rather than adversarial relationships.

Michael J. Boss

Dataquest

Conference Schedule

1986

Semiconductor	October 20-22	Hotel Inter-Continental San Diego, California
Technical Computer	November 3-5	Silverado Country Club Napa, California
Asian Peripherals	November 5-7	Hotel Okura Tokyo, Japan
Semiconductor Users/ Semiconductor Application Markets	November 10	Sheraton Harbor Island San Diego, California
Electronic Publishing	November 17-18	Westin Copley Place Boston, Massachusetts
CAD/CAM EDA	December 4-5	Santa Clara Marriott Santa Clara, California

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Semiconductor Users/ Semiconductor Application Markets	February 4-6	Saddlebrook Resort Tampa, Florida
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Financial Services	August 17-18	Silverado Country Club Napa, California
Western European Printer	September 9-11	Palace Hotel Madrid, Spain
European Telecommunications	October 1-2	Monte Carlo, Monaco
Semiconductor	October 19-21	The Pointe Resort Phoenix, Arizona
Office Equipment Dealers	November 5-6	Hyatt Regency Monterey, California
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  - Japanese Telecommunications Strategy
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RESEARCH NEWSLETTER

SIS Code: 1986-1987 Newsletters: December
1986-57

FAST 256K SRAM UPDATE

SUMMARY

We expect the market for fast 256K MOS SRAMs to be $7 million in 1986, and $45 million in 1987. Parts are just beginning to be shipped in small volumes in 1986. Suppliers who are currently sampling include AMD, Fujitsu, Mitsubishi, and MOSel, with at least six additional companies planning to supply parts by mid-1987. Primary applications for the part include cache and main memory applications for high-speed mainframe and minicomputers.

FORECAST

Table 1 shows the expected fast 256K SRAM market size by organization, dollars and units, for 1986, 1987, and 1991. These estimates are extracted from the fast SRAM forecast published by Dataquest in September 1986.

Table 1

FAST 256K MOS SRAM FORECAST
(Millions of Dollars and Units)

	1986	1987	1991
Revenue			
256Kx1	$1	$14	$166
64Kx4	4	18	293
32Kx8	2	13	248
Total	$7	$45	$707
Units			
256Kx1	0	0.4	35.0
64Kx4	0.1	0.6	65.0
32Kx8	0	0.5	55.0
Total	0.1	1.5	155.0

Source: Dataquest
December 1986

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We expect the largest segment of the fast SRAM market to be organized 64Kx4, which is quite different from the historical pattern. In past generations, vendors have first come out with a part organized x1 and only later developed a x4 or x8 high-speed part. At the 64K density, for instance, 85 percent of the high-speed parts are currently 64Kx1. At the 256K density, however, we expect the x4 and x8 parts to be as common as the x1. In 1987, we expect 256K SRAM units to be divided as follows: 27 percent x1, 40 percent x4, and 33 percent x8.

We will discuss some of the reasons for this shift in the applications section below.

Many vendors are introducing all three parts within a few months of each other. Those who are introducing only one or two organizations are generally including a x4 or x8 (see Table 2).

VENDOR STATUS

Table 2 shows: vendors who have announced their intentions of entering the fast 256K MOS SRAM market; the specifications of the part to be built; and the current status of those parts. At least ten vendors will enter the market by the first half of 1987, with more companies planning products by the end of 1987. Product diversity, by way of organization and special features, is much greater at this density than at any previous density, and there are a number of very high-speed parts at 35ns or less.

Currently, AMD, Fujitsu, Mitsubishi, and MOSel are sampling, and at least five more manufacturers will be sampling by early next year (see Table 2). Several manufacturers are planning devices at or below 35ns, including AMD, Hitachi, IDT, Inmos, Lattice, Mitsubishi, and NEC.

There are fast 256K modules available from several vendors, including IDT and EDI. Modules are made by taking several monolithic chips, in this case four 64K SRAMs, and combining them in module form to make a device that functions essentially as a monolithic device. Modules are generally available much earlier than the monolithic chips, and users will usually replace them with the monolithic chips when they become available, since the modules tend to be much more expensive.

Table 2

HIGH-SPEED 256K CMOS STATIC RAM AVAILABILITY

Company	Part Number	Organization	Speed (ns)	Package	Samples	Production	Notes
Alliance	7C256	32Kx8	35		Q1 1987		Also x4 and x1
AMD	99C328	32Kx8	35	28 DIP	Now	Q4 1986	
Fujitsu	81C84	64Kx4	45	DIP, LCC	Now	Q1 1987	Common I/O
	81C86	64Kx4	55	DIP, LCC		Now	Separate I/O
	81C81	256Kx1	45	DIP, LCC	Now	Q1 1987	
Hitachi	HM6208	64Kx4	35	DIP, SOJ	Q2 1987		Also biCMOS
	HM6207	256Kx1	35	DIP, SOJ	Q3 1987		
	HM6707	256Kx1	20	DIP, SOJ	Q4 1987		
IDT	71257	256Kx1	35	24 DIP	Q1 1987	Q2 1987	
	71258	64Kx4	35	24 DIP	Q1 1987	Q2 1987	
	71256	32Kx8	45	28 DIP, 32 LCC	Q1 1987	Q2 1987	
Inmos	1800	256Kx1	25	24 DIP, 28 LCC	Q1 1987	Q2 1987	
	1820	64Kx4	25	24 DIP, 28 LCC	Q4 1986	Q2 1987	
Lattice	SR246K1	256Kx1	35		Q1 1987	Q1 1987	
	SR246K4	54Kx4	35		Q1 1987	Q1 1987	
	SR246K8	32Kx8	35		Q1 1987	Q1 1987	
Mitsubishi	M5M5257	256Kx1	35	24 DIP, SOJ	Now	Q2 1987	
	M5M5258	64Kx4	35	24 DIP, SOJ	Now	Q2 1987	
MOSel	62256	32Kx8	55	28 KIP	Now	YE 1986	
NEC	43254	64Kx4	35	DIP	Q1 1987	Q1 1987	
	43251	256Kx1	35		Q1 1987	Q1 1987	
Modules							
IDT	7M856	32Kx8	40	28 DIP		Now	
	8M656	16Kx16	50	40 DIP		Now	
EDI	8832	32Kx8	45	28 DIP		Now	
	8864	64Kx4	35	28 SIP		Now	

Source: Dataquest
December 1986

APPLICATIONS

The major application for the 256Kx1 will be in main memory of very high-speed mini and mainframe computers, which require very deep memory arrays. The 64Kx4 and 32Kx8 will go primarily into cache memory and writable control store (WCS) designs.

One of the reasons for the increasing usage of x4 and x8 parts is that as the performance of many systems improves, and as new high-performance systems are designed, more OEMs find uses for fast statics. Many of these new users do not need a large, deep memory array, but they will still use the high-density parts in the x4 and x8 organizations for cost effectiveness and lower chip count.

There are some OEMs that have shown more interest in these new 256K devices than they have shown in lower density devices. Graphics and workstation vendors seem to be particularly interested in the higher density combined with high speed (35ns or faster). Expanding graphics applications require wider, high-density, high-speed parts.

FAST SRAM MARKET

We predict that the overall fast static RAM market will grow quite strongly through 1991. This market was the only MOS memory market to grow (in revenue) in 1985. However, because this market has exhibited good growth and stability, many vendors have decided to participate in it. At last count, there were 34 manufacturers either in this market or moving into it.

Dataquest believes that vendors who participate in this market or are considering participation should be aware of the potential overcrowding in the overall fast SRAM market if all of the intended participants actually make it into production. If that happens, price pressure will increase, and it may become more difficult to remain profitable in this segment of the market.

However, the fast static RAM market is characterized by the focus on performance. Even if the market becomes quite crowded, those vendors with the highest-performance parts will always be in demand, and will generally be able to obtain a price premium for their product. Product innovation and timely production of the next-generation product are also critical to success.

Despite the competition in this market, there is still great opportunity for the company that plans and executes well and can meet the increasing performance requirements of the market.

Susan Scibetta

Dataquest

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RESEARCH NEWSLETTER

SIS Code: 1986-1987 Newsletters: December
1986-54

SYMPOSIUM HIGHLIGHTS LATEST GaAs IC DEVELOPMENTS

SUMMARY

The 1986 IEEE-sponsored GaAs IC Symposium and associated activities served the emerging GaAs IC industry as an excellent forum for the interchange of R&D and manufacturing concepts and practices. A design workshop preceded the three days of meetings; a manufacturing conference (open only to citizens and permanent residents of the United States of America) followed the symposium. Fifty-five papers (selected from 126 submissions) and four panel sessions covered a broad range of topics: digICs, MMICs, materials, design, testing, manufacturing, and others. The United States was well represented, giving 41 papers (75 percent). Japan was represented by 9 papers (16 percent), followed by France (3 papers), the United Kingdom (2 papers), and Canada (1 paper). Speakers from West Germany and several other countries were notably absent, although GaAs R&D is progressing in those countries as well. Conference attendance exceeded 830 persons.

Some significant advances in GaAs ICs in 1986 were:

- Development of 4-inch NDF (near-defect-free) GaAs wafers
- Demonstration of 600ps 1Kx1 SRAMs
- ECL-compatible one gigasample/sec. 8-bit DAC with untrimmed nichrome resistors on-chip
- Operation of GaAs MMIC amplifier with 135mW output power at 41 GHz
- Successful multiple-sourcing of GaAs 12x12 multiplier chips
- Development of 88-pin LCC for 8-GHz operation in 50-Ohm system

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MATERIALS

The current status of IC-grade GaAs ingots (from which wafers are produced) was reviewed by R.N. Thomas of Westinghouse. Mitsubishi-Monsanto and others presented results on 3-inch and 4-inch NDF crystals grown using vertical-magnetic-field (VMF), indium-doped, LEC methodology. Crystal Specialties is promoting NDF HB (horizontal Bridgman) crystal growth and presented data in support of this approach.

Based on an informal survey of some of the attendees, Dataquest believes that approximately 70 Cambridge Instruments CI-352 pullers are now in use for growing GaAs crystals (approximately 10 in Europe and 30 each in the United States and Japan). The Seidensha LEC-801 is gaining popularity; both the CI-352 and the LEC-801 are useful for growing In-doped GaAs boules. Presently, carbon contamination appears to be the limiting factor in In-doped wafer quality. LEC-grown GaAs wafer production is now approximately 65 percent 3-inch and 30 percent 2-inch, with 4-inch wafer production expected to grow rapidly in the next two to three years as defect and contamination issues are resolved.

RAMS

Rockwell has developed a 1Kb SRAM, using HEMT structures (see Table 1). The device has 0.6ns access time at 25°C and 450mW power dissipation, opening new applications in memory hierarchies. Mitsubishi described the development of a 4Kb SRAM with 2.5ns t_{aa} and 200mW P_d using a power supply voltage of 0.7V; while the performance and power are impressive, the part is not ECL compatible. Honeywell and GigaBit presented data on their 1K SRAM efforts.

Although Ford, Fujitsu, Texas Instruments, and Vitesse did not present RAM papers, each of these companies has developed GaAs SRAMs; examples of their product efforts are included in Table 1 for comparison purposes. HEMT structures clearly allow superior performance and speed-power efficiency, two of the major factors that usually drive the commercial user to apply GaAs technology to systems.

Table 1

GaAs SRAMs

Company	Org.	T_{aa} max. (ns)	P_d max. (mW)	First Reported (Mo./Yr.)	Package	Comments
Rockwell	1Kx1	0.6	450	10/86	N/A	E/D HEMT
Rockwell	256x4	3	150	10/86	N/A	E/D MESFET, 110x110 sq. mil. die
GigaBit 12G014	256x4	2.3	2,500	4/85	40-pin LCC	D MESFET, I/O latches, ECL compatible
Mitsubishi	1Kx4	2.5	200	10/86	N/A	0.7V power supply
Ford 40G01	256x4	3	1,400*	1985	28-pin LCC	E/D, latched I/Os
Fujitsu	1Kx1	0.87	360	2/86	42-pin FP	1.6V supply, E/D HEMT, DCFL
Texas Instruments	1K	6	500	9/86	N/A	GaAs on Si substrate
Vitesse 12G474	1Kx4	3.5	TBD	9/86	LCC, FP	E/D, I/O latches

N/A = Not Available
TBD = To Be Determined
*Typical value

Source: AZTEK Associates

OTHER DIGICS

A one-day course on digIC device physics, process technology, and circuit design was held on Monday, October 27, 1986. Three conference sessions focused on digICs; these included 20 technical papers (36 percent of the total). Presenters of digIC papers included persons from these companies and organizations:

- AT&T
- Ford
- Gigabit Logic
- Honeywell (2)

- IBM
- ITT
- Matsushita
- Mayo Foundation
- McDonnell Douglas
- Mitsubishi
- NTT (3)
- Oki
- Plessey
- Rockwell (4)
- TriQuint
- TRW

Multiplexer/demultiplexer chips from Matsushita, NTT, Oki, and Rockwell/TriQuint, geared toward fiber-optic applications in the 1- to 3-GHz range, attracted much interest. A Honeywell/Mayo Foundation team has developed and multisourced a 6,000-gate array based on SDFL structures and has tested it to 160°C operating temperature. This chip contrasts with the largest ECL gate array to date, which has 8,000 gates and maximum operating temperature of 125°C. The 6,000-gate GaAs array has 176 I/O leads plus 40 power/ground leads, and it has been used to implement a single-chip 12x12 multiplier.

HBT (heterojunction bipolar transistor) structures offer very high performance potential in digital systems because of the very high cutoff frequency of HBTs (f_t to 456 GHz). Rockwell reported the first uncompensated-CML MSI circuits in HBT, including a 3-GHz 8-bit shift register. TRW (Internal R&D) and Plessey (ESPRIT Program project) also reported HBT results. Although progress has been made, the integration level of HBT is not yet sufficient to offer a speed advantage compared to silicon ECL LSI. Also, temperature compensation is needed to enhance usefulness of HBT ICs.

MMICs

Texas Instruments reported MMIC power amplifiers with output power of 200mW at 34 GHz and 135mW at 41 GHz. Hughes described a 1.3W output 7-15.5 GHz MMIC amplifier. ITT, Pacific Monolithics, LEP (Philips), and Raytheon authors described their work in other special-purpose MMICs. These chips allow users to further miniaturize communications and other equipment.

Fabrication

Ford Microelectronics detailed a self-aligned, low temperature E/D process that is employed in Ford's 561-cell 4-input NOR array, 1K SRAM, and other LSI chips. Ford's exhibit included a demonstration of a multiplier implemented with the 561-cell array chip. Matsushita described an all-implant MMIC process. Hughes has developed an E/D process using pure tungsten gates. Hewlett-Packard presented a method for improved control of threshold voltage, heretofore a significant limiting factor in GaAs IC development. Together, the papers represent a maturing of GaAs IC fabrication technology.

Packaging

Dataquest believes that the most significant breakthrough discussed in this area is the work reported by the Mayo Foundation in packages ranging in lead count from 24 to 240. Mayo efforts have resulted in 88 I/O lead chip carriers using copper/polymide structures with 50-Ohm properties at frequencies to 8 GHz (see Table 2). Jeff Frisco of Harris summarized GaAs packaging problems and challenges.

Table 2

GaAs IC CHIP CARRIERS--88 I/O LEADS

Vendor	Material	BW (GHz)	Line W/S (mils)	Thermal Imped. (°C/W)	Signal Environment	Proto-Type Price ($)
Interamics	Cofired alumina	3.0	4/6	0.3	Coated microstrip	$ 90.00
Brush/Wellman	Cofired beryllia	4.5	4/8	0.25	Stripline	$650.00
Augat/Microtec	Copper/polymide	8.0	4/5	0.3	Stripline	$ 65.00
Gen. Microwave	Thin film beryllia	N/A	3/3	0.25	Coated microstrip	$100.00

N/A = Not Available

Source: Mayo Foundation

Applications

Eugene Gregory of Hughes described the large-volume MMIC demand developing in the United States defense market, driven by radar, EW, and smart weapons. Corresponding demands are now placed on GaAS MMIC chip costs, which are presently 10 to 30 times greater than required for expendable hardware.

IBM reported the monolithic integration of a 3-GHz photodetector and preamp, using a process that is fully compatible with high-performance MESFETs. This approach is expected to pave the way to highly integrated photoreceivers, leading to lower-cost optical storage retrieval electronics, fiber-optic LANs receivers, and other developments. Other applications addressed by various speakers included image rejection frequency converters, mixers and dividers for communications, and DSP functions including the Honeywell/Mayo multiplier.

During informal discussions, the subject of systems implications of sub-ns GaAs devices was examined. Dataquest believes that SRAMs (such as the Rockwell 600ps device) will have a greater impact on system architecture than will other logic devices. Because of the ratio of speeds achievable in GaAs SRAMs and CMOS/NMOS DRAMs, it appears necessary for systems designers to consider multilevel caches--in many cases, for the first time. In a multilevel cache approach, the first-level GaAs cache RAM will probably be most efficient if placed on the processor package. The second-level cache technology is open to question; 5 to 10ns ECL or 15ns CMOS SRAM may be more appropriate than GaAs due to the number of chips and corresponding interconnect impedances involved. Location of second-level cache is critically dependent on relative timing of loaded devices as well as other factors.

GaAs INDUSTRY TRENDS

Many attendees are involved in bringing GaAs technology to bear on some of the electronics industry's most challenging problems. There is a growing concern that U.S. and European users of ICs are allowing their Japanese competitors to beat them to market with products that take advantage of this critical technology. Increasingly, the problem is no longer one of availability but one of acceptance; currently, products exist and capacity goes unused. The military arena, despite strong budget pressures, is pressing forward to take advantage of the unique properties of GaAs. However, if a broad range of customers' price demands are to be met, a strong commercial applications base must develop to provide adequate economies of scale, not unlike the "chicken and egg" scenario in the silicon world in 1969.

DATAQUEST CONCLUSIONS

GaAs ICs are here to stay. Suppliers are making great strides toward production of functions suitable for tommorrow's high-performance systems. Dataquest believes that the growing number of systems houses presently making judicious use of this technology will help create their own economic recovery despite overall market conditions. It's November 1986; do you know what your competitors are doing with GaAs technology?

Gene Miles

Dataquest

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1986

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Technical Computer	November 3-5	Silverado Country Club Napa, California
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RESEARCH NEWSLETTER

SIS Code: 1986-1987 Newsletters: December
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SIGNIFICANT PRODUCT ANNOUNCEMENTS--GaAs ICs

Product development activity is accelerating in the GaAs industry. Important announcements have been made by several GaAs houses in recent months; this newsletter examines the most significant recent product introductions.

BIT SLICES--THE RACE IS ON

Vitesse introduced the first commercially available LSI GaAs digital IC set, an ECL 100K compatible 4-bit slice family, on September 10, 1986, at Midcon. The product family consists of the VE29G01 4-Bit Microprocessor Slice, the VE29G02 Look-Ahead Carry Generator, and the VE29G10 Microcontroller. Engineering samples of the VE29G02 are available now, and engineering samples of the VE29G01 and VE29G10 are expected by February 1987. Earlier, McDonnell-Douglas released details on a 2901-type GaAs bit slice; however, McDonnell-Douglas is not a merchant market supplier of the device. Vitesse's product family is supported by a 3.5ns cycle 1024x4 registered static RAM, the VE12G474.

The VE29GXX family is expected to permit customers to achieve a factor of 3x speed improvement over a CPU implementation using the AMD2901C, a bipolar device. Interestingly, Vitesse has employed LCC packaging to preserve the device speed advantage at the system level as much as practical. Very aggressive forward pricing is available from Vitesse, allowing the user to project systems costs through 1990. So far, more than 1,000 customers have expressed interest in this product set. Dataquest expects a wide range of applications to make use of this technology, including minisupercomputers, "smart" high-speed instrumentation, DSPs and other military functions, arithmetic/logic accelerators, and high-speed graphics equipment.

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STATIC RAMs

For several months, 1K SRAMs have been offered for beta site evaluation by GigaBit, Ford Microelectronics, and others. GigaBit just received a $500 thousand, two-year U.S.A.F. contract to perform Class 8 screening, reliability evaluation, and radiation hardness evaluation on its 1K SRAM.

Vitesse's VE12G474 is the first commercially available 4K GaAs SRAM. Other announcements are expected this month, including devices from Honeywell, Rockwell, and GAIN. Several Japanese companies have been working on SRAMs for at least three years; these products appear targeted first for internal needs before being taken to merchant market. GaAs SRAMs feature cycle times in the 0.6 to 3.5ns range at 1K and 4K densities, compared to the 5 to 7ns range for the fastest commercially available silicon ECL RAMs (see Table 1).

CUSTOM DESIGN

GAIN Electronics Corporation has announced a custom design service based initially on E/D MESFET technology and followed by SDHT (selectively doped heterostructure transistor), otherwise known as HEMT (high electron mobility transistor), technology. SDHT, invented by Dr. Raymond Dingle (GAIN's president), offers the highest-performance commercially available GaAs circuitry. Typical transistor cutoff frequency is 80 GHz, versus 50 and 15 GHz, respectively, for GaAs FETs and Si bipolar transistors. GAIN will also offer a full line of device and design capabilities, and an epitaxial GaAs/ALGaAs wafer.

GigaBit Logic (GBL) has announced a standard cell library of D-MESFET logic blocks featuring 1 geometries and 100 to 200ps gate delays at 1 to 2mW per gate. The initial family includes 13 macrocells, with 17 additional macros including a 4-bit adder planned for 1987. GigaBit charges $10,000 for its cell library diskette and user manual, refundable against the cost of the first development program.

MMICs

Dataquest believes that the most significant announcement in GaAs MMIC (microwave monolithic IC) technology in recent months is the introduction of a GaAs linear/analog macrocell library by Pacific Monolithics. The library consists of more than 25 macrocells fabricated and tested prior to July 1986, with another 20 macros in development. The cells cover the 0.5 to 18 GHz frequency range and include amplifiers, switches, combiners, splitters, attenuators, and VCOs (see Table 2).

Pacific Monolithics' macrocell library offers its users two major advantages. First, the design lead time, which ranges from 1 to 2-1/2 years for a custom MMIC, can be reduced by a factor of 2 to 5 using standard cells. Second, development cost is dramatically reduced, by a factor of 3 to 8 for a typical MMIC design. Dataquest believes that Pacific Monolithic's library availability at this device performance level may radically alter the approach to electronic warfare systems design. Furthermore, the approach may have a major impact on the entire present microwave industry structure, which includes hybrid houses, silicon device suppliers, third-party designers and other relatively expensive, time-consuming factors.

GATE ARRAYS

Honeywell, TriQuint, Texas Instruments, and others are developing gate arrays using GaAs technology. Honeywell recently withdrew its 2K gate array and is reportedly developing a standard cell alternative. Suppliers are polarizing into two camps regarding GaAs ASICs. One group is pursuing gate arrays of 400 to more than 5,000 gate density. The second group is proceeding on the basis that a standard cell solution will offer the best performance/cost trade-off to the user. Dataquest believes that sufficient applications exist to support both approaches, and expects additional announcements in this area in the coming months.

DATAQUEST CONCLUSIONS

The pace of GaAs product activity is quickening, spurred by major capital investments in 1984 and 1985 and by a soft electronics market in 1985 and 1986. Users have a growing variety of GaAs design options available, supported by an expanding infrastructure of suppliers. Dataquest believes that performance-oriented applications will gravitate at an accelerating rate toward the use of GaAs in critical hardware paths. Significant commercial systems house announcements based on the use of GaAs components are expected, starting in 1987.

Gene Miles

Table 1

GaAs RAM PRODUCTS

Part Number (Company)	Organization	Taa Maximum (ns)	Pd Maximum (mW)	100-Piece Price	Intro. Date	Package	Comments
40G01 (Ford)	256 x 4	3.0	1,400*	TBA	TBA	28-pin LCC	E/D MESFET, I/O latches
12G014 (GBL)	256 x 4	3.0	2,000	N/A	1Q87	40-pin LCC	D MESFET, I/O latches
12G474 (Vitesse)	1K x 4	3.5	N/A	$595	9/86	LCC, FP	E/D MESFET, I/O latches
Rockwell	1K	0.6	N/A	N/A	TBA	N/A	E/D HEMT
Honeywell	256 x 4	3.0	150	N/A	TBA	N/A	E/D MESFET, 110 x 110 sq. mil die
Texas Instruments	1K	6.0	500	N/A	N/A	N/A	GaAs on silicon substrate

*Typical Value
TBA = To Be Announced
N/A = Not Available

Source: AZTEK Associates

Table 2

PACIFIC MONOLITHICS CELL LIBRARY

Existing

Function	Frequency (GHz)
Amplifier Gain Blocks:	
10dB	2 to 6
15dB	0.1 to 2
15dB	1 to 3
AGC amp, 10dB	2 to 6
Oscillators (VCOs, DROs):	
Neg. resistance	1 to 3
Neg. resistance	3 to 6
Double-Balanced Mixers:	
Diode Mixer	1 to 3
Diode Mixer	3 to 6
Diode Mixer	6 to 8
Attenuator	DC-12
FET SPDT switch	DC-12
Low-Noise Amplifiers	
FET LNA, 16dB	3.7 to 4.2
FET LNA, 13bB	4.4 to 5.0
FET LNA, 16dB	1.2 to 1.6
Power Amplifier, 12dB	3 to 7
Biphase Modulator	5 to 10
QPSK Modulator	5 to 10
Power Splitter/Combiner	5 to 10
90° Hybrid	3.5 to 4.5
Active Isolator	0.1 to 10
Balun	1 to 3
Balun	2 to 6
Balun	5 to 8

In Development

Function	Frequency (GHz)
Amplifiers:	
SS amp, 10dB	6 to 18
SS amp, 10dB	6 to 12
LNA, 12dB	11 to 14
Power amp, 10dB	6 to 18
Power amp, 10dB	6 to 12
AGC amp, 10dB	6 to 18
Mixers:	
Balanced-Diode	6 to 10
Balanced-Diode	10 to 18
Dual-Gate	2 to 6
High-Dynamic Range	6 to 10
Oscillators:	
Neg. resistance	6 to 12
Neg. resistance	12-18
Subsystems:	
Freq. Downconv.	10 to 14
Freq. Downconv.	6 to 17
Freq. Synthesizers	DC-5
Digital ICs:	
Dividers	6
Flip-Flops/Latches	1.5
Other Building Blocks:	
Balun	6 to 12
Balun	6 to 18
Attenuator	6 to 18
Limiting Amplifiers	2 to 6
Vector modulator	5 to 10
Subsystems:	
Freq. Downconv.	1 to 3
Freq. Downconv.	3 to 6
Freq. Downconv.	5 to 8
Image-Rej. Dnconv.	3.7 to 4.2

Source: Pacific Monolithics

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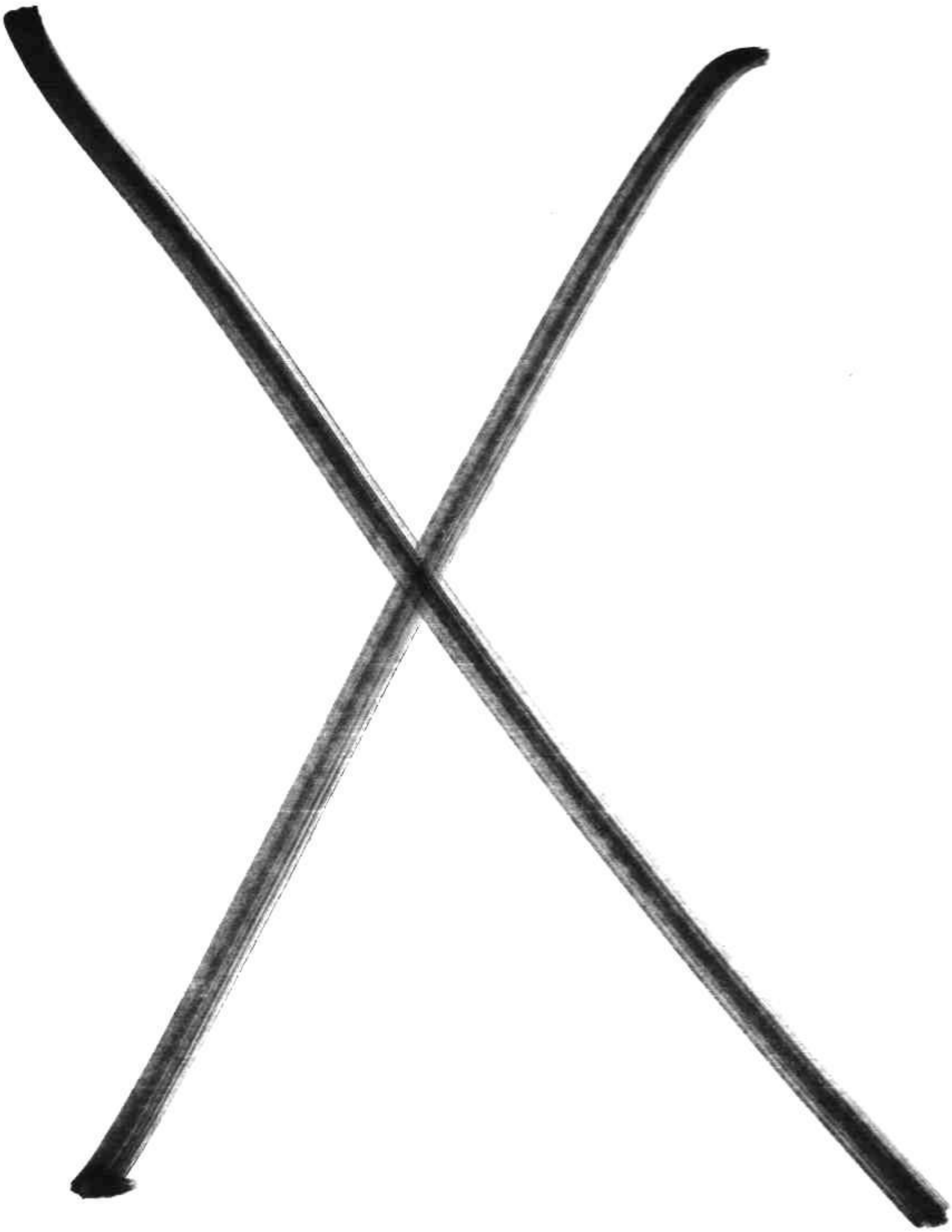

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RESEARCH NEWSLETTER

SIS Code: 1986-1987 Newsletters: January
1987-3

PROGRAMMABLE LOGIC DEVICES: THE SLEEPING TIGER AWAKENS

INTRODUCTION

Programmable logic devices (PLDs) have been a sleeping tiger for a number of years. The tiger has now awakened and is stalking the ASIC market. What was a $219.9 million market in 1984 will be a $1 billion market by 1991. Why is this happening? The answer is productivity. PLD diversity has been quietly expanding while application-specific IC (ASIC) designers have been turning to other ASIC alternatives for quick turnaround products.

Also fueling this productive PLD expansion are:

- The demand for an instant ASIC device
- The rapid growth of PLD suppliers
- A variety of emerging products and technologies
- The emergence of sophisticated PLD-CAD systems that allow designing with PLDs to occur at the designer's desk
- The emergence of overseas suppliers that have both technology for and experience with EPROMs or EEPROMS

This newsletter will further elaborate on the PLD phenomenon by:

- Defining a PLD
- Explaining the different PLD architectures
- Describing the PLD suppliers and toolmakers
- Detailing the PLD market
- Explaining the PLD trends and issues

The newsletter concludes with an analysis of future PLD market characteristics.

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DATAQUEST DEFINES A PLD

A PLD is an ASIC that can be used to implement random logic. Designers specify the logic using Boolean equations, net lists, or state machine designs that are translated by PLD-CAD software into a set of patterns that customize the device. An important feature that separates PLDs from other ASICs is that they are programmed by the user instead of by the supplier, thus reducing time to market. The user can purchase a standard off-the-shelf device, eliminating the inventory cost and procurement risks inherent in other ASIC products.

ARCHITECTURES: A VITAL LINK

PLD architectures are the driving force behind faster market growth. Architectural innovations are significant because new structures offer the potential to solve many more design problems with user-programmable devices. PLDs are divided into two segments: products that offer faster performance and products that offer architectural flexibility and high density. At present, there are three basic PLD architectures on the market:

- PLD/IFL Programmable Logic Devices formerly called Integrated Fuse Logic (IFL) devices

- Programmable Array Logic (PAL) devices (PAL is a registered trademark of Monolithic Memories.)

- Microprogrammed structures called Logic Cell Arrays (LCAs) (Logic Cell Array is a trademark of Xilinx.)

The PAL and the PLD/IFL have similar internal AND/OR structures but vary in the allocation of logic features and the amount of programmability. The LCA uses a microcoded function that is programmed by a PROM.

History/Evolution of PLD Architectures

In 1978, Signetics introduced the IFL device. In 1980, designers at Monolithic Memories found that IFL devices offered a limited degree of flexibility, making PLDs difficult to use. They produced a more flexible device called the PAL, which was easier to use than the available IFL device. Currently, a surge of newer bipolar and CMOS architectures has been introduced that differ from the PLD/IFL and PAL architectures.

In 1985 AMD introduced the 22V10, a bipolar device that can be used to replace up to 20 PAL devices. Altera introduced a CMOS family of PLDs with equivalent gate counts of up to 1,800 gates and output macrocells offering a degree of flexibility unavailable in earlier PLDs. This part, with its user customization approach, was aimed at capturing designs from gate array applications, beginning a new wave of products offering a higher degree of flexibility.

In 1985, Xilinx introduced a unique PLD, the LCA. The LCA is programmed by loading a configuration program pattern from an external memory. Its chief advantage is that an LCA can be programmed while in the system, thereby allowing the system's logic or the device's architecture to be changed while the system continues to operate.

In May 1985, Lattice Semiconductor introduced an EEPROM-based CMOS device called the Generic Array Logic (GAL), offering programmable output macrocells that enable reprogrammability. The GAL replaces many PALs and also offers testability that guarantees the functionality of the device. Lattice then followed up with an enhanced GAL--the ispGAL (in-system programmable Generic Array Logic) device.

In late 1986, Signetics introduced a bipolar device, Programmable Macro Logic (PML), that provides users with a higher level of logic integration.

These are just a few enhanced architectures. Look to 1987 for the emergence of new suppliers offering higher degrees of PLD flexibility and density, thus fueling further growth of the PLD market.

Programming Methods

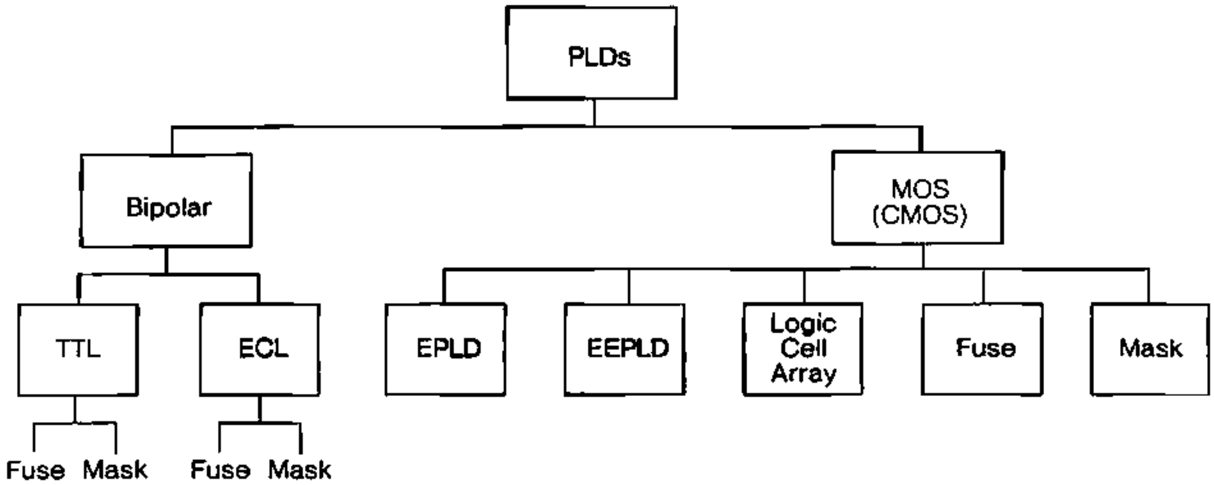
Figure 1 shows the family tree for programmable logic along with the two major process categories: bipolar and CMOS. Although bipolar is the more mature technology, the rival CMOS technology is causing much commotion.

On the bipolar branch, both TTL and ECL PLDs offer two approaches to programming. In the first approach, programming is achieved by blowing fuses, allowing customization at the user's site. The second approach is to order the device customized by the supplier. Here the manufacturer tailors the PLD by using customized masks during wafer fabrication. The use of a mask device is attractive because it is more cost-efficient than fuse-link-device programming. When programming with a fuse-link device, gates of the PLD that are not programmed are left unused but are a part of the cost of the device. When a demand exists for a high volume of PLDs to be programmed, a designer first uses the fuse-link device and then converts to a mask PLD after the design is ready for production to reduce costs.

In the CMOS branch shown in Figure 1, there are five ways to customize a PLD. The most popular approaches are the erasable programmable logic device (EPLD), an outgrowth of EPROM technology, and the electrically erasable programmable device (EEPLD), an outgrowth of EEPROM technology. As discussed earlier, the LCA offers in-system programmability. Mask and fuse PLDs are similar to those found in the bipolar mask and fuse category.

Figure 1

PROGRAMMABLE LOGIC FAMILY TREE



Source: Dataquest
January 1987

Table 1 shows our estimated PLD consumption forecast by product and technology. The market is divided into one-time programmable (OTP) devices and reprogrammable devices. Dataquest has also estimated growth by process technology and by programming technology. The forecast for all CMOS technologies, including OTP and reprogrammable, is for strong growth for the balance of the decade. We also expect a modest but growing demand for ECL PLDs when speed is a critical factor. Figure 2 shows that we estimate worldwide consumption of PLDs will be $1,058.6 million in 1991, with CMOS products expected to capture 51 percent of the sales.

Table 1

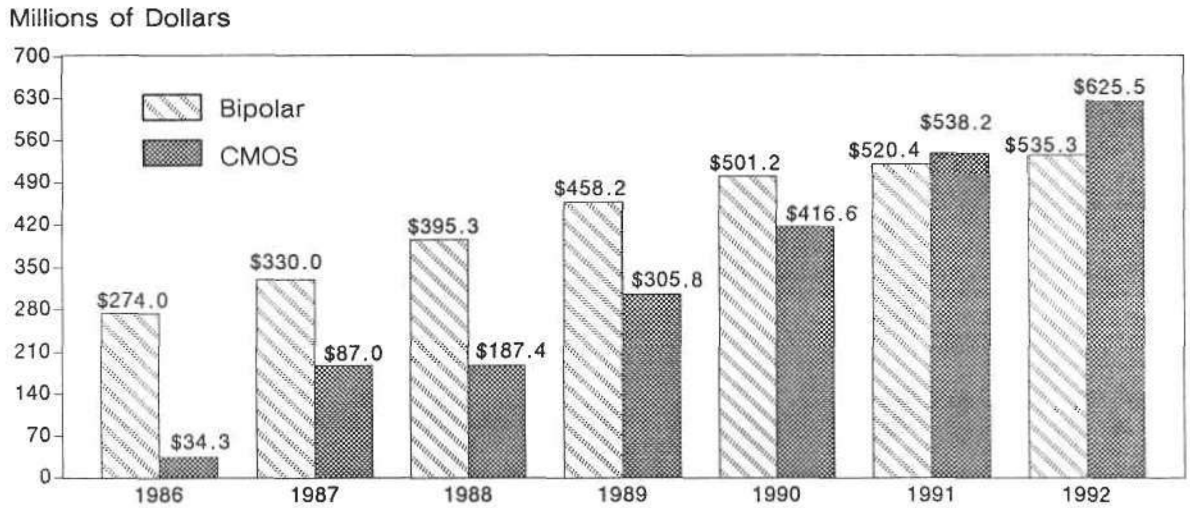
PRELIMINARY 1986
WORLDWIDE CONSUMPTION OF PROGRAMMABLE LOGIC DEVICES BY PRODUCT
(Millions of Dollars)

	1985	1986	1987	1988	1989	1990	1991	1992
Total PLD	235.3	308.3	417.0	582.6	764.0	917.8	1,058.6	1,160.8
MOS (CMOS)	10.3	34.3	87.0	187.4	305.8	416.6	538.2	625.5
Bipolar	225.0	274.0	330.0	395.3	458.2	501.2	520.4	535.3
One-time Programmable	231.2	293.7	386.7	522.0	646.7	721.1	795.0	860.1
MOS (CMOS)	6.2	19.6	56.7	126.7	188.5	220.0	274.6	324.8
EPLD	2.1	12.2	42.6	102.3	153.4	176.5	220.6	260.3
Fuse Link	3.1	3.5	4.9	6.1	7.6	9.4	11.7	14.5
Mask	1.0	4.0	9.1	18.3	27.4	34.1	42.4	50.0
Bipolar	225.0	274.0	330.0	395.3	458.2	501.2	520.4	535.3
TTL	225.0	273.0	327.0	386.3	444.7	481.0	492.4	503.6
Fuse Link	218.0	265.0	318.0	375.2	431.5	466.0	475.4	484.9
Mask	7.0	8.0	9.0	11.0	13.2	15.0	17.0	18.7
ECL	0.0	1.0	3.0	9.0	13.5	20.2	28.0	31.7
Fuse Link	0.0	1.0	2.8	8.4	12.6	18.9	26.5	29.9
Mask	0.0	0.0	0.2	0.6	0.9	1.3	1.6	1.8
Reprogrammable	4.1	14.6	30.3	60.7	117.4	196.7	263.6	300.8
MOS (CMOS)	4.1	14.6	30.3	60.7	117.4	196.7	263.6	300.8
EPLD	3.1	7.1	11.3	15.3	19.1	22.5	25.9	29.3
EEPLD	0.7	2.5	7.0	17.4	56.3	107.0	137.0	150.7
Cell Array	0.3	5.0	12.0	28.0	41.9	67.1	100.7	120.8

Source: Dataquest
January 1987

Figure 2

PRELIMINARY 1986
ESTIMATED WORLDWIDE CONSUMPTION OF PROGRAMMABLE LOGIC DEVICES
BY TECHNOLOGY



Source: Dataquest
January 1987

WHO ARE THE PLD SUPPLIERS?

Table 2 lists the major PLD suppliers and the technologies they offer. The market is currently dominated by bipolar suppliers that are rushing to establish CMOS product lines. Not far behind are CMOS start-up companies that offer products rivaling some of the leading TTL products.

Currently the PLD market is dominated by North American suppliers. Nevertheless, we estimate that by late 1987 there will be an emergence of overseas suppliers, since several now have EPROMs or EEPROMs technology and experience. Toshiba, for example, has published research papers on PLDs and has used PLDs internally, but does not offer them in the merchant market. As the market continues to grow, we expect increased participation from overseas suppliers.

Table 2

WORLDWIDE PROGRAMMABLE LOGIC DEVICE SUPPLIERS

	Bipolar		CMOS				
Company	TTL	ECL	Fuse	Mask	EPLD	EEPLD	Other
Advanced Micro Devices	X	X				X	
Altera Corporation					X		
Atmel Corporation				X			
Cypress Semiconductor					X		
Exel Microelectronics Inc.						X	
Fairchild Semiconductor	X	X					
Gould Semiconductor						X	
Harris Semiconductor			X				
Intel Corporation					X		
International CMOS Technology						X	
Lattice Semiconductor						X	
Monolithic Memories	X	X					
National Semiconductor	X	X					X
Panatech Semiconductor					X		
Signetics	X	X			X		
Sprague Solid State					X		
Texas Instruments	X						
VLSI Technology				X	X	X	
Xilinx							X

Source: Dataquest
January 1987

Another element driving the growth of the PLD market is the improvement in software and programming equipment. Table 3 lists the toolmaker suppliers and the products they support. Most third-party programmer suppliers have been cautious in the past when considering whether to support a start-up company until its product is accepted in the marketplace. As a result, start-ups have been forced to develop their own programming tools. Although most suppliers would prefer to leave the design of PLD-CAD tools to third-party companies, they have often been the leaders in developing innovative systems to support their own products. It is interesting to note that proprietary programmer tools were the key to success for start-up companies like Xilinx and Altera. We believe it is necessary for the start-up suppliers to join forces with third-party toolmaker suppliers in order to expand the market. Emerging products will continue to appear on proprietary development systems, and as they mature they will migrate to third-party systems.

Table 3

PROGRAMMABLE LOGIC DEVICE TOOLMAKER SUPPLIERS

PLD Supplier	Tool	Tool Supplier
Advanced Micro Devices	ABEL	Data I/O
	CUPL	PCAD
	AmCUPL	AMD
Altera Corporation	PLDS2, PLCAD4	Altera
		Third-Party Supplier (pending)
Atmel Corporation	ABEL	Data I/O
Cypress Semiconductor	ABEL	Data I/O
	Model 29B, 60A, 60B	Data I/O
	CUPL	PCAD Systems
	PLPL	AMD
	QuickPro Cy300	Cypress
	STAGPPZ, ZL32m	Stag Microsystems
	DIGILEC Model 803	Digilec
	ALLPROM	Logical Devices
Exel Microelectronics	Perfect	Valley Data Sciences
	ABEL	Data I/O
Fairchild Semiconductor	ZL30	Stag Microsystems
	UP803	Digilec
	ABEL, Model 29B	Data I/O
	CUPL	PCAD
Gould Inc.	PEEL Dev. Syst.	ICT
	29B, 60	Data I/O
	PPZ, ZL30A	Stag Microsystems
	SD1040	Structured Design
	SPO300, GP1140	Varix
	VDS160	Valley Data Sciences
Harris Semiconductor	HELP	Harris
	ABEL	Data I/O
	CUPL	PCAD Systems
Intel Corporation	iPLD	Intel
	DASH	Data I/O
	PC-CAPS	PCAD

(Continued)

Table 3 (Continued)

PROGRAMMABLE LOGIC DEVICE TOOLMAKER SUPPLIERS

PLD Supplier	Tool	Tool Supplier
Int'l CMOS Technology	PEEL Dev. Syst.	ICT
	29B, 60	Data I/O
	PPZ, ZL30A	Stag Microsystems
	SD1040	Structured Design
	SP0300, GP1140	Varix
	VDS160	Valley Data Sciences
Lattice Semiconductor	ABEL	Data I/O
	CUPL	PCAD Systems
Monolithic Memories	PALASM2	MMI
	ABEL	Data I/O
	CUPL	PCAD Systems
National Semiconductor	PLAN	NSC
	ABEL	Data I/O
	CUPL	PCAD Systems
	ECL-1, ECL-2	International Micros
	PALASM	
Panatech Semiconductor	ABEL	Data I/O
	Model 29, Logic Pak	Data I/O
	EPLASM IPLG	Ricoh
	CUPL	Stag Microsystems
Signetics Corporation	AMAZE	Signetics
	ABEL	Data I/O
	CUPL	PCAD Systems
Texas Instruments	ABEL	Data I/O
	CUPL	PCAD Systems
VLSI Technology	ZPL30A	Stag Microsystems
		Data I/O
Xilinx	XACT	Xilinx

Source: Dataquest
January 1987

THE PLD MARKETPLACE

Dataquest estimates that the PLD market will grow from $234.4 million in 1985 to $1,058.6 million in 1991. Table 4 ranks the top ten PLD suppliers for 1985 and 1986. A point of interest is that the top five suppliers are historically bipolar device suppliers. As stated previously, we believe that this ranking will change dramatically by 1991 when consumption of CMOS devices will represent more than 50 percent of the market.

Table 4

ESTIMATED TOP TEN PLD SUPPLIERS
(Millions of Dollars)

Company	1985	1986
Monolithic Memories	$123.0	$140.0
Signetics	$ 44.0	$ 50.0
National Semiconductor	$ 22.0	$ 33.5
Advanced Micro Devices	$ 23.0	$ 32.0
Texas Instruments	$ 12.0	$ 20.5
Altera	$ 3.9	$ 12.0
Xilinx	$ 0.3	$ 4.0
Harris	$ 3.0	$ 3.5
Intel	$ 0.2	$ 3.0
Fairchild	$ 2.0	$ 3.0

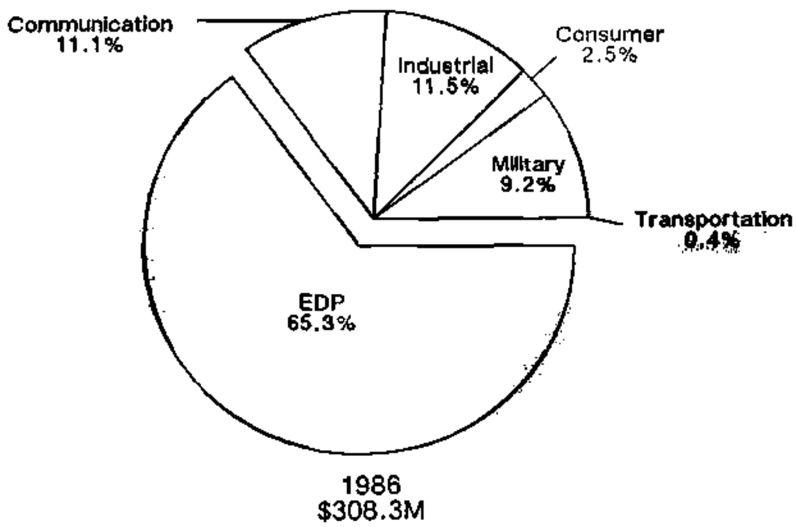
Source: Dataquest
January 1987

A question that usually arises is whether or not sales revenue for CMOS suppliers includes development systems and silicon. Currently, a large portion of the revenue is from the development systems. Dataquest believes that in the future this will change as designs with CMOS PLDs move to production. It should be noted that the design cycle, from prototype to customer to production, may take as long as a year to eighteen months, causing a period of slower growth for these devices.

As shown in Figure 3, the largest user of PLDs worldwide is the electronic data processing (EDP) market segment, consuming an estimated 65.3 percent of all PLDs shipped in 1986 because the data processing segment pushed for reduced component count and power savings. Common applications for PLDs are control logic in computers, and in peripheral controller and CRT display systems.

Figure 3

PRELIMINARY 1986
ESTIMATED PROGRAMMABLE LOGIC DEVICE
END-USE CONSUMPTION BY TECHNOLOGY
(Percent of Revenue)



Source: Dataquest
January 1987

WHAT TRENDS ARE PUSHING PLD MARKET GROWTH?

Dataquest believes that faster performance and flexible architectures will continue to fuel the growth of the PLD market. Early PLDs exhibited usable gate counts in the 100- to 300-gate range. Today gate counts are up to 1,800, and Dataquest expects that devices using 16,000 gates will be available in the early 1990s.

TTL, ECL, and CMOS process technologies are all improving in speed. By 1988, TTL PLDs should reach speeds in the 5ns to 10ns range. ECL devices, offering the ultimate in performance, will reach speeds in the 2ns range. But be aware that CMOS PLD speeds are approaching bipolar PLD speeds. Today, designers can reach speeds of 15ns to 35ns with CMOS devices. Overall, TTL or ECL processes have definite speed advantages but CMOS devices offer both architectural flexibility and high gate count.

While the first trend, enhancements in architectures, will push the limits of technical performance, the second trend will be be a restructuring of product pricing. Today most TTL PLDs cost from 0.5 cents to approximately 1 cent per gate. Dataquest expects this pricing to decline on a per gate basis as CMOS technology becomes more popular and as more products emerge. Other factors that will influence a price restructuring include:

- The emergence of Japanese suppliers in 1987
- Fierce competition among suppliers

- A possible softening in the market due to a projected recession in 1989

Another trend fueling the growth of the PLD market is the off-the-shelf availability of PLDs. PLDs are the ideal ASIC products for distributors as PLD inventories can easily be sold to customers. Unprogrammed devices can be stocked on distributors' shelves and programmed later, giving distributors better inventory control. PLDs allow distributors to add value by making programming equipment available to customize the PLDs.

DATAQUEST CONCLUSIONS

How long will PLDs successfully stalk the ASIC market? The answer again involves productivity--diverse productivity. As the tiger hungers for more good meat, so the ASIC designer hungers for faster and easier-to-use products. The fate of the PLD market lies in the answers to the following questions:

- Will PLD vendors work hand-in-hand with programmer suppliers to ensure timely support of emerging architectures and decrease time to market?
- Will an all-purpose design tool emerge that will take advantage of all existing architectures?
- With their EPROM and EEPROM experience coupled with their business skills, will the Japanese dominate the PLD market?
- As competition increases, who will be the first to withdraw from the market?

As the market matures, we believe there will be a growing synergy between programmer suppliers and PLD vendors, especially in the CMOS segment. Each participant--the PLD supplier, the third-party supplier, and the toolmaker--depends on the other in order to be successful in the market. They cannot survive as separate entities; they must communicate with each other to develop compatible architectures and tools to ensure rapid time to market.

This synergy could promote the emergence of all-purpose tools when users and suppliers realize that the proliferation of architectures could overwhelm them. Designers will begin to implement more than one type of PLD in a design. Changing software and development systems might become cumbersome, yet the demand for them will be evident.

We do believe that there will be offshore competition and that suppliers who plan for this inevitable occurrence will survive and prosper. Conversely, firms that do not plan for offshore competition may be forced to withdraw from the market.

Kelly Gustus
Andrew Prophet

Dataquest

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Computer Storage—Tape Drives

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Semiconductor Equipment and Materials*

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Coporate Technology Program

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I.C. ASIA

I.C. USA

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PC Local Area Networking Markets in Europe

The Education Market for PCs in Europe

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Home Markets for PCs in Europe

Integrated Office Systems—The Market and Its Requirements

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Korean Semiconductor Industry Analysis

Diskettes—The Market and Its Requirements

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SpecCheck—Competitive Whiteboard Guide

Who's Who in CAD/CAM 1986

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Conference Schedule

1987

Semiconductor Users/Semiconductor Application Markets	February 4-6	Saddlebrook Resort Tampa, Florida
Copying and Duplicating	February 23-25	San Diego Hilton Resort San Diego, California
Imaging Supplies	February 25-26	San Diego Hilton Resort San Diego, California
Electronic Printer	March 23-25	Silverado Country Club Napa, California
Imaging Supplies	March 25-26	Silverado Country Club Napa, California
Computer Storage	April 6-8	Red Lion Inn San Jose, California
Japanese Semiconductor	April 13-14	The Miyako Kyoto, Japan
Color Conference	April 24	Red Lion Inn San Jose, California
European Telecommunications	April 27-29	The Beach Plaza Hotel Monte Carlo, Monaco
CAD/CAM	May 14-15	Hyatt Regency Monterey Monterey, California
Graphics/Display Terminals	May 20-22	San Diego Hilton Resort San Diego, California
European Semiconductor	June 4-5	Palace Hotel Madrid, Spain
European Copying and Duplicating	June 25-26	The Ritz Hotel Lisbon, Portugal
Telecommunications	June 29-July 1	Silverado Country Club Napa, California
Financial Services	August 17-18	Silverado Country Club Napa, California
Western European Printer	September 9-11	Palace Hotel Madrid, Spain
Manufacturing Automation	September 14-15	San Diego Hilton Resort San Diego, California
Business/Office Systems and Software	September 21-22	Westford Regency Hotel Littleton, Massachusetts
Asian Peripherals and Office Equipment	October 5-8	Tokyo American Club Tokyo, Japan
Technical Computers	October 5-7	Hyatt Regency Monterey Monterey, California
Semiconductor	October 19-21	The Pointe Resort Phoenix, Arizona
Office Equipment Dealers	November 5-6	Hyatt Regency Monterey Monterey, California
Military IC	November 12	Hotel Meridien Newport Beach, California
Electronic Publishing	November 16-17	Stouffer Hotel Bedford, Massachusetts
Asian Information Systems	November 30-December 4	Tokyo, Japan
CAD/CAM Electronic Design Automation	December 10-11	Santa Clara Marriott Santa Clara, California

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RESEARCH NEWSLETTER

SIS Code: 1986-1987 Newsletters: January
1987-1

1986 PRELIMINARY MARKET SHARE
CURRENCY REVALUATIONS CHANGE MARKET STANDINGS

Preliminary estimates of the world semiconductor market indicate a 26.1 percent increase in revenue when measured in dollars. By this measure, Japanese producers fared well, chalking up approximately a 43 percent growth in worldwide factory shipments. European producers had the next best growth with a 16 percent increase in factory shipments and the North American region fared worst of all with only a 10 percent growth.

These figures do not correlate with the emotional response heard from the major producing regions: cries of anguish from Japan, distress from Europe, and the loud sound of bullet biting in North America. The real market picture is perhaps different from that portrayed by the growth of revenue expressed in dollars.

A different picture appears when consumption in the three regions is expressed in local currencies: The North American region shows a 6.4 percent growth, Japan shows a negative growth of 2.0 percent, and European producers have a market decline of 6 percent. This helps explain the reaction of producers in the three regions, but it still may not be an accurate view.

If producers outside North America can increase their dollar market shares in the face of increasing dollar prices it must be that their products were undervalued. By this argument, the dollar market share is significant. Japanese sales in 1986 outside Japan (expressed in yen) fell only 8 percent from 1985. Currency revaluations against the dollar were an increase of 43 percent in Japanese yen and an increase of 20 percent in the European basket of currencies.

Dataquest believes that the true impact of currency revaluations on market standing lies somewhere between the local-currency point of view and the dollar-denominated point of view. We anticipate that suppliers in various geographic regions will continue to adjust their strategies to further compensate for these changes during 1987.

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1986 MARKET SUMMARY

Tables 1 through 8 rank the top 50 major worldwide suppliers by total semiconductor, integrated circuits, bipolar, MOS, linear, discrete and optoelectronics (opto) product areas. These rankings are all stated in dollars. In each instance, these suppliers accounted for at least 90 percent of the total world market and thus give a good preliminary snapshot of 1986. The total world market increased 26.1 percent, and was made up of an increase of 26.4 percent in ICs and 25.3 percent in discrete and opto. Among the markets comprising ICs, MOS digital exhibited the fastest growth at 28.1 percent and bipolar digital noted the slowest growth at 19.5 percent. Generally, Japanese suppliers exhibit higher growth than European suppliers which in turn exhibit higher growth than North American suppliers. These variations in growth rates reflect the currency revaluations discussed above. In spite of this, a number of North American suppliers exhibited growth rates above the world averages in their segments, reflecting, Dataquest believes, a successful search for niches. These suppliers will be pointed out in the discussion of each table.

SEMICONDUCTOR MARKET SHARE

In total semiconductor, as indicated in Table 1, NEC maintained its first place ranking. Hitachi and Toshiba made it to second and third place, respectively, passing Motorola and Texas Instruments. Toshiba showed an above average growth rate even when currency effects are accounted for. Dataquest believes Toshiba is currently expanding its productive capacity in a bid for even greater market share. In the top 10, Mitsubishi is a new entrant, pushing National Semiconductor from the top 10.

A number of smaller North American companies showed growth rates above the industry average of 26.1 percent. These include TRW, LSI Logic, Honeywell, and VLSI Technology. Dataquest believes these firms have successfully exploited market niches in this difficult year.

IC MARKET SHARE

IC market share rankings are shown in Table 2. These company sales are included in the total semiconductor sales of Table 1. NEC ascended to first position in these rankings, followed by Hitachi, thus relegating Texas Instruments to third place. Toshiba advanced two positions, pushing Motorola from third place to fifth place. In the top 10, Mitsubishi is a new entry, replacing Advanced Micro Devices.

Smaller North American companies showing growth rates above the industry average for this segment of 26.4 percent include Honeywell, Integrated Device Technology, LSI Logic, Silicon Systems TRW, and VLSI Technology.

Gold Star and United Microelectronics are new to the list this year. Gold Star is a Korean company and United Microelectronics is located in Taiwan. This is significant because it is the first time Asian suppliers outside Japan have achieved this ranking. Both companies had growth rates much higher than the world average, which is also significant because both of these countries have currencies that are tied to the dollar.

BIPOLAR DIGITAL MARKET SHARE

The bipolar digital market shares are shown in Table 3. These figures are included in the IC totals of Table 2. This market has fewer suppliers than other markets in the integrated circuit category.

In the top 10, Texas Instruments retained its first place ranking. Philips-Signetics edged out Motorola for second place and Fujitsu climbed into fourth place edging out Fairchild. No new players appear in the top 10.

Honeywell and Raytheon are two North American companies that showed growth rates significantly in excess of the 19.5 percent growth rate of this segment.

MOS DIGITAL MARKET SHARE

MOS digital market shares are shown in Table 4. These figures are included in the IC totals of Table 2.

In the top 10, NEC retains its first place ranking, followed by Hitachi and Toshiba who pushed Intel from second to fourth place. New entrants to the top 10 include Matsushita and Oki, which replace National Semiconductor and Advanced Micro Devices.

North American companies that show growth rates above the average for this segment of 28.1 percent include LSI Logic, Integrated Device Technology, Rockwell, VLSI Technology, Cypress Semiconductor, Micron Technology, and Honeywell.

Two East Asian companies outside Japan showing high growth rates are Samsung and United Microelectronics. Dataquest believes these firms benefitted by being exempt from the U.S. Department of Commerce FMV prices for memory devices, as did Micron Technology, Cypress, and Integrated Device Technology.

LINEAR MARKET SHARE

Linear market shares are shown in Table 5. These figures are included in the IC totals of Table 2.

In the top 10, Matsushita advanced to first place passing National Semiconductor, long the world's leading supplier of linear devices. Toshiba advanced to number three position and NEC maintained its number four slot. There were no new entrants to the top 10.

North American companies that show growth rates above the average for this segment of 27.1 percent include Silicon Systems, TRW, Mitel, Linear Technology, Cherry Semiconductor, Unitrode, and Solitron.

East Asian companies outside of Japan showing above average growth rates include Gold Star, Samsung, and KEC.

DISCRETE/OPTO MARKET SHARE

Discrete/opto market shares are shown in Table 6. These figures are added into the totals of Table 1.

In the top 10, Toshiba advanced to first place, edging out Motorola, long the leader in this segment. Hitachi and NEC retained their third and fourth positions respectively. There were no new entrants to the top 10.

North American companies showing growth above the world average for this segment include TRW and Supertex.

A new entrant to the list this year is Powerex. This company includes the former discrete operations of Westinghouse and a portion of the discrete business of General Electric. The new entity was backed in financing and technology by Mitsubishi.

DISCRETE MARKET SHARE

Discrete market shares are shown in Table 7. These figures are added into the totals of Table 6.

In the top 10, Motorola retained its number one position. Toshiba advanced to second place, pushing Hitachi down to third place. NEC maintained its position as number four. ROHM and Fuji Electric were new additions to the top 10, replacing ITT and International Rectifier. North American companies showing growth above the world average for this segment include TRW and Hewlett-Packard.

OPTO MARKET SHARE

Table 8 gives world market shares of optoelectronics. These figures are added into the totals of Table 6. Note that opto equals the MOS digital area in high growth of 28 percent.

In the top 10, Sharp advanced to first place, edging out Hewlett-Packard. Matsushita and Sony advanced to third and fourth place respectively, relegating Toshiba to fifth place rather than third place. ROHM was a new entrant to the top 10, replacing Hitachi.

RCA was the only North American firm showing growth in excess of the segment average.

Definitions

Our data includes semiconductor revenue from products shipped to non-semiconductor segments of the same company where those products are initiated in the semiconductor group. These products are valued as if they were sold on the merchant market. By using this definition, Dataquest seeks to account for true manufacturing capability of semiconductor suppliers. Because of our definition, we differ from publicly reported semiconductor sector data for companies such as Motorola. Dataquest includes hybrid circuits, if they are manufactured in the semiconductor group. NRE costs are also included for those gate arrays, standard cells, and custom products included in a company's ASIC revenue.

Dataquest's preliminary Market Share Service Section is currently being completed and will be available to all binder holders this month.

Barbara Van
Howard Bogert

Table 1

PRELIMINARY 1986 WORLD SEMICONDUCTOR MARKET SHARE RANKING
(Millions of Dollars)

1986 RANK	1985 RANK	COMPANY	1985	1986	Percent Change
1	1	NEC	1984	2638	33.0%
2	4	HITACHI	1671	2305	37.9%
3	5	TOSHIBA	1468	2261	54.0%
4	2	MOTOROLA	1830	2025	10.7%
5	3	TEXAS INSTRUMENTS	1742	1820	4.5%
6	6	PHILIPS-SIGNETICS	1068	1356	27.0%
7	7	FUJITSU	1020	1310	28.4%
8	10	MATSUSHITA	906	1233	36.1%
9	11	MITSUBISHI	642	1177	83.3%
10	8	INTEL	1020	991	-2.8%
11	9	NATIONAL SEMICONDUCTOR	925	990	7.0%
12	12	ADVANCED MICRO DEVICES	615	629	2.3%
13	14	SANYO	457	585	28.0%
14	13	FAIRCHILD	492	510	3.7%
15	22	SONY	252	475	88.5%
16	15	SIEMENS	420	457	8.8%
17	16	SHARP	329	456	38.6%
18	17	THOMSON-MOSTEK*	324	436	34.6%
19	19	OKI	307	427	39.1%
20	23	ROHM	249	379	52.2%
21	20	SGS	300	370	23.3%
22	18	RCA	310	370	19.4%
23	21	ITT	270	312	15.6%
24	24	HARRIS	247	264	6.9%
25	25	ANALOG DEVICES	226	232	2.7%
26	31	SANKEN	155	220	41.9%
27	29	TELEFUNKEN ELECTRONIC	170	219	28.8%
28	26	HEWLETT-PACKARD	206	217	5.3%
29	36	TRW	125	213	70.4%
30	30	FUJI ELECTRIC	156	213	36.5%
31	28	MONOLITHIC MEMORIES	172	210	22.1%
32	27	GENERAL INSTRUMENT	201	205	2.0%
33	32	LSI LOGIC	140	192	37.1%
34	41	SAMSUNG	95	183	92.6%
35	42	SEIKO EPSON	93	167	79.6%
36	44	HONEYWELL	88	157	78.4%
37	33	AMERICAN MICROSYSTEMS	140	155	10.7%
38	34	INTERNATIONAL RECTIFIER	128	145	13.3%
39	38	SILICONIX	110	126	14.5%
40	39	PLESSEY	99	112	13.1%
41	48	VLSI TECHNOLOGY	78	110	41.0%
42	N/A	POWEREX	0	95	N/A
43	49	BURR-BROWN	78	95	21.8%
44	40	FERRANTI	98	95	-3.1%
45	45	SPRAGUE	87	94	8.0%
46	43	UNITRODE	89	90	1.1%
47	37	GENERAL ELECTRIC	118	89	-24.6%
48	52	PRECISION MONOLITHICS	68	81	19.1%
49	46	INMOS	85	80	-5.9%
50	50	NCR	75	80	6.7%
		Top 50 total	21928	27651	26.1%

*NOTE: MOSTEK AND THOMSON REVENUES ARE AGGREGATED IN 1986 BUT NOT 1985. MOSTEK WOULD ADD AN ADDITIONAL $125 MILLION TO THOMSON'S 1985 REVENUES.

Source: Dataquest
January 1987

Table 2

PRELIMINARY 1986 WORLD IC MARKET SHARE RANKING
(Millions of Dollars)

1986 RANK	1985 RANK	COMPANY	1985	1986	Percent Change
1	2	NEC	1603	2154	34.4%
2	4	HITACHI	1236	1771	43.3%
3	1	TEXAS INSTRUMENTS	1653	1728	4.5%
4	6	TOSHIBA	1004	1605	59.9%
5	3	MOTOROLA	1281	1405	9.7%
6	7	FUJITSU	940	1198	27.4%
7	9	PHILIPS-SIGNETICS	808	1041	28.8%
8	5	INTEL	1020	991	-2.8%
9	8	NATIONAL SEMICONDUCTOR	882	956	8.4%
10	12	MITSUBISHI	465	923	98.5%
11	11	MATSUSHITA	595	807	35.6%
12	10	ADVANCED MICRO DEVICES	615	629	2.3%
13	13	FAIRCHILD	451	464	2.9%
14	14	SANYO	314	407	29.6%
15	15	OKI	289	402	39.1%
16	22	THOMSON-MOSTEK*	197	293	48.7%
17	17	SGS	240	291	21.3%
18	24	SONY	155	290	87.1%
19	19	RCA	225	268	19.1%
20	16	HARRIS	247	264	6.9%
21	21	SHARP	201	259	28.9%
22	20	SIEMENS	205	237	15.6%
23	18	ANALOG DEVICES	226	232	2.7%
24	23	MONOLITHIC MEMORIES	172	210	22.1%
25	27	LSI LOGIC	140	192	37.1%
26	26	ITT	140	168	20.0%
27	30	SEIKO EPSON	93	167	79.6%
28	29	ROHM	105	163	55.2%
29	37	SAMSUNG	75	159	112.0%
30	25	AMERICAN MICROSYSTEMS	140	155	10.7%
31	45	HONEYWELL	57	122	114.0%
32	35	VLSI TECHNOLOGY	78	110	41.0%
33	31	PLESSEY	89	98	10.1%
34	33	BURR-BROWN	78	95	21.8%
35	53	TRW	43	88	104.7%
36	40	TELEFUNKEN ELECTRONIC	68	82	20.6%
37	39	PRECISION MONOLITHICS	68	81	19.1%
38	48	SANKEN	53	81	52.8%
39	32	INMOS	85	80	-5.9%
40	36	NCR	75	80	6.7%
41	34	FERRANTI	78	78	0.0%
42	44	ZILOG	59	74	25.4%
43	51	INTEGRATED DEVICE TECH.	50	72	44.0%
44	50	SILICON SYSTEMS	51	72	41.2%
45	46	WESTERN DIGITAL	56	70	25.0%
46	41	SILICONIX	63	69	9.5%
47	38	INTERSIL	70	68	-2.9%
48	60	GOLD STAR	32	65	103.1%
49	43	SPRAGUE	60	65	8.3%
50	58	UNITED MICROELECTRONICS	33	65	97.0%
		Top 50 total	16963	21444	26.4%

*NOTE: MOSTEK AND THOMSON REVENUES ARE AGGREGATED IN 1986 BUT NOT 1985. MOSTEK WOULD ADD AN ADDITIONAL $125 MILLION TO THOMSON'S 1985 REVENUES.

Source: Dataquest
January 1987

Table 3

PRELIMINARY 1986 WORLD BIPOLAR DIGITAL MARKET SHARE RANKING
(Millions of Dollars)

1986 RANK	1985 RANK	COMPANY	1985	1986	Percent Change
1	1	TEXAS INSTRUMENTS	796	875	9.9%
2	3	PHILIPS-SIGNETICS	372	427	14.8%
3	2	MOTOROLA	379	398	5.0%
4	6	FUJITSU	267	347	30.0%
5	4	FAIRCHILD	329	341	3.6%
6	7	HITACHI	195	339	73.8%
7	5	ADVANCED MICRO DEVICES	276	303	9.8%
8	9	MONOLITHIC MEMORIES	170	206	21.2%
9	8	NATIONAL SEMICONDUCTOR	194	206	6.2%
10	10	NEC	129	176	36.4%
11	11	MITSUBISHI	75	155	106.7%
12	16	TOSHIBA	33	129	290.9%
13	12	HONEYWELL	50	86	72.0%
14	13	FERRANTI	49	43	-12.2%
15	15	SIEMENS	41	41	0.0%
16	22	RAYTHEON	22	33	50.0%
17	24	MATSUSHITA	21	30	42.9%
18	17	PLESSEY	30	30	0.0%
19	21	OKI	22	26	18.2%
20	26	ROHM	15	25	66.7%
21	23	AMCC	21	24	14.3%
22	25	SANYO	18	23	27.8%
23	14	HARRIS	43	21	-51.2%
24	20	INTEL	22	21	-4.5%
25	18	SGS	26	20	-23.1%
26	19	THOMSON-MOSTEK	24	10	-58.3%
27	29	GOLD STAR	4	7	75.0%
28	28	INTERDESIGN	6	5	-16.7%
29	27	RIFA	9	5	-44.4%
30	33	CHERRY SEMICONDUCTOR	3	3	0.0%
31	34	TELEDYNE	3	3	0.0%
32	32	TRW	4	3	-25.0%
33	35	FUJI ELECTRIC	1	2	100.0%
34	30	MATRA-HARRIS	4	1	-75.0%
		Top 34 total	3653	4364	19.5%

Source: Dataquest
January 1987

Table 4

PRELIMINARY 1986 WORLD MOS DIGITAL MARKET SHARE RANKING
(Millions of Dollars)

1986 RANK	1985 RANK	COMPANY	1985	1986	Percent Change
1	1	NEC	1174	1615	37.6%
2	3	HITACHI	852	1167	37.0%
3	4	TOSHIBA	736	1106	50.3%
4	2	INTEL	998	970	-2.8%
5	6	FUJITSU	631	791	25.4%
6	5	MOTOROLA	668	727	8.8%
7	10	MITSUBISHI	290	583	101.0%
8	7	TEXAS INSTRUMENTS	522	501	-4.0%
9	11	MATSUSHITA	269	384	42.8%
10	12	OKI	264	372	40.9%
11	8	NATIONAL SEMICONDUCTOR	318	366	15.1%
12	13	PHILIPS-SIGNETICS	228	314	37.7%
13	9	ADVANCED MICRO DEVICES	305	290	-4.9%
14	14	SHARP	173	214	23.7%
15	20	THOMSON-MOSTEK*	107	210	96.3%
16	15	RCA	160	194	21.3%
17	17	LSI LOGIC	140	192	37.1%
18	21	SEIKO EPSON	93	167	79.6%
19	16	AMERICAN MICROSYSTEMS	140	155	10.7%
20	32	SAMSUNG	55	123	123.6%
21	19	HARRIS	111	117	5.4%
22	29	SONY	59	116	96.6%
23	26	VLSI TECHNOLOGY	78	110	41.0%
24	23	ITT	90	107	18.9%
25	24	SGS	88	106	20.5%
26	22	SIEMENS	92	96	4.3%
27	28	SANYO	68	88	29.4%
28	25	INMOS	85	80	-5.9%
29	27	NCR	75	80	6.7%
30	30	ZILOG	59	74	25.4%
31	34	INTEGRATED DEVICE TECH.	50	72	44.0%
32	31	WESTERN DIGITAL	56	70	25.0%
33	42	UNITED MICROELECTRONICS	33	65	97.0%
34	35	ROCKWELL	44	64	45.5%
35	33	STANDARD MICROSYSTEMS	54	56	3.7%
36	51	CYPRESS SEMICONDUCTOR	18	50	177.8%
37	39	MICRON TECHNOLOGY	36	49	36.1%
38	38	MATRA-HARRIS	36	44	22.2%
39	36	GENERAL INSTRUMENT	42	40	-4.8%
40	43	XICOR	32	40	25.0%
41	37	HUGHES	36	39	8.3%
42	40	PLESSEY	35	39	11.4%
43	62	HONEYWELL	7	36	414.3%
44	41	SEEQ	33	31	-6.1%
45	48	EUROSIL	21	30	42.9%
46	46	IMP	25	30	20.0%
47	44	SOLID STATE SCIENTIFIC	28	30	7.1%
48	50	ASEA-HAFO	18	22	22.2%
49	47	FAIRCHILD	22	22	0.0%
50	49	MEDL	20	22	10.0%
		Top 50 total	9574	12266	28.1%

*NOTE: MOSTEK AND THOMSON REVENUES ARE AGGREGATED IN 1986 BUT NOT 1985. MOSTEK WOULD ADD AN ADDITIONAL $125 MILLION TO THOMSON'S 1985 REVENUES.

Source: Dataquest
January 1987

Table 5

PRELIMINARY 1986 WORLD LINEAR MARKET SHARE RANKING
(Millions of Dollars)

1986 RANK	1985 RANK	COMPANY	1985	1986	Percent Change
1	3	MATSUSHITA	305	393	28.9%
2	1	NATIONAL SEMICONDUCTOR	370	384	3.8%
3	5	TOSHIBA	235	370	57.4%
4	4	NEC	300	363	21.0%
5	2	TEXAS INSTRUMENTS	335	352	5.1%
6	9	PHILIPS-SIGNETICS	208	300	44.2%
7	7	SANYO	228	296	29.8%
8	6	MOTOROLA	234	280	19.7%
9	10	HITACHI	189	265	40.2%
10	8	ANALOG DEVICES	226	232	2.7%
11	13	MITSUBISHI	100	185	85.0%
12	14	SONY	96	174	81.3%
13	11	SGS	126	165	31.0%
14	16	ROHM	85	129	51.8%
15	15	HARRIS	93	126	35.5%
16	12	FAIRCHILD	100	101	1.0%
17	18	SIEMENS	72	100	38.9%
18	17	BURR-BROWN	78	95	21.8%
19	19	PRECISION MONOLITHICS	68	81	19.1%
20	26	SANKEN	53	81	52.8%
21	21	RCA	65	74	13.8%
22	20	THOMSON-MOSTEK	66	73	10.6%
23	27	SILICON SYSTEMS	51	72	41.2%
24	30	TRW	39	70	79.5%
25	22	SILICONIX	60	65	8.3%
26	23	SPRAGUE	60	65	8.3%
27	24	TELEFUNKEN ELECTRONIC	55	63	14.5%
28	28	ITT	50	61	22.0%
29	29	FUJITSU	42	60	42.9%
30	25	INTERSIL	53	53	0.0%
31	38	GOLD STAR	22	48	118.2%
32	35	SHARP	28	45	60.7%
33	33	MITEL	29	38	31.0%
34	31	ADVANCED MICRO DEVICES	34	36	5.9%
35	32	EXAR	30	36	20.0%
36	40	SAMSUNG	20	36	80.0%
37	39	LINEAR TECHNOLOGY	22	29	31.8%
38	36	PLESSEY	24	29	20.8%
39	34	RAYTHEON	29	28	-3.4%
40	44	FUJI ELECTRIC	13	26	100.0%
41	37	FERRANTI	23	24	4.3%
42	45	CHERRY SEMICONDUCTOR	11	18	63.6%
43	43	INTERDESIGN	18	17	-5.6%
44	41	GENERAL INSTRUMENT	19	15	-21.1%
45	42	GTE MICROCIRCUITS	18	14	-22.2%
46	47	TELEDYNE	11	13	18.2%
47	50	UNITRODE	8	13	62.5%
48	49	SOLITRON	8	12	50.0%
49	48	KEC	8	11	37.5%
50	46	MICRO POWER SYSTEMS	11	10	-9.1%
		Top 50 total	4428	5626	27.1%

Source: Dataquest
January 1987

Table 6

PRELIMINARY 1986 WORLD DISCRETE/OPTO MARKET SHARE RANKING
(Millions of Dollars)

1986 RANK	1985 RANK	COMPANY	1985	1986	Percent Change
1	2	TOSHIBA	464	656	41.4%
2	1	MOTOROLA	549	620	12.9%
3	3	HITACHI	435	534	22.8%
4	4	NEC	381	484	27.0%
5	5	MATSUSHITA	311	426	37.0%
6	6	PHILIPS-SIGNETICS	260	315	21.2%
7	9	MITSUBISHI	177	254	43.5%
8	7	SIEMENS	215	220	2.3%
9	8	HEWLETT-PACKARD	206	217	5.3%
10	10	ROHM	144	216	50.0%
11	16	SHARP	128	197	53.9%
12	21	SONY	97	185	90.7%
13	13	FUJI ELECTRIC	136	178	30.9%
14	11	SANYO	143	178	24.5%
15	12	GENERAL INSTRUMENT	140	150	7.1%
16	15	INTERNATIONAL RECTIFIER	128	145	13.3%
17	14	ITT	130	144	10.8%
18	17	THOMSON-MOSTEK	127	143	12.6%
19	19	SANKEN	102	139	36.3%
20	20	TELEFUNKEN ELECTRONIC	102	137	34.3%
21	24	TRW	82	125	52.4%
22	26	FUJITSU	80	112	40.0%
23	23	RCA	85	102	20.0%
24	N/A	POWEREX	0	95	N/A
25	22	TEXAS INSTRUMENTS	89	92	3.4%
26	18	GENERAL ELECTRIC	112	81	-27.7%
27	27	SGS	60	79	31.7%
28	25	UNITRODE	81	77	-4.9%
29	29	SEMIKRON	48	72	50.0%
30	30	SILICONIX	47	57	21.3%
31	32	FAIRCHILD	41	46	12.2%
32	33	KEC	34	39	14.7%
33	36	BROWN-BOVERI	29	35	20.7%
34	34	HONEYWELL	31	35	12.9%
35	31	NATIONAL SEMICONDUCTOR	43	34	-20.9%
36	35	SOLITRON	30	30	0.0%
37	37	SPRAGUE	27	29	7.4%
38	42	OKI	18	25	38.9%
39	41	SAMSUNG	20	24	20.0%
40	38	ACRIAN	23	18	-21.7%
41	44	TAG	18	18	0.0%
42	40	FERRANTI	20	17	-15.0%
43	45	MEDL	15	17	13.3%
44	43	RAYTHEON	18	16	-11.1%
45	39	VARO	22	15	-31.8%
46	49	PLESSEY	10	14	40.0%
47	46	ASEA-HAFO	10	13	30.0%
48	48	PIHER	10	11	10.0%
49	47	INTERSIL	10	7	-30.0%
50	50	SUPERTEX	5	7	40.0%
		Top 50 total	5493	6880	25.3%

Source: Dataquest
January 1987

Table 7

PRELIMINARY 1986 WORLD DISCRETE MARKET SHARE RANKING
(Millions of Dollars)

1986 RANK	1985 RANK	COMPANY	1985	1986	Percent Change
1	1	MOTOROLA	532	602	13.2%
2	3	TOSHIBA	368	549	49.2%
3	2	HITACHI	393	484	23.2%
4	4	NEC	351	439	25.1%
5	6	MATSUSHITA	227	293	29.1%
6	5	PHILIPS-SIGNETICS	235	288	22.6%
7	7	MITSUBISHI	177	254	43.5%
8	11	FUJI ELECTRIC	126	170	34.9%
9	13	ROHM	110	160	45.5%
10	8	SIEMENS	140	155	10.7%
11	10	INTERNATIONAL RECTIFIER	128	145	13.3%
12	9	ITT	130	144	10.8%
13	12	THOMSON-MOSTEK	123	138	12.2%
14	16	SANKEN	97	132	36.1%
15	14	SANYO	103	129	25.2%
16	15	GENERAL INSTRUMENT	100	115	15.0%
17	N/A	POWEREX	0	95	N/A
18	20	TELEFUNKEN ELECTRONIC	61	84	37.7%
19	19	RCA	76	83	9.2%
20	21	SGS	60	79	31.7%
21	18	UNITRODE	81	77	-4.9%
22	24	SEMIKRON	48	72	50.0%
23	31	TRW	36	70	94.4%
24	26	SONY	42	65	54.8%
25	22	TEXAS INSTRUMENTS	56	58	3.6%
26	25	SILICONIX	47	57	21.3%
27	17	GENERAL ELECTRIC	92	56	-39.1%
28	27	HEWLETT-PACKARD	40	51	27.5%
29	29	FUJITSU	37	48	29.7%
30	28	FAIRCHILD	39	45	15.4%
31	34	BROWN-BOVERI	29	35	20.7%
32	32	KEC	32	35	9.4%
33	30	NATIONAL SEMICONDUCTOR	37	34	-8.1%
34	33	SOLITRON	30	30	0.0%
35	35	SPRAGUE	27	29	7.4%
36	39	SAMSUNG	20	24	20.0%
37	36	ACRIAN	23	18	-21.7%
38	41	TAG	18	18	0.0%
39	38	FERRANTI	20	17	-15.0%
40	42	MEDL	15	17	13.3%
		Top 40 total	4306	5394	25.3%

Source: Dataquest
January 1987

Table 8

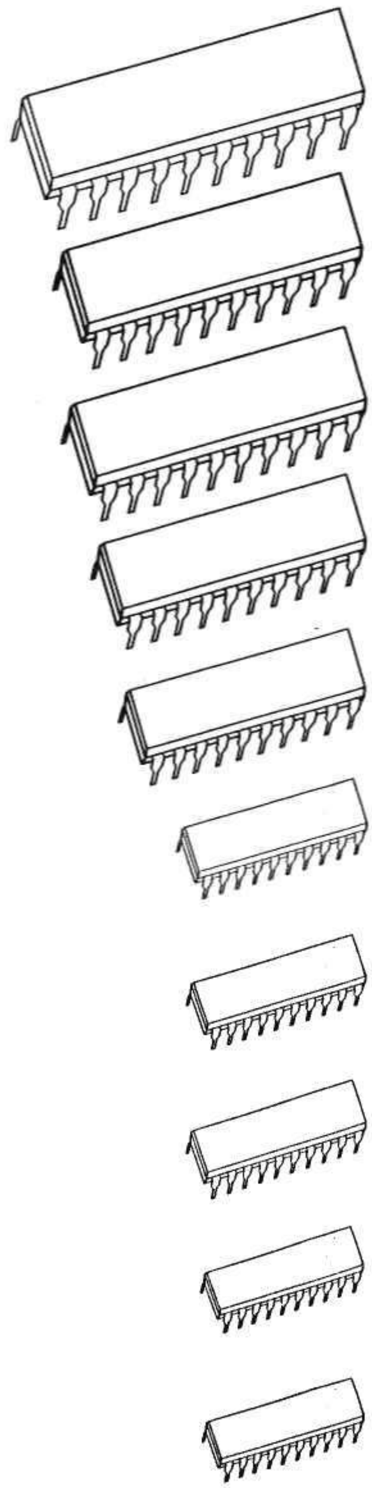
PRELIMINARY 1986 WORLD OPTO MARKET SHARE RANKING
(Millions of Dollars)

1986 RANK	1985 RANK	COMPANY	1985	1986	Percent Change
1	2	SHARP	128	197	53.9%
2	1	HEWLETT-PACKARD	166	166	0.0%
3	4	MATSUSHITA	84	133	58.3%
4	6	SONY	55	120	118.2%
5	3	TOSHIBA	96	107	11.5%
6	5	SIEMENS	75	65	-13.3%
7	8	FUJITSU	43	64	48.8%
8	13	ROHM	34	56	64.7%
9	7	TRW	46	55	19.6%
10	10	TELEFUNKEN ELECTRONIC	41	53	29.3%
11	9	HITACHI	42	50	19.0%
12	12	SANYO	40	49	22.5%
13	16	NEC	30	45	50.0%
14	11	GENERAL INSTRUMENT	40	35	-12.5%
15	15	HONEYWELL	31	35	12.9%
16	14	TEXAS INSTRUMENTS	33	34	3.0%
17	17	PHILIPS-SIGNETICS	25	27	8.0%
18	18	GENERAL ELECTRIC	20	25	25.0%
19	20	OKI	14	19	35.7%
20	23	RCA	9	19	111.1%
21	19	MOTOROLA	17	18	5.9%
22	22	PLESSEY	10	14	40.0%
23	21	FUJI ELECTRIC	10	8	-20.0%
24	26	SANKEN	5	7	40.0%
25	25	ASEA-HAFO	5	6	20.0%
		Top 25 total	1099	1407	28.0%

Source: Dataquest
January 1987

Top 10 Worldwide Semiconductor Manufacturers for 1986

	1986 Rank	1985 Rank	1986 Sales (Millions of Dollars)	1985 Sales (Millions of Dollars)
NEC	1	1	2,638	1,984
Hitachi	2	4	2,305	1,671
Toshiba	3	5	2,261	1,468
Motorola	4	2	2,025	1,830
Texas Instruments	5	3	1,820	1,742
Philips/Signetics	6	6	1,356	1,068
Fujitsu	7	7	1,310	1,020
Matsushita	8	10	1,233	906
Mitsubishi	9	11	1,177	642
Intel	10	8	991	1,020



Source: Dataquest
January 1987

February Newsletters

The following is a list of the newsletters in this section:

February Newsletters

Dataquest
a company of
The Dun & Bradstreet Corporation

Research Newsletter

SIS Code: 1986-1987 Newsletters: February
1987-8

SURFACE MOUNT TECHNOLOGY:
THE OPPORTUNITY IS MEETING THE CHALLENGE

OVERVIEW

Dataquest forecasts that by 1990, the PCB CAD market will grow to more than $1 billion from $477 million in 1985. Yet the percent change in revenue from year to year is declining from 34 percent in 1985 to only 15 percent growth in 1990 (please refer to Figure 1 and Table 1). How can vendors grow amid such change?

Dataquest believes that surface-mount technology (SMT) represents a significant opportunity for vendors looking to grow their businesses in the PCB CAD market. We recently completed a survey focusing specifically on the needs of end users implementing SMT on CAD systems. The survey has yielded information and analysis regarding this design technology. In addition to reviewing the survey results and six months of focus research, this newsletter discusses the following issues:

- Technology differences between traditional, through-hole design methodologies (THT) and SMT
- End-user attitudes that directly impact their impressions of currently available CAD systems for SMT
- What vendors can do to meet the challenges SMT offers

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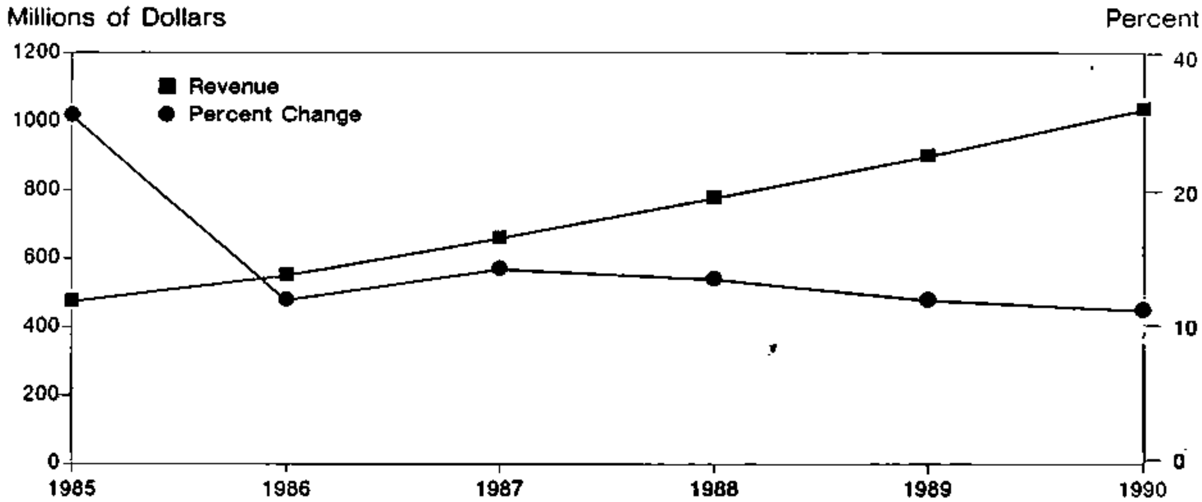
Dataquest, Incorporated, 1290 Ridder Park Drive, San Jose, CA 95131-2398, (408) 971-9000, Telex 171973

Figure 1

PCB CAD REVENUE FORECAST
(Percent Change)



Source: Dataquest
February 1987

Table 1

PCB CAD MARKET FORECAST

	1985	1986	1987	1988	1989	1990
Revenue	477	552	659	778	902	1,038
Percent Change	34%	16%	19%	18%	16%	15%

Source: Dataquest
February 1987

SMT--What is it?

Before taking an in-depth look at survey results we offer a brief history and definition of surface-mount design methodologies.

SMT was first used in the United States in the early 1960s by the military because it met their requirements for space savings and high reliability. Surface-mount technology was available for commercial use in the United States in the 1970s. Today, SMT is used most often in the automotive, computer, and consumer electronics industries as well as aerospace.

Dataquest defines SMT CAD as the laying out of printed circuit boards (PCBs) with chips mounted to the surface of the board. The differences between through-hole technology and SMT that affect CAD systems include device footprints, packaging, and access to internal layers of the board.

How is it Different?

When designers lay out PCBs with through-hole devices, footprints (the graphic shape of a device) for components consist of round pads that go through all layers of the board. In SMT, footprints are made up of rectangular pads that reside on the external layers of the board only (please refer to Figure 2).

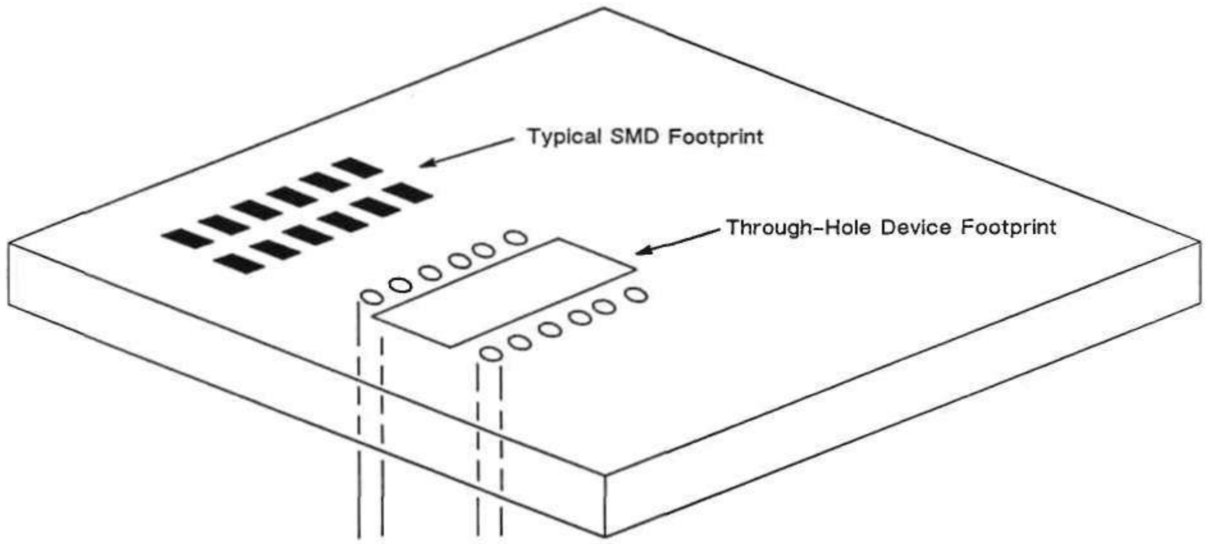
Looking further into the differences among THT and SMT devices, there are standards for through-hole device packages (i.e., the same-shaped device is available from a variety of vendors), while there are no such standards for SMT devices. Although there are several organizational efforts to standardize SMT device packages, today's users contend with the confusion caused by the same technology or device being available in too many packages.

The variation in packages causes designers confusion because they must create the footprints and physical library for each SMT device. Before they begin the physical layout, users need to know which manufacturer's components will be used so that the footprint graphic will match the actual device.

Another difference between these technologies is that through-hole devices use vias that go through all layers of the board, whereas in surface mounting, designers use blind and/or buried vias to access the internal layers of the board (see Figure 3).

Figure 2

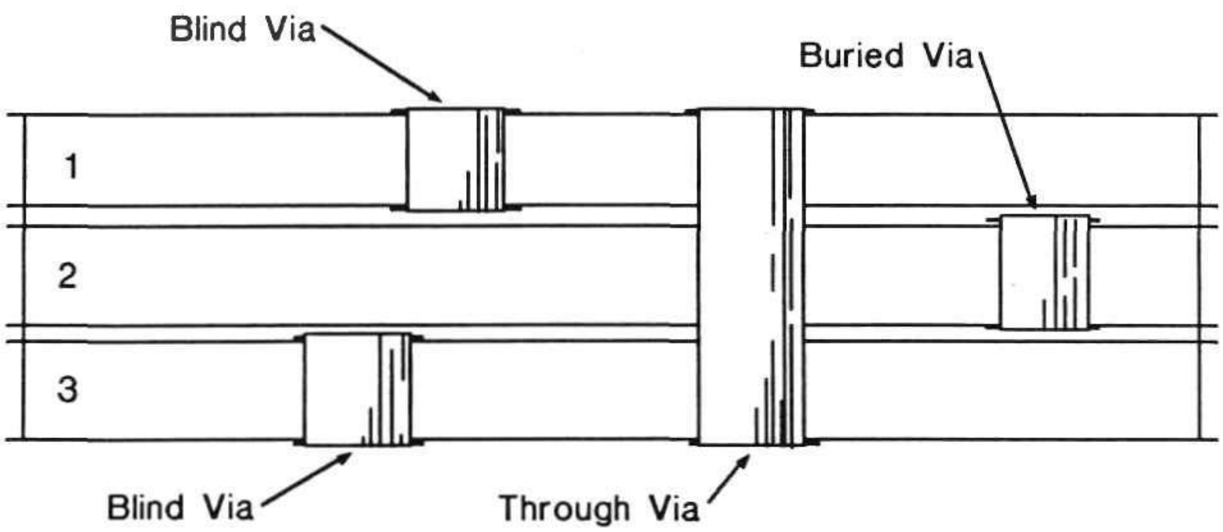
DEVICE FOOTPRINTS



Source: Nugrafix Group
Design Guideline Book

Figure 3

VIAS



Source: Nugrafix Group
Design Guideline Book

THE SURVEY

Demographics

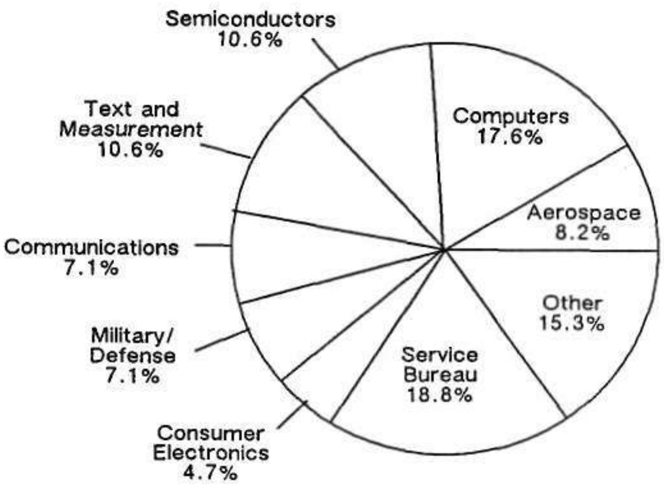
The survey sample consisted of 100 PCB CAD end users. Our selection criterion was based on whether the users were using their CAD systems for PCB layout rather than whether they were using SMT or not.

Nineteen percent of the responses came from service bureaus and another 18 percent from computer companies. Please refer to Figure 4 for further details on the industries of the respondents.

Thirty-three percent of the respondents indicated that they have been using SMT for one year or less. However, the bulk of the respondents, 47 percent, responded that they have been using surface-mount technology for two to three years. Approximately 20 percent have been using SMT for more than three years. Less than 1 percent indicated that they do not use SMT and have no plans to do so in 1987.

Figure 4

RESPONDENTS BY END-USER INDUSTRY

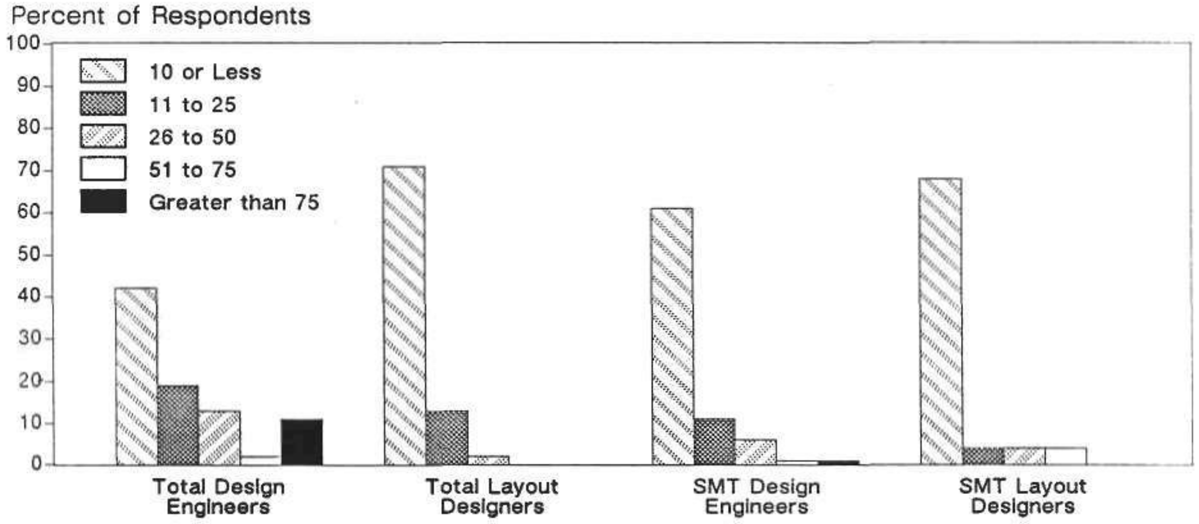


Source: Dataquest
February 1987

Most responding organizations had a total design engineering staff of 10 people or less. Sixty-one percent responded that these engineers are doing surface-mount design. Similarly, total layout designers numbered 10 or less for the majority of respondents, with 68 percent indicating that 1 to 10 designers are designing with surface-mount technology (please see Figure 5).

Figure 5

NUMBER OF ENGINEERS AND DESIGNERS



Source: Dataquest
February 1987

How is SMT Being Used?

In examining the prevalence of SMT design in proportion to traditional through-hole technology (THT), we looked at this issue from several angles: Total annual design starts (see Figure 6); which of those use SMT (see Figure 7); how SMT is implemented (see Figure 8); the number of components and the number of layers per design (see Figures 9 and 10).

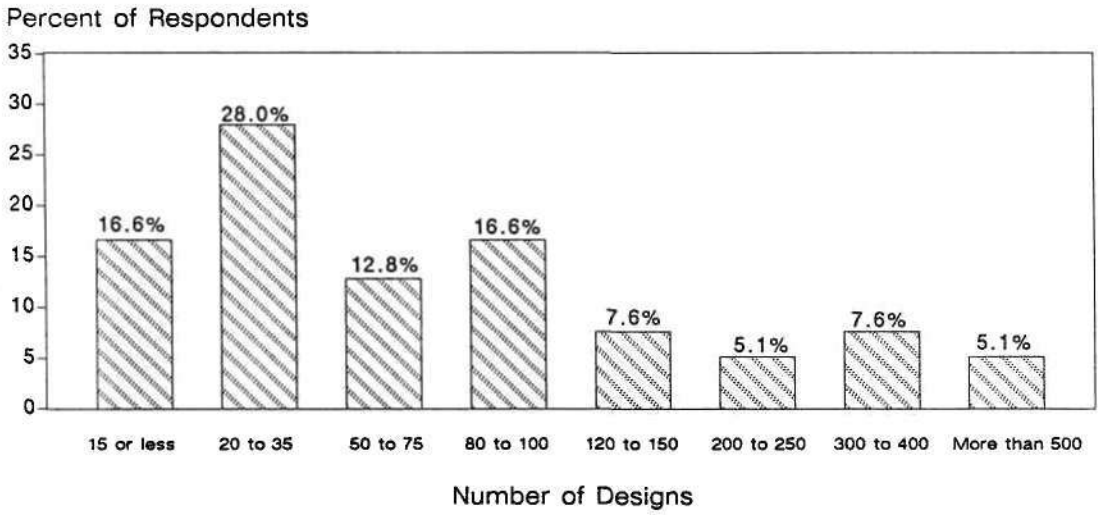
Results indicate that implementation of surface-mount technology on CAD systems is still relatively new and definitely not widespread. Why are users converting to SMT? Figure 11 shows the top five reasons respondents have chosen to use surface-mount technology over through-hole design methods.

In spite of the sparsity of SMT usage, there is a perception, particularly among responding service bureaus, that users must support SMT to stay in business because their customers demand it and their competition supports it.

Figure 12 shows the layout phase of the design cycle as a percent of the total design time, comparing through-hole technology to SMT. In our focus research, end users indicated that one of the benefits of using SMT was that they could get their products designed and manufactured faster. Yet, the results of our survey show that there is little or no time saved by choosing surface-mount technology instead of THT. In researching this issue further, we learned that the time savings involved in SMT comes from the manufacturing process, where SMDs are more suited to automated manufacturing processes.

Figure 6

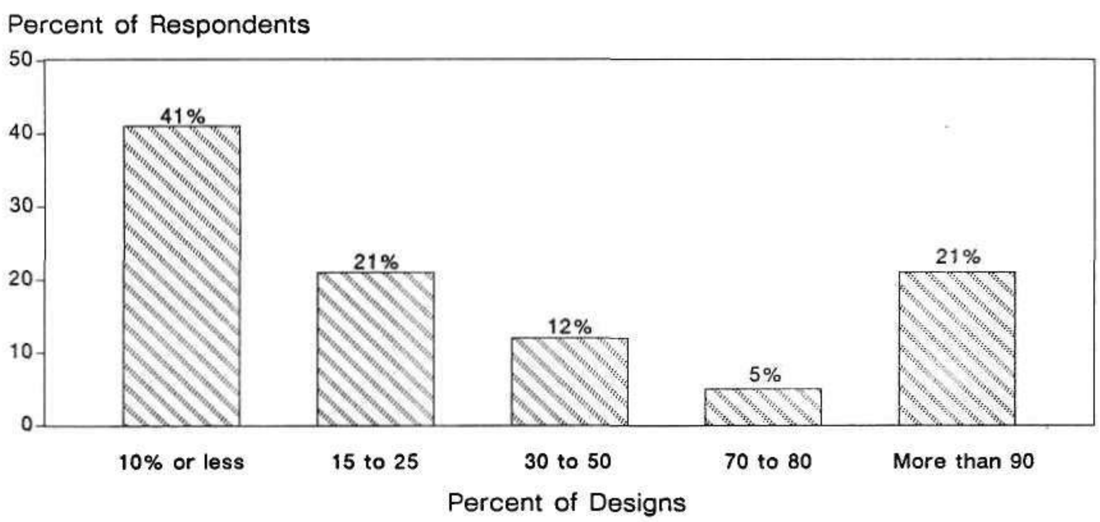
TOTAL ANNUAL PCB DESIGN STARTS



Source: Dataquest
February 1987

Figure 7

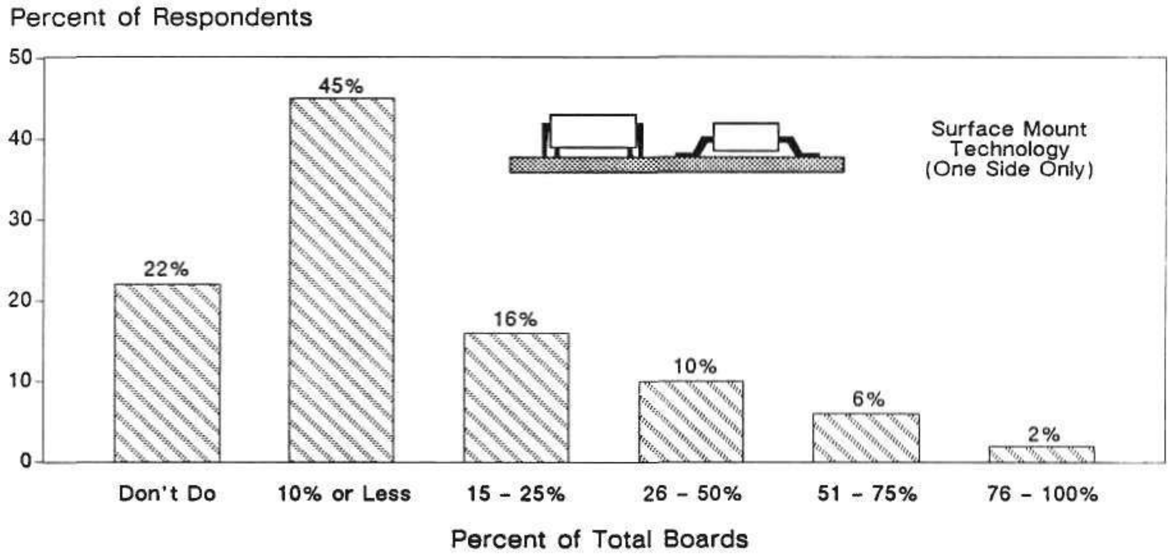
DESIGNS WITH SMT

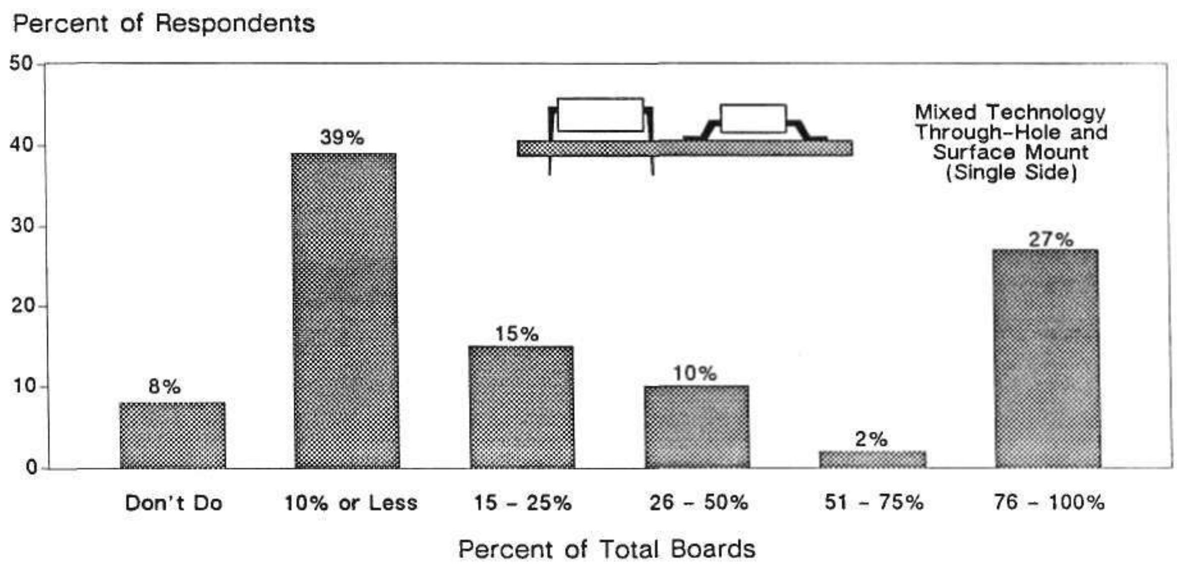


Source: Dataquest
February 1987

Figure 8

DISTRIBUTION OF DESIGNS
BY TECHNOLOGY IMPLEMENTATION

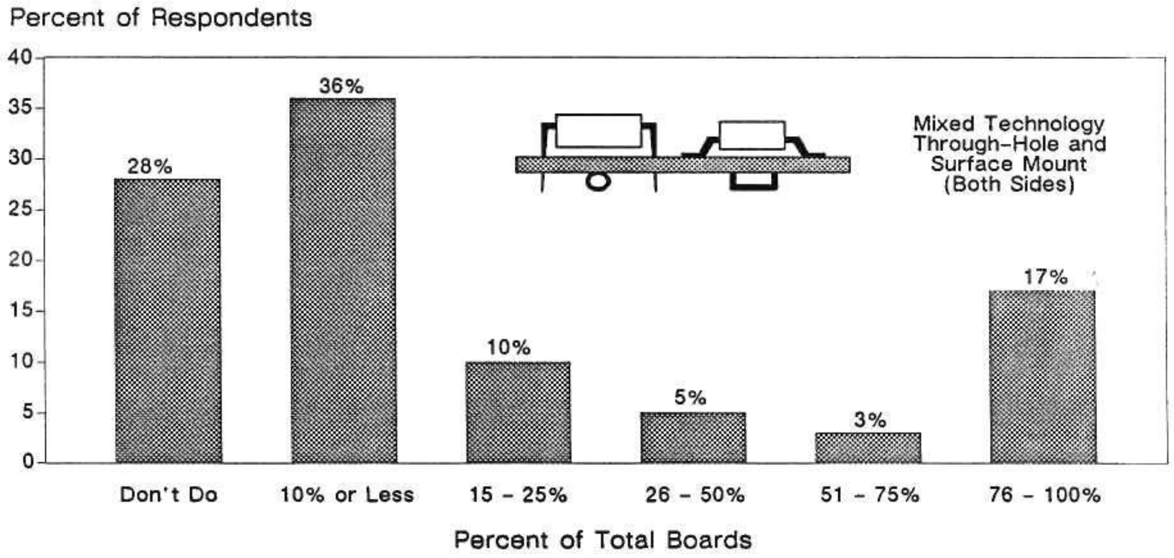


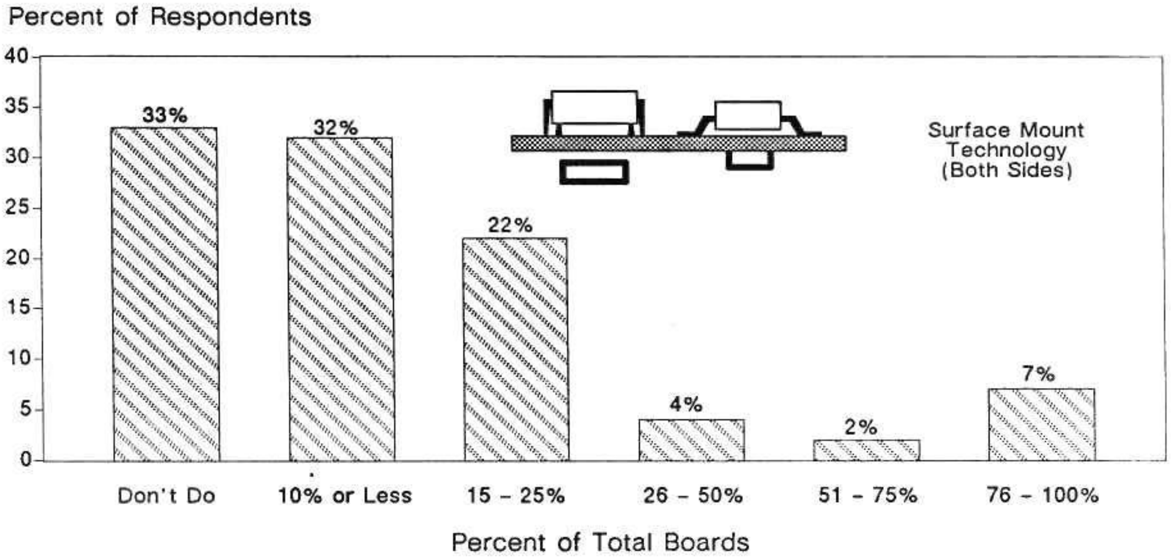


Continued

Figure 8 (Continued)

DISTRIBUTION OF DESIGNS
BY TECHNOLOGY IMPLEMENTATION





Source: Dataquest
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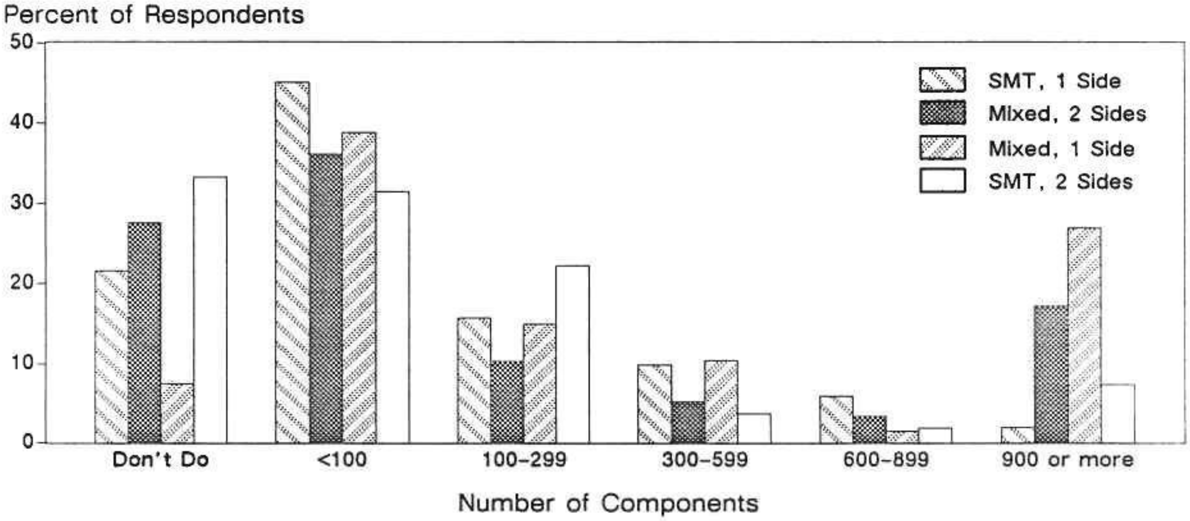
Figure 9

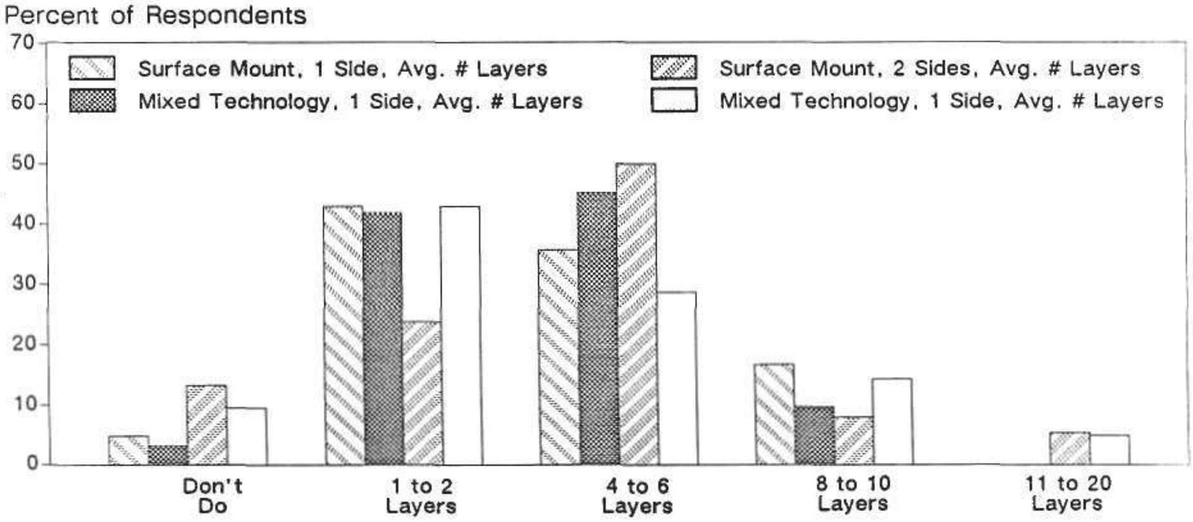
AVERAGE NUMBER OF COMPONENTS
BY BOARD TYPE



Source: Dataquest
February 1987

Figure 10

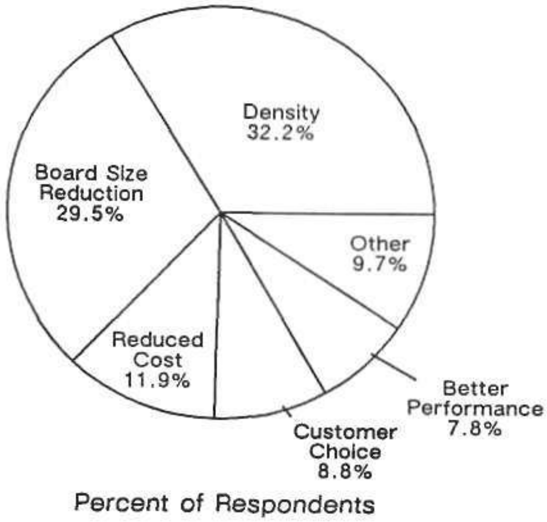
AVERAGE NUMBER OF LAYERS
BY BOARD TYPE



Source: Dataquest
February 1987

Figure 11

REASONS FOR USING SMT



Source: Dataquest
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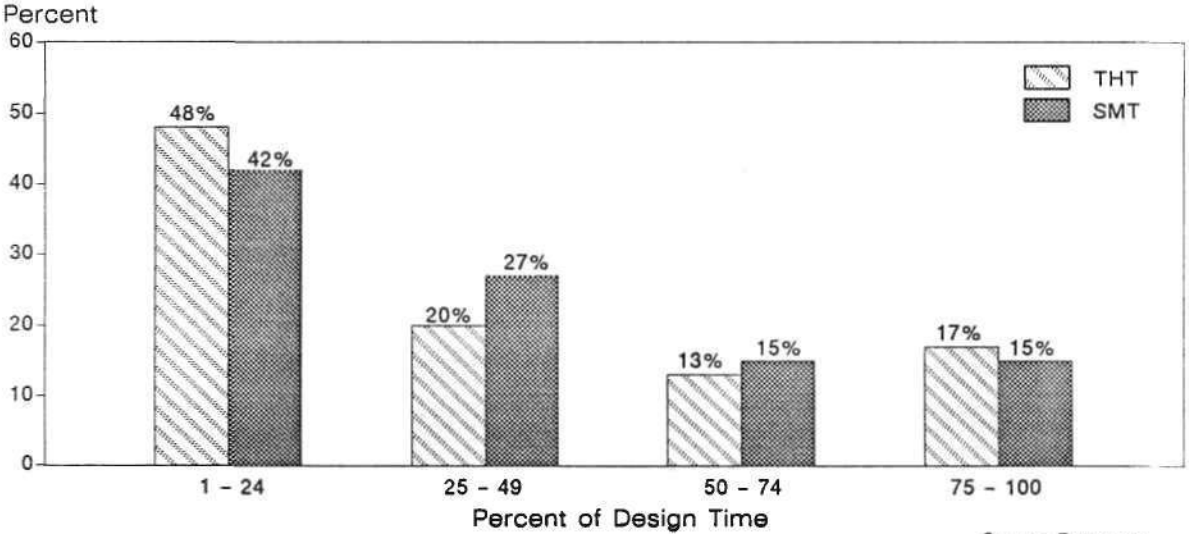
Figure 12

LAYOUT AS A PERCENT OF TOTAL DESIGN TIME



Source: Dataquest
February 1987

SMT and CAD

What Do End Users Think?

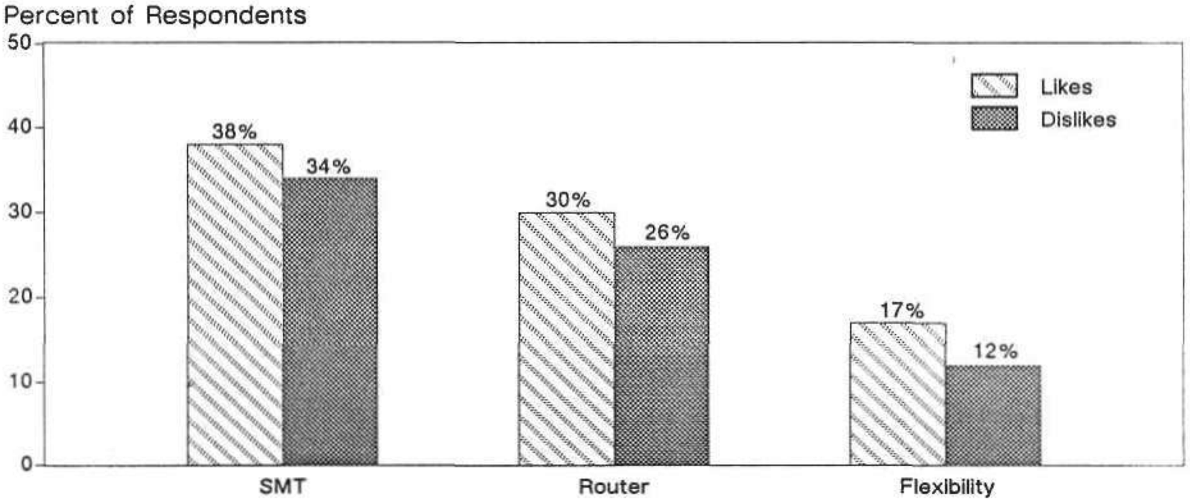
The attitude of most end users is less than optimistic regarding the currently available CAD tools. They feel that although CAD vendors have made a good start, they have a long way to go in terms of adequately supporting SMT. Other end users stated that they had been sold tricks and workarounds as true design solutions. Overall, less than 10 percent of the respondents were satisfied with the way their CAD systems support SMT.

As Figure 13 shows, the likes and dislikes of the end users closely parallel each other. Closer inspection of the data revealed no technological reasons, thus leaving us with one conclusion: The likes and dislikes cited are vendor-specific.

Ranking specific SMT support functions in order of importance, definition of pad geometries topped the list, followed by multilayer routing, off-grid design, and auto-routing of two-sided boards. End users are saying that, in order to support these important SMT functions, PCB CAD systems must be flexible and interactive enough to accommodate SMT as well as THT features.

Figure 13

END-USER LIKES AND DISLIKES



Source: Dataquest
February 1987

Users are also saying that they view SMT support as a PCB CAD system feature that must be capable of integration into users' particular design environments. Because SMT is highly process-dependent, users need to interface easily with manufacturing to ensure the manufacturability of the design.

Flexibility and integration are the two most important buying criteria for future SMT CAD purchases cited by respondents.

<u>What Are the Challenges of SMT?</u>

Earlier, we referred to several characteristics of SMT that affect CAD systems that support through-hole technology:

- Footprints
- The lack of standards
- Access to internal layers of the board

It is the shape of SMT device footprints as well as the fact that they reside only on the surface of the board that affects PCB CAD systems. Most systems are set up to acknowledge the footprints of through-hole devices and are not surface-intelligent.

The lack of standard geometries for the same device functionality was cited by respondents as the major drawback in converting designs to SMT. The lack of standards for SMD has created a need for a high degree of flexibility and interactivity in PCB CAD systems.

Because most PCB CAD systems are not surface-intelligent, users have to trick the system into believing that it is routing a through-hole device. To accomplish this, designers place stringers (round pads) at the end of each rectangular pad so that the system thinks it is routing a component whose leads run through all layers of the board. Although this workaround does route the board, it does not provide a long-term design solution.

How Big is the Market?

End users are budgeting for design solutions that support SMT. Nearly 60 percent of the respondents replied that they have budgeted up to $100,000 for SMT CAD tools in 1987. The highest figure budgeted for SMT CAD expenditures in 1987 was just over $1 million, cited by nearly 10 percent of the respondents.

To quantify and qualify the SMT opportunity, we based the forecast in Figure 14 on a combination of factors:

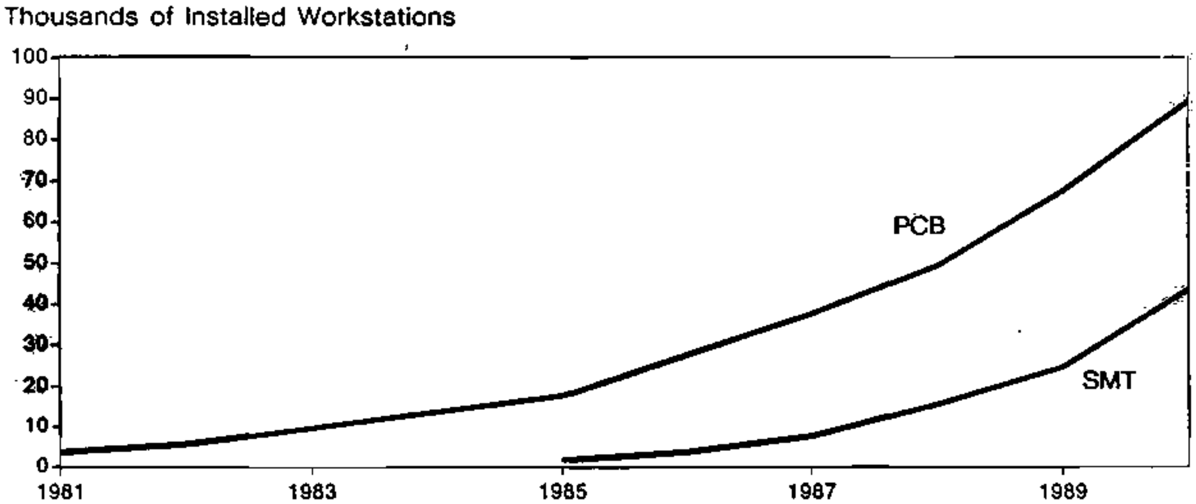
- Dataquest forecast data base, which consists of four years of research on more than 140 companies
- Data from another ECAD end-user survey, indicating number of designs and engineers
- The Dataquest Semiconductor Industry Service's forecast for SMDs that approximately 16 billion units will be shipped in 1990
- End-users' forecast for 1987, where more than 61 percent indicated that they will use SMT in 15 to 25 percent of their designs

As Figure 14 shows, Dataquest estimated that in 1985, there were more than 17,000 workstations in the installed base for PCB CAD. Of those, we estimate that approximately 2,000 supported SMT. We forecast that by 1990 the installed base of workstations used for PCB applications will be more than 90,000 units, more than half of which will support SMT.

In compiling our forecast, we considered SMT to be a function of a PCB CAD system, not a turnkey product offering. Therefore, we believe that a number of software licenses may be sold as repeat business to a vendor's installed base as well as to new customers.

Figure 14

PCB WORKSTATION INSTALLED BASE
WITH SMT CAPABILITY



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DATAQUEST CONCLUSIONS

We believe that SMT is here to stay because end users need reduced board size with increased density, more reliable end products, and faster and less expensive manufacturing processes to keep up with their worldwide competition.

Dataquest believes that SMT support tools will be marketed as features of a CAD system, not standalone turnkey products. As such, meeting the technological differences with true design solutions is the challenge for CAD vendors in this market.

To recapitulate, the likes and dislikes of responding end users are vendor-specific. We believe that in addition to watching the competition, vendors have to overcome the negative attitudes of the end users by demonstrating that they understand the nature of their customers' problems.

Dataquest believes that the successful CAD vendors will be those who work closely with their customers to provide the needed solutions. To meet the opportunity SMT offers, vendors need to project that their products are what the end user wants: A means to an end--a quick turnaround on a manufacturable design.

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Mary A. Olsson
Kelly D. Leininger

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RESEARCH NEWSLETTER

SIS Code: 1986-1987 Newsletters: February 1987-6

LINEAR ICs: THE PATH TO LONG-TERM GROWTH

INTRODUCTION

This newsletter provides an analysis of Dataquest's 1987-1988 quarterly forecast of global consumption of linear integrated circuits (linear ICs) with the focus on the North American market during 1987. As the worldwide semiconductor industry recovers from the 1985 recession, the forecast for growth in consumption of linear ICs during the next two years reflects a familiar long-term pattern. The pattern: during the growth phases of the semiconductor industry, consumption of analog (i.e., linear) ICs will expand steadily, but at a somewhat slower rate than the entire integrated circuit (IC) business. This pattern should continue to hold true. We expect worldwide IC consumption to increase 17.3 percent this year, while linear ICs should achieve a 9 percent rate. Similarly, the worldwide growth rate for integrated circuits is expected to hit nearly 25 percent in 1988, and linear ICs just 15 percent. Manufacturers of analog circuits face considerable challenge in a "world going digital," but after a slow first quarter in 1987, stable growth at a 12 percent compound annual rate is forecast for linear IC producers over the next two years.

The worldwide linear IC consumption forecast, by regions, for the next eight quarters is shown in Table 1 at the end of this newsletter.

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Dataquest Incorporated, 1290 Ridder Park Drive, San Jose, CA 95131-2398, (408) 971-9000, Telex 171973, Fax (408) 971-9003

NORTH AMERICAN CONSUMPTION

Consumption of linear ICs in North America is expected to increase 12.8 percent in 1987 and nearly 20 percent in 1988. The recent rise in semiconductor bookings, however, is not expected to result in any measurable increase in North American consumption of linear ICs until the second quarter of 1987.

A Slow First Quarter, Then Growth

No growth is forecast for North American IC consumption the first quarter. For every manufacturer experiencing an increase in consumption during the first quarter, another will confront either flat or declining demand. Among major North American suppliers, Motorola's analog operation seeks to maintain the momentum that developed during 1986, while Texas Instruments and National Semiconductor Corporation will likely capitalize on the sharp second-quarter rise of 9.8 percent in North American consumption. These firms supply the full spectrum of linear circuits--from commodity-grade operational amplifiers through data converters to specialized hybrid circuits--although their strategic plans for 1987 through 1988 typically focus on a more aggressive search for profitable niche market opportunities.

We believe that linear houses that have established reputations as specialized suppliers of high-performance analog circuits--such as Analog Devices (specifically, data conversion products) and Precision Monolithics Inc. (for example, precision operational amplifiers)--will continue to exploit that competitive advantage in 1987. We expect their revenue streams to grow more rapidly after the first quarter as new product introductions take hold in the marketplace and component buyers loosen the strings on their 1987 purchasing budgets.

Select Linear IC Products

Regarding linear products, consumption of data converters (15.5 percent annual rate forecast for 1987) should continue to outpace the North American analog market growth rate, fueled by strong demand for analog-to-digital converters (nearly 20 percent rate) from vendors of instrumentation and computer equipment. We expect North American consumption of operational amplifiers (12.1 percent rate) to grow at nearly the same pace this year as the linear market. The internal dynamics of the op amp business, however, reflect a prevalent trend in the analog marketplace: the drive for high-performance versus general-purpose circuits. Consumption of high-performance op amps is expected to expand by 20 percent this year, while we forecast that general-purpose types will increase only 6.5 percent.

A Challenge for Start-Ups

North American start-up firms will find the linear arena a challenging business in 1987, in part because of increasing competition from foreign firms like Gold Star, SGS, and Siemens, which have targeted the United States as vital to their long-term survival and success. There are exceptions like Crystal Semiconductor and Linear Technology: we anticipate that both of these start-ups will experience growth in the first quarter as well as throughout 1987. Even though the ease of entry into the linear business has stiffened, however, analog start-up activity remains high in contrast to the commodity sectors of the semiconductor industry. Linear technology, in fact, has reached the point where it is forging the kind of strategy--the development of a portfolio of proprietary products--that should lead to a permanent position in the linear IC industry.

The North American Market Environment

Looking at end markets, the automotive sector should sustain its position as a growth market for North American analog circuit suppliers during first quarter 1987. Budgetary concern tempers military consumption at the same time and a cautious outlook limits expenditures by producers of industrial and instrumentation equipment until the second quarter. During second quarter 1987, original equipment manufacturers (OEMs) of industrial equipment, computers and peripherals, automotive electronics, and communications gear are expected to boost consumption of data converters, telecom circuits, and high-performance op amps, among other linear products. The third quarter slowdown in consumption should occur as usual, but not as dramatically as during past years. By fourth quarter 1987, we believe that military consumption of analog circuits will contribute to strong year-end demand from OEMs in the automotive, computer, industrial, and instrumentation sectors.

JAPAN

The heavy dependence of the Japanese linear IC business on consumer electronics production has exposed Japanese manufacturers of these circuits to Japan's version of the offshore manufacturing problem. The phenomenal strengthening of the yen on foreign exchange markets that began in September 1985 forced a significant shift of Japanese consumer electronics production to offshore sites like South Korea, Taiwan, Hong Kong, and Singapore. Sourcing of linear ICs (primarily, consumer circuits, but also operational amplifiers, voltage regulators, and related products) followed the manufacturing shift from Japan to these offshore sites. Japanese consumption of linear ICs dropped nearly 5 percent during fourth quarter 1986 when measured in dollars (and even more dramatically when expressed in yen). Japanese consumption of linear ICs is not expected to recover during the first half of 1987; we predict a 3 percent drop in consumption during the first quarter, followed by a flat second quarter. If the yen-dollar relationship stabilizes during 1987, so should linear IC consumption in tandem with consumer electronics production. Recently, the yen has shown more strength against the dollar, indicating little growth in Japanese consumption of linear ICs until 1988.

EUROPE

The record cold experienced by Europe during January and February 1987 will cut into industrial production, dulling an already "unrosy" forecast for linear IC consumption. However, there are several areas of growth in a market that should dip over the first half of 1987, and recover slightly during the second half of the year. Europe is participating in the worldwide trend toward systems that can process both analog and digital information, so consumption of data converters should increase nearly 10 percent during this year, and quite dramatically in 1988. Consumption of specialized consumer circuits represents another growth opportunity for suppliers of these products over the next two years; Europe has tightened its doors on imports of consumer electronics, forcing Japanese producers to shift some manufacturing to Europe and stimulating increased production by European manufacturers. A solid double-digit advance in European consumption of linear consumer circuits is forecast for the 1987 through 1988 period.

REST OF WORLD COUNTRIES

The boom in semiconductor consumption among the rest of the nations of the world certainly includes linear ICs. In large measure, Japan's loss in consumer electronics has become the gain of producers in Asian countries like South Korea and Taiwan. Consequently, linear IC consumption is forecast to jump 34 percent during 1987 and 29 percent in 1988. We estimate consumption increasing 14 percent over the first half of this year and 18 percent over the second half, before "slowing" to a 9 percent gain during the first two quarters of 1988. A major chunk of the demand should be for linear consumer circuits (e.g., video cassette recorders), and for commodity-type voltage regulators and operational amplifiers used in both consumer electronics and personal computers.

Ron Bohn

Table 1

WORLDWIDE LINEAR IC QUARTERLY FORECAST BY REGION
1987-1988
(Millions of Dollars, by Percentage Growth)

	Q1/87	Q2/87	Q3/87	Q4/87	Total 1987
Worldwide	$1,632	$1,685	$1,734	$1,809	$6,860
	(0.7%)	3.2%	2.9%	4.3%	9.0%
North America	$ 417	$ 458	$ 474	$ 514	$1,863
	0.0%	9.8%	3.5%	8.4%	12.8%
Japan	$ 766	$ 770	$ 793	$ 800	$3,129
	(3.0%)	0.5%	3.0%	0.9%	3.7%
Europe	$ 275	$ 272	$ 273	$ 275	$1,095
	0.0%	(1%)	0.4%	0.7%	4.4%
Rest of World	$ 174	$ 185	$ 194	$ 220	$ 773
	7.4%	6.3%	4.9%	13.4%	34%

	Q1/88	Q2/88	Q3/88	Q4/88	Total 1988
Worldwide	$1,862	$1,946	$2,015	$2,067	$7,890
	2.9%	4.5%	3.5%	2.6%	15.0%
North America	$ 528	$ 562	$ 569	$ 574	$2,233
	2.7%	6.4%	1.2%	0.9%	19.9%
Japan	$ 814	$ 839	$ 872	$ 886	$3,411
	1.8%	3.1%	3.9%	1.6%	9.0%
Europe	$ 290	$ 305	$ 320	$ 337	$1,252
	5.5%	5.2%	4.9%	5.3%	14.3%
Rest of World	$ 230	$ 240	$ 254	$ 270	$ 994
	4.5%	4.3%	5.8%	6.3%	29%

Source: Dataquest
February 1987

Dataquest

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Semiconductor*

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The Education Market for PCs in Europe

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SpecCheck—Competitive Electronic Typewriter Guide

SpecCheck—Competitive Whiteboard Guide

Who's Who in CAD/CAM 1986

Future Products

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Conference Schedule

1987

Semiconductor Users/Semiconductor Application Markets	February 4-6	Saddlebrook Resort Tampa, Florida
Copying and Duplicating	February 23-25	San Diego Hilton Resort San Diego, California
Imaging Supplies	February 25-26	San Diego Hilton Resort San Diego, California
Electronic Printer	March 23-25	Silverado Country Club Napa, California
Imaging Supplies	March 25-26	Silverado Country Club Napa, California
Computer Storage	April 6-8	Red Lion Inn San Jose, California
Japanese Semiconductor	April 13-14	The Miyako Kyoto, Japan
Color Conference	April 24	Red Lion Inn San Jose, California
European Telecommunications	April 27-29	The Beach Plaza Hotel Monte Carlo, Monaco
CAD/CAM	May 14-15	Hyatt Regency Monterey Monterey, California
Graphics/Display Terminals	May 20-22	San Diego Hilton Resort San Diego, California
European Semiconductor	June 4-5	Palace Hotel Madrid, Spain
European Copying and Duplicating	June 25-26	The Ritz Hotel Lisbon, Portugal
Telecommunications	June 29-July 1	Silverado Country Club Napa, California
Financial Services	August 17-18	Silverado Country Club Napa, California
Western European Printer	September 9-11	Palace Hotel Madrid, Spain
Manufacturing Automation	September 14-15	San Diego Hilton Resort San Diego, California
Business/Office Systems and Software	September 21-22	Westford Regency Hotel Littleton, Massachusetts
Asian Peripherals and Office Equipment	October 5-8	Tokyo American Club Tokyo, Japan
Technical Computers	October 5-7	Hyatt Regency Monterey Monterey, California
Semiconductor	October 19-21	The Pointe Resort Phoenix, Arizona
Office Equipment Dealers	November 5-6	Hyatt Regency Monterey Monterey, California
Military IC	November 12	Hotel Meridien Newport Beach, California
Electronic Publishing	November 16-17	Stouffer Hotel Bedford, Massachusetts
Asian Information Systems	November 30-December 4	Tokyo, Japan
CAD/CAM Electronic Design Automation	December 10-11	Santa Clara Marriott Santa Clara, California

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RESEARCH NEWSLETTER

SIS Code: 1986-1987 Newsletters: February
1987-5

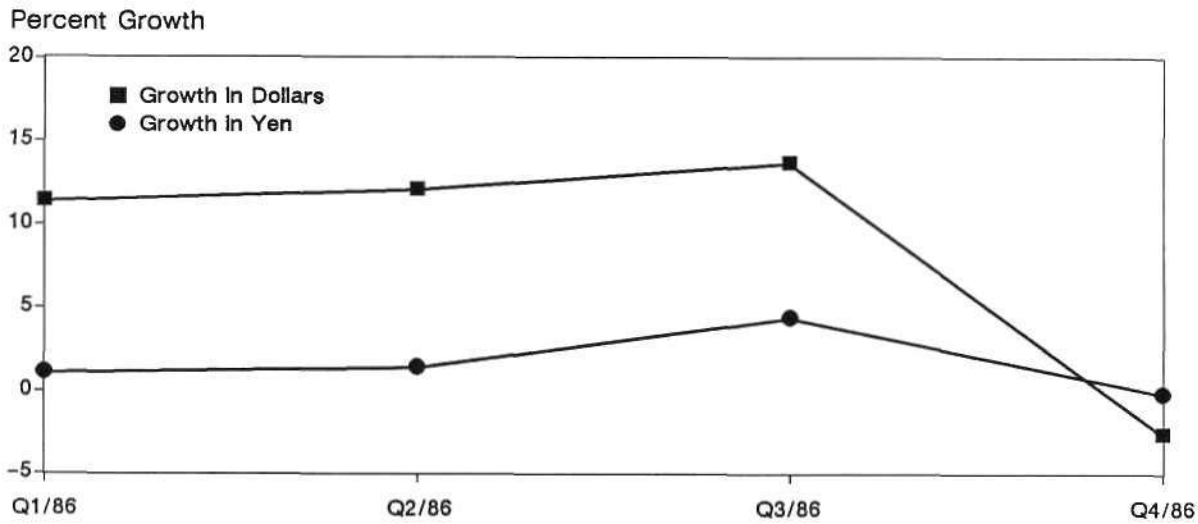
FALLING DOLLAR OVERSTATES LACKLUSTER GROWTH

SUMMARY

Worldwide semiconductor consumption measured in U.S. dollars rose 25.6 percent in 1986. This seems anomalous considering the mere 6.5 percent growth in North America. Did Japan strike again? Not really. The falling dollar overstates the real growth in consumption in overseas markets. Note the disparity in quarterly growth rates of Japanese semiconductor consumption measured in U.S. dollars versus growth rates measured in yen (see Figure 1). Japanese semiconductor consumption grew only 1.9 percent in 1986 as measured in yen, but this translates to a 44.9 percent growth rate as measured in U.S. dollars.

Figure 1

1986 JAPANESE SEMICONDUCTOR CONSUMPTION GROWTH RATES
(Dollars Versus Yen)



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February 1987

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Dataquest expects slow but positive growth in all regions of the world in the first quarter of 1987, recovering to a healthy but moderate 15.1 percent growth in worldwide semiconductor consumption for 1987. We expect the recovery to pick up momentum in 1988, resulting in a hefty 21.6 percent growth. Though these growth rates pale in comparison to historical boom years, we must bear in mind that the industry has now grown much bigger and seems to be maturing in certain product markets.

Our projections assume a fairly stable U.S. dollar exchange rate with the yen. Given the steep fall of the U.S. dollar in 1986, readers should exercise much caution when comparing growth rates in 1986 to subsequent years. We are indeed projecting a much healthier semiconductor industry for 1987 and 1988 in all regions, compared to the lackluster industry growth in 1986.

ASSUMPTIONS FOR THIS FORECAST

Book/Bill Trend is Up

The U.S. book/bill ratio has been rising since October, and we expect it to stay above 1.0 during the first quarter of 1987. The worldwide book/bill ratio rose to parity in November 1986, after falling to 0.9 in the third quarter of 1986. We expect the worldwide book/bill ratio to stay above parity during the first quarter of 1987.

Movement to ROW Dampens U.S. Growth

Preliminary results from a Dataquest Semiconductor Application Markets (SAM) procurement survey indicate a 9 percent shift in semiconductor purchases from the United States to the Asia-Pacific basin in 1987, compared to a 7 percent shift in 1986. Since the U.S. dollar exchange rate remains virtually unchanged relative to Korea and Taiwan, U.S. electronics companies are leveraging this movement to compete with the Japanese. The movement to ROW (Rest of World) has a significant moderating effect on the growth in U.S. semiconductor consumption.

Exchange Rates Remain Stable

Since the forecast is expressed in U.S. dollars, it is critical to note the assumption that the U.S. dollar remains stable with respect to the yen, the European basket of currencies, and the Asia-Pacific currencies. The yen is pegged at 160 for a dollar.

TRACKING REGIONAL SHIFTS

North American share of worldwide semiconductor consumption declined from about 39 percent in 1985 to less than a third in 1986. At the same time, Japanese share rose from about 35 percent in 1985 to 40 percent in 1986. European share declined one percentage point in 1986. Though the shifts in 1986 are attributed mostly to the rise of the yen, the gain in ROW share from 7.7 percent in 1985 to 9.5 percent in 1986 has been under fairly stable currency exchange rates. We are projecting the trend to continue, with ROW share rising to 12 percent by 1988 (see Table 1).

Table 1

WORLDWIDE SEMICONDUCTOR CONSUMPTION
(Percent Change, U.S. Dollars)

	Yearly Growth			Market Share		
	1986	1987	1988	1986	1987	1988
North America	6.5%	12.7%	23.4%	32.8%	32.1%	32.6%
Japan ($)	44.9%	14.0%	19.0%	40.0%	39.6%	38.7%
Japan (yen)	1 9%	9.0%	19.0%			
Europe	17.2%	10.0%	19.9%	17.7%	16.9%	16.7%
ROW	55.6%	38.1%	28.2%	9.5%	11.4%	12.0%
Worldwide	25 6%	15.1%	21.6%	100.0%	100.0%	100.0%

Source: Dataquest
February 1987

WORLD PRODUCT CONSUMPTION TRENDS

Our 1987 quarterly forecast of worldwide product consumption is shown in Table 2. During 1986, MOS logic was the star product category, growing more than 41 percent. MOS microdevices grew 35 percent. Linear and discrete devices showed surprising strength, growing 32 percent and 22 percent, respectively. MOS memory was the weakest product category, growing less than 8 percent.

Table 2

ESTIMATED WORLDWIDE SEMICONDUCTOR CONSUMPTION
(Millions of U.S. Dollars)

	1986	Q1/87	Q2/87	Q3/87	Q4/87	1987	% Chg. 1987
Total Semiconductor	31,173	8,444	8,771	9,125	9,550	35,889	15.1%
Total IC	23,885	6,551	6,834	7,140	7,495	28,019	17.3%
Bipolar Digital	4,397	1,162	1,220	1,262	1,314	4,957	12.7%
Memory	680	180	191	200	204	774	13.8%
Logic	3,717	982	1,029	1,062	1,110	4,183	12.5%
MOS Digital	13,192	3,757	3,929	4,144	4,372	16,202	22.8%
Memory	4,329	1,192	1,246	1,321	1,392	5,151	19.0%
Micro	3,699	1,029	1,078	1,145	1,218	4,470	20.8%
Logic	5,164	1,536	1,605	1,678	1,762	6,581	27.4%
Linear	6 296	1,632	1,685	1,734	1,809	6,860	9.0%
Discrete	5,697	1,475	1,504	1,540	1,597	6,116	7.4%
Optoelectronic	1,591	418	433	445	458	1,754	10.2%

	1987	Q1/88	Q2/88	Q3/88	Q4/88	1988	% Chg. 1988
Total Semiconductor	35,889	9,953	10,683	11,262	11,750	43,647	21.6%
Total IC	28,019	7,861	8,526	9,052	9.517	34,955	24.8%
Bipolar Digital	4,957	1,387	1,479	1,531	1,592	5,988	20.8%
Memory	774	210	219	228	236	892	15.3%
Logic	4,183	1,177	1,260	1 303	1,356	5,096	21.8%
MOS Digital	16,202	4,612	5,101	5,506	5,858	21,077	30.1%
Memory	5,151	1,475	1,727	1,885	1,971	7,058	37.0%
Micro	4,470	1,271	1,352	1,451	1,559	5,633	26.0%
Logic	6,581	1,866	2,022	2,170	2,328	8,386	27.4%
Linear	6,860	1,862	1,946	2,015	2,067	7,890	15.0%
Discrete	6,116	1,619	1,660	1,689	1,699	6,667	9.0%
Optoelectronic	1,754	473	497	521	534	2,025	15.5%

Source: Dataquest
February 1987

Our projection is for MOS logic and MOS micros to remain strong growth areas in 1987 and 1988, with growth rates in the 20 to 30 percent range. MOS memory is expected to rebound to 19 percent in 1987 and 38 percent in 1988, as production ramps up for 1Mb DRAMs. Discretes are projected to slow down as ASIC penetration increases. Linear (analog) growth will slow down to track total semiconductors.

DATAQUEST CONCLUSIONS

Although the sharp fall of the U.S. dollar against the yen dramatically overstates the Japanese consumption growth rates, 1986 was a slow year. We expect healthy but moderate growth in world semiconductor consumption in 1987, strengthening into 1988. We seem to miss the fever of the customary upswing, but the reality is a moderate and more stable growth in a bigger industry that is getting older and wiser.

Howard Bogert
Joe Borgia

Dataquest

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1987

Semiconductor Users/Semiconductor Application Markets	February 4-6	Saddlebrook Resort Tampa, Florida
Copying and Duplicating	February 23-25	San Diego Hilton Resort San Diego, California
Imaging Supplies	February 25-26	San Diego Hilton Resort San Diego, California
Electronic Printer	March 23-25	Silverado Country Club Napa, California
Imaging Supplies	March 25-26	Silverado Country Club Napa, California
Computer Storage	April 6-8	Red Lion Inn San Jose, California
Japanese Semiconductor	April 13-14	The Miyako Kyoto, Japan
Color Conference	April 24	Red Lion Inn San Jose, California
European Telecommunications	April 27-29	The Beach Plaza Hotel Monte Carlo, Monaco
CAD/CAM	May 14-15	Hyatt Regency Monterey Monterey, California
Graphics/Display Terminals	May 20-22	San Diego Hilton Resort San Diego, California
European Semiconductor	June 4-5	Palace Hotel Madrid, Spain
European Copying and Duplicating	June 25-26	The Ritz Hotel Lisbon, Portugal
Telecommunications	June 29-July 1	Silverado Country Club Napa, California
Financial Services	August 17-18	Silverado Country Club Napa, California
Western European Printer	September 9-11	Palace Hotel Madrid, Spain
Manufacturing Automation	September 14-15	San Diego Hilton Resort San Diego, California
Business/Office Systems and Software	September 21-22	Westford Regency Hotel Littleton, Massachusetts
Asian Peripherals and Office Equipment	October 5-8	Tokyo American Club Tokyo, Japan
Technical Computers	October 5-7	Hyatt Regency Monterey Monterey, California
Semiconductor	October 19-21	The Pointe Resort Phoenix, Arizona
Office Equipment Dealers	November 5-6	Hyatt Regency Monterey Monterey, California
Military IC	November 12	Hotel Meridien Newport Beach, California
Electronic Publishing	November 16-17	Stouffer Hotel Bedford, Massachusetts
Asian Information Systems	November 30-December 4	Tokyo, Japan
CAD/CAM Electronic Design Automation	December 10-11	Santa Clara Marriott Santa Clara, California

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RESEARCH NEWSLETTER

SIS Code: 1986-1987 Newsletters: February
1987-4

COPING WITH THE CRISES OF MODERATE GROWTH

SUMMARY

The semiconductor industry is accustomed to wide swings in its marketplace--frenzied growth followed by abrupt recessions. Now, for the second year in a row, it looks like there will be only moderate growth, lacking the luster of the usual industry upswings.

The challenge for the U.S. semiconductor industry is to learn to cope with this moderate growth in consumption. Industry participants are continuing to consolidate and restructure to deal with the reality of lower long-term growth rates. The continued shift of U.S. electronic equipment production to the Asia-Pacific basin will have a significant moderating effect on growth in U.S. semiconductor consumption.

U.S. semiconductor consumption grew 6.5 percent in 1986 as Dataquest projected at the October Semiconductor Industry Conference. We now project positive growth in the first quarter and an upswing in the second quarter of 1987. Though annual consumption in 1987 is expected to grow 12.7 percent or twice the 1986 rate, this growth rate pales in comparison to the historical rates in the boom years. We do not anticipate growth rates in excess of 20 percent until in 1988.

HOW DID WE DO WITH LAST YEAR'S FORECAST?

A comparison of the quarterly growth rates that we forecast in February 1986 with our current estimate of 1986 consumption is shown in Figure 1. Shipments grew faster than we predicted in the second quarter of 1986, and then flattened out rather than continuing to grow as we expected. Annual shipments in 1986 in U.S. dollars came within 4 percent of what we predicted in February 1986.

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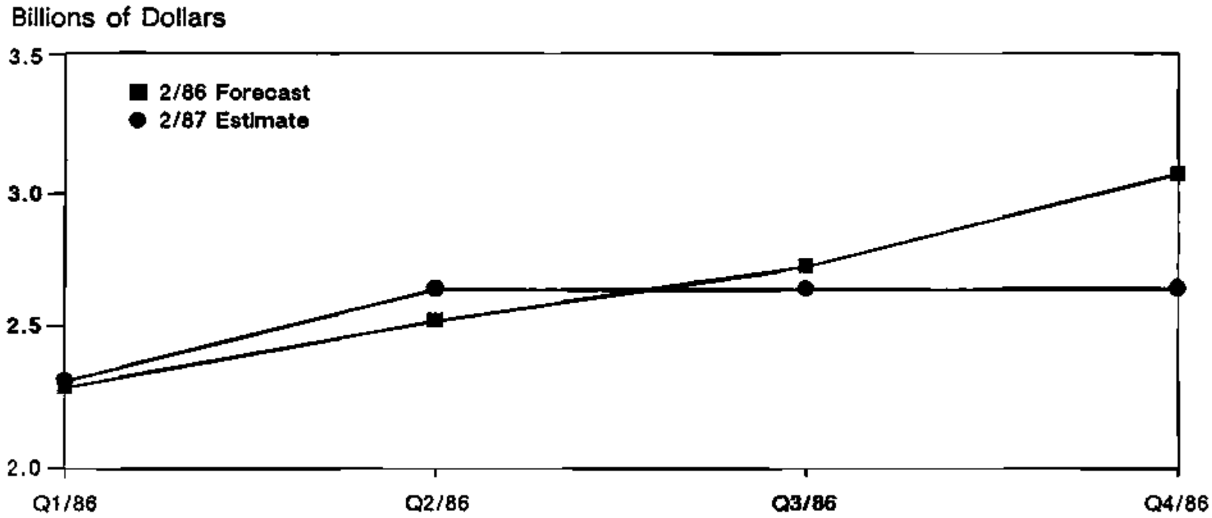
Figure 1

U.S. QUARTERLY SEMICONDUCTOR CONSUMPTION
1986



Source: Dataquest
February 1987

ASSUMPTIONS FOR THIS FORECAST

The Book-to-Bill is Up

The book-to-bill ratio has been rising since October, and we expect the current level of bookings to result in 1.1 percent growth in first-quarter shipments. We expect the book-to-bill to stay above 1.0 percent in the first quarter, contributing to a healthy 6.2 percent growth in the second quarter. Recent upward movement in semiconductor stocks also anticipates this growth.

Modest Growth in End Equipment

Our current semiconductor industry forecast assumes a modest 7 percent growth in end-equipment shipments in 1987. End-equipment trends tracked include computers, communications, industrial, transportation (including automotive), military, and consumer electronics.

Movement to ROW Dampens U.S. Growth

Preliminary results from a Dataquest Semiconductor Application Markets (SAM) procurement survey indicate a 9 percent shift in electronics production from the United States to the Asia-Pacific basin in 1987, compared with a 7 percent shift in 1986. Since the U.S. dollar exchange rate remains virtually unchanged relative to Korea and Taiwan, U.S. electronics companies are leveraging this movement to compete with the Japanese. The movement to ROW has a significant moderating effect on the growth in U.S. semiconductor consumption.

Other Economic Assumptions--1987

GNP is expected to grow about 3 percent in 1987, with about a 4 percent rise in the consumer price index. Further interest rate cuts are expected to spur investment.

For the semiconductor industry, we expect a stable environment with tight inventory levels and no large swings. We do not expect shortages or steep price erosions. Capacity remains largely underutilized, with about 70 percent utilization in 1987.

THE FORECAST: MODERATE GROWTH

Our quarterly forecast of North American semiconductor consumption for 1987 and 1988 is shown in Table 1.

Table 1

ESTIMATED NORTH AMERICAN SEMICONDUCTOR CONSUMPTION
(Millions of Dollars)

	1986	Q1/87	Q2/87	Q3/87	Q4/87	1987	% Chg. 1987
Total Semiconductor	10,233	2,678	2,845	2,922	3,087	11,532	12.7%
Total IC	8,162	2,159	2,300	2,362	2,502	9,323	14.2%
Bipolar Digital	2,061	513	545	563	605	2,226	8.0%
Memory	339	90	97	101	106	394	16.2%
Logic	1,722	423	448	462	499	1,832	6.4%
MOS Digital	4,449	1,229	1,297	1,325	1,383	5,234	17.6%
Memory	1,570	416	441	448	459	1,764	12.4%
Micro	1,241	330	348	354	375	1,407	13.4%
Logic	1,638	483	508	523	549	2,063	25.9%
Linear	1,652	417	458	474	514	1,863	12.8%
Discrete	1,652	413	431	444	466	1,754	6.2%
Optoelectronic	419	106	114	116	119	455	8.6%

	1987	Q1/88	Q2/88	Q3/88	Q4/88	1988	% Chg. 1988
Total Semiconductor	11,532	3,265	3,551	3,666	3,744	14,226	23.4%
Total IC	9,323	2,667	2,925	3,031	3,116	11,739	25.9%
Bipolar Digital	2,226	638	681	701	718	2,738	23.0%
Memory	394	109	113	118	123	463	17.5%
Logic	1,832	529	568	583	595	2,275	24.2%
MOS Digital	5,234	1,501	1,682	1,761	1,824	6,768	29.3%
Memory	1,764	499	585	615	598	2,297	30.2%
Micro	1,407	409	456	479	526	1,870	32.9%
Logic	2,063	593	641	667	700	2,601	26.1%
Linear	1,863	528	562	569	574	2,233	19.9%
Discrete	1,754	475	493	499	488	1,955	11.5%
Optoelectronic	455	123	133	136	140	532	16.9%

Source: Dataquest
February 1987

CONSUMPTION TRENDS

While 1986 was a slow year with only 6.5 percent growth in overall North American semiconductor consumption, some product categories fared better than others. MOS logic was a winner, growing 28.2 percent, particularly due to the strength in ASICs. MOS memory declined 11.5 percent and MOS micros grew only 3.8 percent, slower than total semiconductors. Linear and discrete product categories did better than total semiconductors.

Our projection for 1987 is for MOS logic to remain the fastest-growing segment, with ASICs showing stellar performance. MOS memories and micros are expected to rebound with growth rates more than 12 percent, hinging on an upswing in computers and data processing equipment.

DATAQUEST CONCLUSIONS

Dataquest projects 12.7 percent growth in U.S. semiconductor consumption in 1987. Though this is moderate growth, this rate is about twice the rate of growth in 1986. We are already seeing signs of an upswing. There is optimism in the industry. End-equipment demand seems to be bottoming out, inventory levels are low, prices are holding, and bookings are up.

Howard Z. Bogert
Joseph K. Borgia

Dataquest

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Asian Information Systems	November 30-December 4	Tokyo, Japan
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Research Newsletter

SIS Code: 1986-1987 Newsletters: March 1987-9

GATE ARRAY SUPPLIERS POSITION FOR FUTURE GROWTH

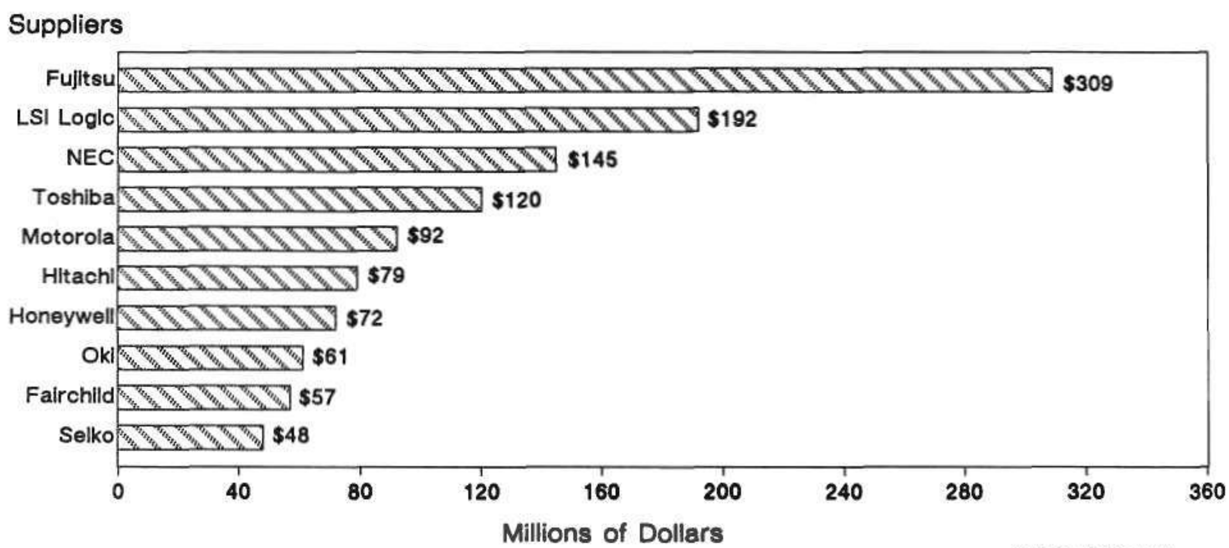
EXECUTIVE SUMMARY

Dataquest has projected the $1.8 billion gate array market of 1986 to exceed $7.8 billion by 1992. Today, there are in excess of 100 merchant gate array suppliers. Fierce competition in the North American market has caused nonrecurring engineering charges (NRE) as well as device pricing to decline to the point where most suppliers sacrifice profits for market share.

Dataquest believes that large, broad-based IC suppliers will dominate the mainstream gate array market and force the small suppliers to be acquired, to move to niche markets, or to move out of the market altogether. Figure 1 shows that three out of the top five 1986 gate array suppliers are large, broad-based Japanese companies. Toshiba had a large number of designs go to production and went from eighth position in 1985 to fourth in 1986.

Figure 1

ESTIMATED WORLDWIDE GATE ARRAY SHIPMENTS
TOP 10 SUPPLIERS--TOTAL



Source: Dataquest
March 1987

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During 1986, worldwide MOS gate array consumption increased 49 percent compared to 1985, while bipolar gate array consumption rose 23 percent. North American companies shipped 46 percent of the total worldwide gate arrays while Japanese companies shipped 45 percent. However, Japanese companies had 43 percent of their shipment revenue generated from intracompany sales (sales to internal divisions) while North American companies only had 11 percent intracompany sales. The yen-to-dollar exchange rate also increased the market share of Japanese companies by changing from 238 in 1985 to 167 in 1986. This newsletter will address the following key areas:

- Preliminary 1986 company shipment estimates
- Technology forecast
- Design starts
- Merchant revenue versus intracompany revenue
- NRE and device pricing
- Regional trends

PRELIMINARY 1986 GATE ARRAY RESULTS

Dataquest Definitions

Dataquest defines the commonly used terms as follows:

- Gate arrays--These are digital or linear/digital integrated circuits containing a configuration of uncommitted elements customized by interconnecting one or more routing layers.
- NRE--These are nonrecurring engineering charges or simply the cost of developing the array.
- Intracompany revenue--When an IC manufacturer takes a product line, which was developed and produced for internal consumption, to the merchant market, the revenue associated with this internal consumption is called intracompany revenue; the revenue from sales to outside companies is called merchant revenue.
- Dataquest gate array shipments--The shipment revenue equals the estimated production revenue plus intracompany revenue plus NRE revenue.

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Total Gate Arrays

As Figure 1 indicates, Fujitsu is the leader in total gate array revenue. Fujitsu is number two in MOS gate arrays and number one in bipolar arrays as shown in Tables 1 and 2, respectively. However, one must consider that a large portion of Fujitsu's revenue comes from sales to its own divisions. LSI Logic came in number two in total gate arrays with an exclusive MOS product line. NEC remains in third place with a healthy 54 percent increase in 1986 sales over 1985. Toshiba is climbing the top 10 supplier roster at a rapid rate, going from number eight in 1985 to number four in 1986. The next six suppliers are in a close race for market share. The top 10 suppliers in 1986 shared 65 percent of the total available market (TAM). During 1985, the top 10 suppliers shared 61 percent of the TAM. This comparison shows that the top 10 suppliers are gaining market share at the expense of the smaller suppliers.

Table 1

ESTIMATED 1986 WORLDWIDE GATE ARRAY SHIPMENT REVENUE--MOS (Millions of Dollars)

1985 Rank	1986 Rank	Company	1985 Revenue	1986 Revenue
1	1	LSI Logic	$140.0	$192.0
2	2	Fujitsu	101.3	145.0
4	3	Toshiba	45.6	120.0
3	4	NEC	49.0	72.0
7	5	Oki	28.0	49.0
5	6	Sieko	33.8	48.0
6	7	Hitachi	29.1	45.0
8	8	Gould AMI	25.0	27.0
22	9	Honeywell	7.0	27.0
9	10	Hughes	19.2	22.0
Total			$478.0	$747.0

Source: Dataquest
March 1987

Table 2

ESTIMATED 1986 WORLDWIDE GATE ARRAY SHIPMENT REVENUE--BIPOLAR (Millions of Dollars)

1985 Rank	1986 Rank	Company	1985 Revenue	1986 Revenue
1	1	Fujitsu	$120.1	$164.0
2	2	Motorola	68.4	82.6
3	3	NEC	45.0	73.0
5	4	Fairchild	39.8	47.7
4	5	Honeywell	42.0	45.0
6	6	Ferranti Electronics	29.0	38.0
7	7	Hitachi	29.0	34.0
10	8	Siemens	23.4	26.0
8	9	Signetics	28.8	26.0
9	10	Texas Instruments	27.5	24.7
Total			$453.0	$561.0

Source: Dataquest
March 1987

MOS Gate Arrays

As Table 1 indicates, LSI Logic maintained its number one position in MOS gate arrays with a 37 percent growth in 1986 over 1985. However, Toshiba had a large number of designs go to production and it increased sales by an estimated 163 percent. Fujitsu captured many new designs in 1986 and remains in second place. Oki is gaining market share by capturing lower-density designs with high-production volumes. Four of the top 5 MOS suppliers are Japanese companies. The top 10 MOS suppliers accounted for 69 percent of the total 1986 MOS market, compared to 66 percent in 1985.

Bipolar Gate Arrays

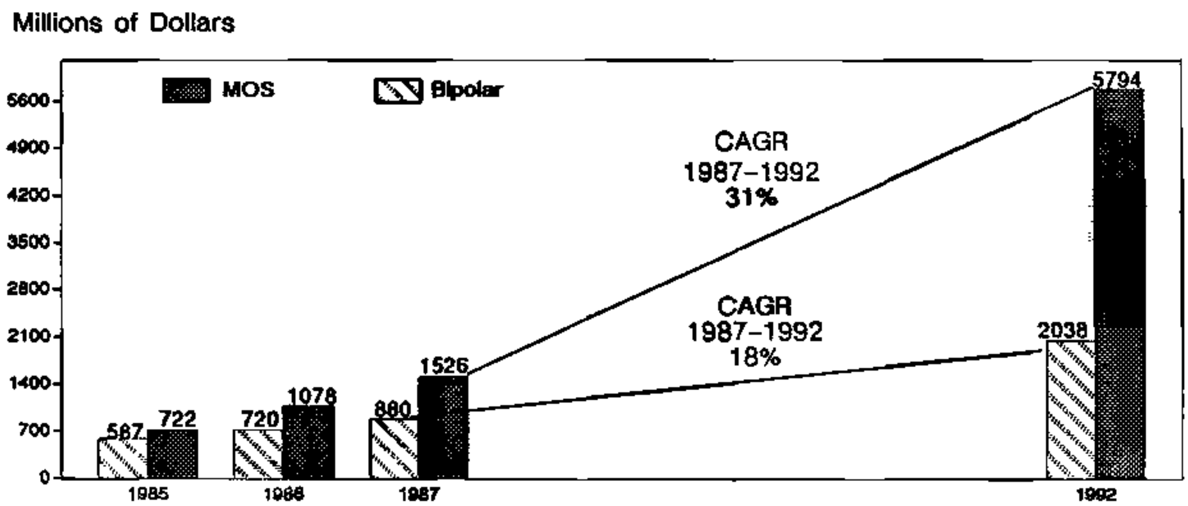
The ECL market continues to flourish while the TTL market fades. Mainframe computers are large consumers of ECL arrays. Fujitsu, Motorola, NEC, Fairchild, and Honeywell are the key suppliers to the mainframe manufacturers. These top 5 ECL suppliers shared 74 percent of the $412 million 1986 ECL market. AMCC is also a supplier of ECL arrays and had sales of 24 million dollars mainly in the military and industrial markets. Ferranti Interdesign and Exar dominate the North American linear and mixed linear/digital array markets. It is interesting to note that only 2 of the top 5 bipolar array suppliers shown in Table 2 are Japanese companies. The top 10 bipolar suppliers shared 78 percent of the total 1986 bipolar market, compared to 77 percent in 1985. This is a capital-intensive mature market dominated by large IC suppliers.

GATE ARRAY SUPPLIERS POSITION FOR FUTURE GROWTH

The worldwide gate array market is expected to increase from $1.8 billion in 1986 to $7.8 billion by 1992. Figure 2 illustrates that by 1992 the MOS market will dominate with a $5.8 billion market followed by the $2 billion bipolar market. The compounded annual growth rates from 1987 through 1992 for the MOS and bipolar gate array markets shown in Table 3 are 31 percent and 18 percent, respectively.

Figure 2

ESTIMATED WORLDWIDE GATE ARRAY CONSUMPTION BY TECHNOLOGY



Source: Dataquest
March 1987

Table 3

ESTIMATED WORLDWIDE GATE ARRAY CONSUMPTION
BY TECHNOLOGY
(Millions of Dollars)

	1985	1986	1987	1988	1989	1990	1991	1992
Total	1,308.5	1,797.8	2,406.5	3,163.9	3,773.6	4,851.2	6,175.4	7,832.2
Total MOS	721.6	1,078.0	1,526.4	2,102.0	2,563.9	3,406.3	4,459.0	5,793.9
MOS Digital	704.1	1,057.0	1,500.9	2,071.3	2,527.0	3,360.9	4,402.8	5,723.6
MOS Linear	17.5	21.0	25.4	30.7	36.9	45.4	56.3	70.3
Total Bipolar	586.9	719.8	880.2	1,061.9	1,209.7	1,444.9	1,716.4	2,038.3
Bipolar Digital	516.9	646.8	801.3	977.5	1,120.3	1,351.3	1,618.7	1,937.7
TTL	135.9	154.1	169.5	178.0	176.2	172.7	164.0	150.9
ECL	313.6	412.6	540.5	697.3	836.7	1,071.0	1,349.4	1,686.8
Other	67.4	80.1	91.3	102.3	107.4	107.4	105.2	100.0
Bipolar Linear	70.0	73.0	78.8	84.4	89.4	93.9	97.6	100.6

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

Source: Dataquest
March 1987

During 1986, the MOS portion of the gate array market increased 49 percent compared to 1985, while the bipolar market experienced a more modest 23 percent growth. Most of the bipolar growth was attributed to ECL arrays with a 32 percent rise in 1986 consumption compared to 1985. Please remember that shipments and consumption include NRE, intracompany, and production. The yen-per-dollar exchange rate applied in 1985 was 238 and 167 in 1986.

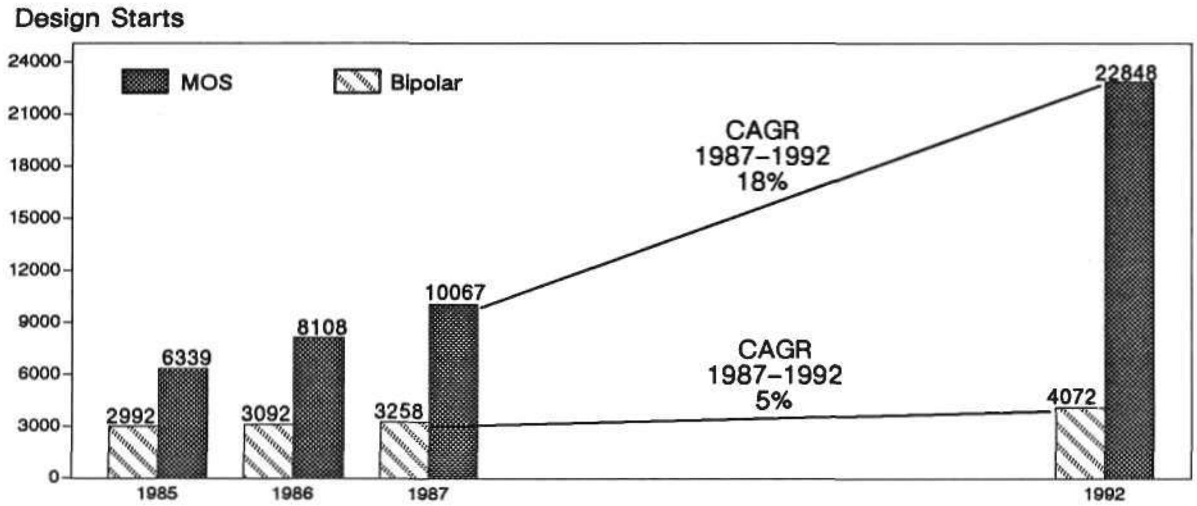
Most gate array suppliers are currently sacrificing today's profits for increased market share. During 1986, device pricing as well as NRE charges decreased in CMOS gate arrays to the point where most suppliers experienced small profits or even losses. Suppliers want to gain as much market share as possible so that they will be able to capitalize on the $7.8 billion market in 1992. NRE charges and device pricing will be addressed later in this newsletter.

DESIGN STARTS DETERMINE FUTURE GROWTH

Design starts are a leading indicator of future gate array revenue. Figure 3 illustrates that there were 11,200 total design starts in 1986 and we expect 26,920 total design starts in 1992. During 1986, MOS gate array design starts grew an estimated 28 percent compared to 1985, while bipolar design starts grew only 3 percent. This low growth rate in bipolar arrays can be attributed to the fact that TTL designs are being phased out while the number of ECL designs are increasing. Dataquest analysis indicates that designs captured in 1986 will take an average of 6 to 12 months to reach the production phase. Thus, a high number of designs in 1986 will result in high production revenue in 1987. However, the percentage of designs that ultimately reach production phase can vary widely. Our analysis indicates that the percentage of designs that go to production for the industry ranges from 30 percent during a depressed semiconductor economy to 70 percent in a thriving semiconductor economy.

Figure 3

ESTIMATED WORLDWIDE GATE ARRAY DESIGN STARTS BY TECHNOLOGY



Source: Dataquest
March 1987

Table 4 shows the number of designs captured in 1985 and 1986 by companies from each region. During 1986, North American companies experienced a 22 percent increase in MOS designs and an 11 percent decrease in bipolar designs. Part of the decline in bipolar designs can be attributed to the shift from TTL designs to ECL designs. However, Japanese companies grew 37 percent in MOS designs while increasing 22 percent in bipolar designs, which indicates that Japanese companies will gain market share in both the MOS and bipolar gate array markets during the next two years.

Table 4

ESTIMATED WORLDWIDE GATE ARRAY DESIGN STARTS BY REGION

	1985	1986
Worldwide Total	9,331	11,200
MOS	6,339	8,108
Bipolar	2,992	3,092
North American Companies	4,924	5,439
MOS	3,184	3,885
Bipolar	1,740	1,554
Japanese Companies	3,297	4,389
MOS	2,429	3,334
Bipolar	868	1,055
Western European Companies	1,041	1,272
MOS	657	789
Bipolar	384	483
ROW	69	100
MOS	69	100
Bipolar	0	0

Source: Dataquest
March 1987

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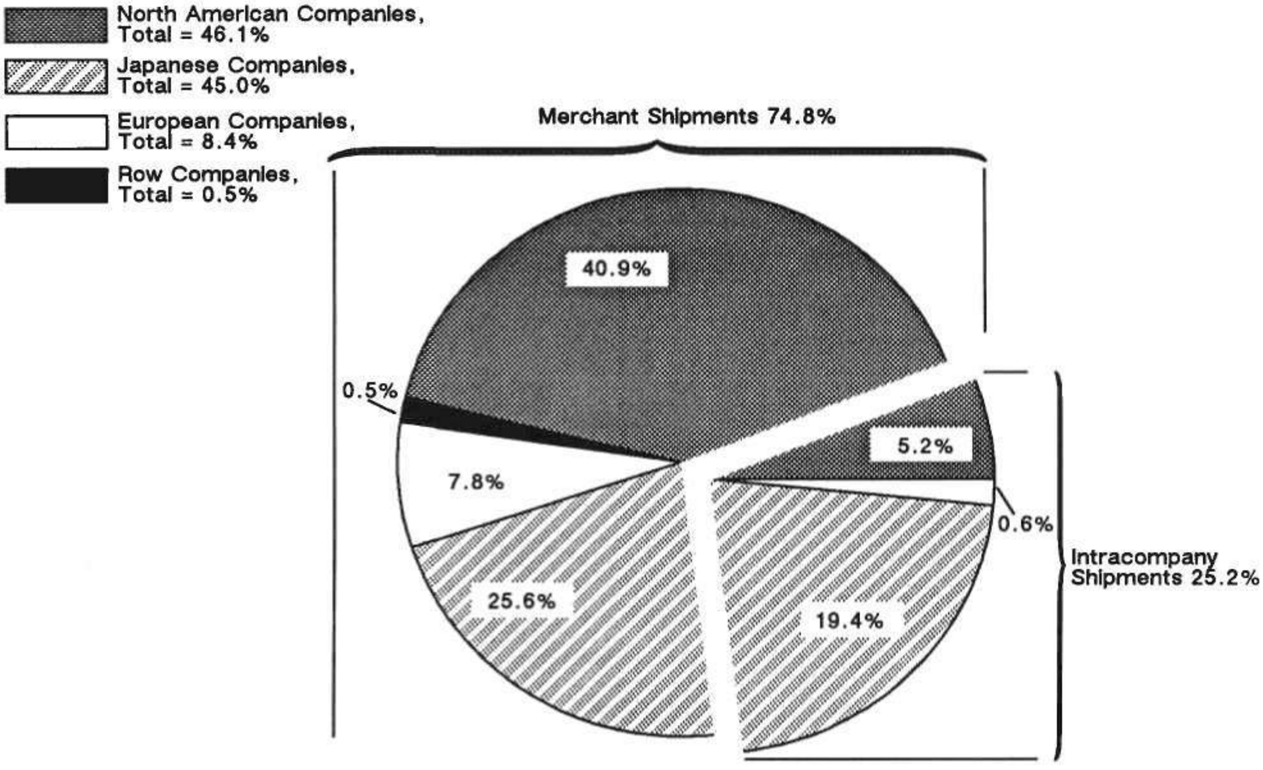
MERCHANT REVENUE VERSUS INTRACOMPANY REVENUE

It is important to examine the source of revenue when exploring regional trends. There was 25.2 percent intracompany revenue in the total 1986 worldwide gate array market as shown in Figure 4. Japanese companies had 43 percent of their 1986 worldwide revenue generated from sales to internal divisions compared to only 11 percent for North American companies. During 1986, Japanese companies had 77 percent of the $453 million intracompany market and 35 percent of the $1,345 million merchant market. North American companies had 21 percent of the intra-company market and 55 percent of the merchant market. Intracompany markets are less volatile and less vulnerable to outside competition. However, Figure 4 shows that the combined intracompany and merchant revenue for North American companies and Japanese companies is 46.1 percent and 45 percent, respectively.

Figure 4

ESTIMATED 1986 INTRACOMPANY AND MERCHANT WORLDWIDE SHIPMENTS BY REGION



Source: Dataquest
March 1987

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MARKET TRENDS

Fierce competition from the more than 100 gate array suppliers produced the following trends:

- Amortized or low NRE pricing
- Declining device pricing
- Increased offshore manufacturing and consumption

NRE Pricing

Suppliers are experimenting with different NRE strategies. Some suppliers try to minimize the up-front NRE charge and amortize the cost of the design over production volume. This can be risky since some designs never go to production. Japanese companies in Japan charge low or zero NRE and require a production order. At the other extreme is the supplier that charges NRE and production cost separately, making each part self-reliant. Between these extremes are various combinations of NRE and production charges that may not represent the true cost of either part. In today's North American market, an increasing number of companies are offering NRE below cost and amortizing the cost of the design over the production volume.

Pricing on NRE for low-density CMOS arrays declined drastically in 1986. During 1985, 1,500-gate CMOS devices had a typical NRE charge of $25,000 to $30,000. In late 1986, these same devices had an average NRE charge of $15,000 to $20,000. This can be attributed to the competitive environment brought about by the 60 to 70 suppliers offering comparable products.

Device Pricing

The price per device is difficult to estimate because prices vary widely due to technology, gate count, and packaging configurations. Thus, a CMOS 2,000-gate device may sell for as low as $3 in high quantities, while an ECL 2,500-gate device may sell for $170. A better way to monitor gate array pricing is on a price-per-gate basis.

The most popular gate arrays (CMOS, 2,000 gates, die only, in quantities of thousands) took a sharp price-per-gate drop from between $0.01 and $0.012 in 1984, to between $0.002 and $0.004 in 1985. During 1986, the price per gate for these same devices fell to between $0.001 and $0.003. Higher gate count CMOS devices took a much smaller drop annually. The price per gate for ECL gate arrays only took an estimated 15 percent drop annually. Price decreases did occur in gate arrays, but not equally across all product lines.

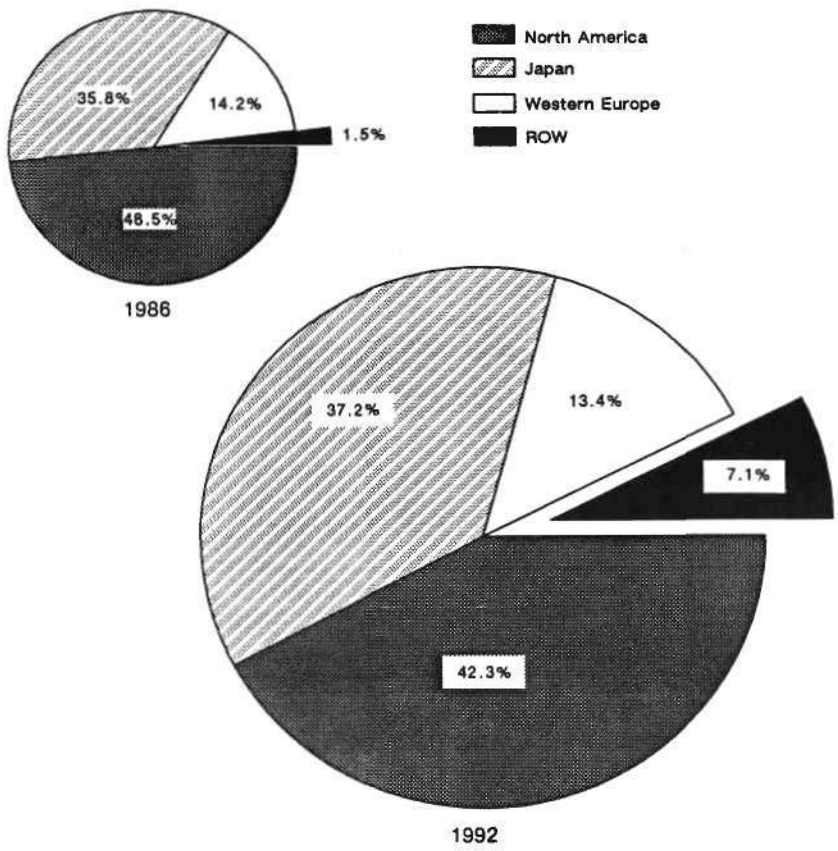
Few suppliers can make a profit with pricing at $0.001 per gate.

Offshore Manufacturing

The escalating value of the yen against other currencies is having a major impact on system manufacturers. This is especially true for those companies that make consumer electronics. In the highly competitive consumer electronics market, building the product at the lowest possible cost can make the difference between success or failure. We see a strong shift of system manufacturing to the Asian Pacific basin. This is true for Japanese system companies as well as North American companies. Dataquest has noted in other publications that there is an increasing demand for all types of semiconductors in Korea, Taiwan, Hong Kong, and Singapore. The Japanese Ministry of Finance reported that in 1986, Japan exported 498 million ICs to the United States while also exporting 444 million units to Korea, 442 million to Taiwan, and 481 million to Hong Kong. The trend in gate arrays is no different. Figure 5 illustrates that Dataquest expects the consumption of gate arrays in Rest of World (ROW) to increase from 1.5 percent in 1986 to 7.1 percent in 1992.

Figure 5

ESTIMATED WORLDWIDE GATE ARRAY CONSUMPTION BY REGION



Source: Dataquest
March 1987

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1987 AND BEYOND

The total worldwide gate array market is expected to grow from $1.8 billion in 1986 to $2.4 billion in 1987. We expect a 42 percent increase in 1987 MOS consumption and a 22 percent increase in bipolar consumption. Most of the bipolar growth will be in ECL arrays. We believe that CMOS device pricing will stabilize and not drop below $0.001 per gate. However, low or amortized NRE charges will be common as suppliers battle for design wins.

Suppliers need to position their design wins to capitalize on their strengths while avoiding major competition. We expect Japanese companies in the North American market to continue focusing on capturing lower-density, high-volume CMOS gate array designs as well as high-density ECL designs. North American companies are expected to focus more on capturing high-density CMOS designs and the full range of ECL designs. The gate array market is now dominated by large IC suppliers. The data suggest that Japanese companies will gain market share in both the MOS and bipolar gate array markets over the next two years. We expect 1987 to be the year of truth for the small gate array suppliers. They must decide which path to take: move to a niche market, look to be acquired, or retreat from the market altogether.

Bryan G. Lewis

April

Dataquest
a company of The Dun & Bradstreet Corporation

Research Newsletter

SIS Code: 1986-1987 Newsletters: April
1987-10

ISSCC 87: SYSTEMS VIEWPOINT DOMINATES DISCUSSIONS AND PROCESS TECHNOLOGY TAKES ANOTHER STEP FORWARD

INTRODUCTION

The 34th annual International Solid State Circuits Conference (ISSCC) was held during the last week in February in New York City. Authors from 34 companies delivered 116 papers. Leading contributing companies were Hitachi with 15 papers, AT&T with 10, and Toshiba with 8. Authors from Japanese companies delivered 44 percent of the papers, including 68 percent of the memory papers. The Japanese papers also described impressive devices in consumer applications and high-speed circuitry.

In addition to the everpresent thrust toward finer lines, denser memories, and larger chips, the principal topics that distinguished this year's ISSCC are as follows:

- There were a large number of papers that discussed devices with massive processing capabilities (DSP, image processing, 32-bit RISC processors, and special purpose MPUs and accelerators).

- There was increased attention to practical chip-production issues: CAD and the efficient use of design resources, design verification methods, test problems, packaging issues, and device manufacturability.

- With the movement to systems-on-a-chip, independent chip makers appear to be getting an ever-smaller piece of the pie, as vertically integrated, well-financed systems houses apply their expertise and finances to increasingly expensive design undertakings.

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ISSCC PRESENTATION SCORECARD

With some qualifications, the mix of ISSCC papers can be a useful indicator of industry trends. As in previous issues of the Dataquest ISSCC newsletter, we have updated several tables showing the make-up of this year's session and several such trends.

Session Summary

Table 1 profiles the 22 regular ISSCC sessions and the 10 evening sessions. North American authors decreased from 53 percent to 43 percent of the total, while European authors increased from 10 percent to 13 percent, and Japanese authors increased from 37 percent to 44 percent of the total, compared to ISSCC 1986. This year there were a large number of papers from universities (20), some with co-authors from merchant or captive suppliers.

As expected, the technology employed continued to shift toward the use of CMOS. In the 1986 IC market, CMOS comprised about 23 percent of total IC sales, about equal to its percent of ISSCC papers just five years ago.

Trend by Country of Origin

Authors from Japanese companies continue to increase in number (up sharply from 1986), and they presented in many sessions where they were weaker in the past. Europeans were well represented across all sessions. Table 2 compares authorship of ISSCC papers for the last few years.

Leading Companies Presenting Papers

Table 3 lists the leading companies in terms of ISSCC presentations for the past three years. In 1987, among the leading seven companies were four Japanese: Fujitsu, Hitachi, Mitsubishi, and Toshiba. The leading large U.S. captives were: AT&T, Hewlett Packard, and IBM. NTT also was a significant contributor. The leading U.S. independents were General Electric with four papers, and Motorola and Texas Instruments with two each. For the first time in memory, Intel had no presentation, nor were there papers from several other U.S. majors: AMD, Fairchild, and Signetics. Harris Semiconductor and National Semiconductor supplied one paper each. There were, however, U.S. papers from several of the smaller start-ups from the most recent wave of venture activity: Anadigics, Crystal Semiconductor, Linear Technology, Microlinear, and SEEQ Technology.

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Table 1

1987 ISSCC SESSION SUMMARY

Session Number	Topic	Number of Papers	Authorship: North America Merch.	Authorship: North America Captive	Authorship: Japan	Authorship: Europe	Technology Employed: MOS CMOS	Technology Employed: MOS NMOS	Technology Employed: CCD	Technology Employed: Bipolar	Technology Employed: BICMOS	Technology Employed: GaAs	Technology Employed: Other
1	Megabit DRAMs	6		1	4	1	6						
2	32-bit Microprocessors	6	1	4	1		5	1					
3	Sampled-Data Analog Circuits	5	2	1	2		3					2	
4	High-Speed Circuit Technology	6	1	1	3	1	3			1	1		1
5	Opening of Conference												
6	Keynote Address												
7	Nonvolatile Memories	5	3		2		4	1					
8	Microprocessors-Design Methodology	5	1		2	2	5						
9	High-Speed A/D Converters	5		1	3	1				4		1	
10	Image Sensors & Processing Circuits	5		1	3	1		1	3				1
11	Fast Static RAMs	6			5	1	1			1	1	3	
12	Semi-Custom Array Design	5	1		4		3			1		1	
13	Digital Signal Processors	5	2	1	2		5						
14	Wideband Amplifiers	5	3	1		1		2		3			
15	High-Speed Signal Processing	6	1	1	3	1	3			2	1		
16	Microprocessors-Special Purpose	6	1	1	3	1	6						
17	Analog Techniques	7	2	3		2	4			1	1	1	
18	Test & Packaging	5	1	2	1	1	2	1		1			1
19	High-Density SRAMs	9	2	1	6		9						
20	Special-Purpose Accelerators	5	2	1	2		5						
	& DRAMs	4			4		3				1		
21	Telecommunication ICs	6	3		1	2	6						
22	VLSI Systems & Architectures	4	2	2	—	—	2	—	1	—	—	—	1
	Totals	116	28	22	51	15	75	6	4	14	5	8	4
	1985 Percent of Total:						52%	18%	5%	18%	0%	6%	1%
	1986 Percent of Total:						50%	16%	2%	20%	3%	4%	5%
	1987 Percent of Total:						65%	5%	3%	12%	4%	7%	3%

Wednesday Evening Informal Sessions

DRAM Cell Structures & Technologies
ASIS Architectures for the '90s
Next Generation IC Technology for Analog/Digital VLSI
Future Trends in Nonvolative Memories
Directions in Smart Power ICs

Thursday Evening Informal Sessions

Digital ICs with Embedded Memory
Competing Technologies for High-Speed Digital Systems
Trends in Design Automation for Mixed Analog/Digital ASICs
Educating Future Chip Designers
Technologies for Broadband Networks

Source: 1987 ISSCC Digest of Technical Papers
Dataquest
April 1987

Table 2

ISSCC TECHNICAL PAPERS BY COUNTRY OF ORIGIN
(Percent)

Country	1981	1982	1983	1984	1985	1986	1987
Japan	25%	29%	42%	39%	45%	37%	44%
United States	61	66	50	51	43	53	43
Western Europe	14	5	8	10	12	10	13
Total	100%	100%	100%	100%	100%	100%	100%
Total Papers*	89	88	100	97	112	108	116

*Excluding panel sessions and keynote speakers

Source: Dataquest
April 1987

Table 3

LEADING SOURCES OF ISSCC PAPERS IN 1987
(Number of Papers)

Company	1987
Hitachi	15
AT&T Bell Laboratories	10
Toshiba	8
Fujitsu	6
Mitsubishi	6
Hewlett-Packard	5
IBM	5
NEC	5
NTT	5
Motorola	3
Sony	3
Others	45
Total	116

Source: Dataquest
April 1987

DOMINANT ARCHITECTURAL TREND--HIGH-THROUGHPUT PROCESSING CAPABILITY

One of the major themes of the 1987 ISSCC was evident in the efforts of circuit designers to dramatically increase the processing capabilities of the chips they design. These include chips that incorporate on-chip caches, pipelining, parallel processing capabilities, and RISC architectures. Chips are being made as large as is economically feasible, and every effort is made to avoid going off-chip for time-consuming operations.

A further set of papers sought the same goal through the design of dedicated special purpose accelerators. Mixed into several sessions were dedicated specialty memories that combine logic with standard memories to dramatically speed the delivery of data in special applications, especially video.

The conference made it clear that designers are increasingly oriented to producing chip systems that address and resolve the design problems of the systems houses, in silicon.

32-Bit Processors--RISC Architectures Overwhelm

Although the discussion of RISC architectures was an evening session in 1986, this year it emerged fully developed in the session dealing with 32-bit MPUs. Of the six papers presented, four used RISC-type architectures. The only exceptions were Digital's 32-bit MPU with on-chip caches and MMU, and Matsushita's chip. Digital's device used a minicomputer instruction set.

Each of the devices described typically put 115,000 to 172,000 transistors on a 8-10mm square die using 1.5um CMOS technology. However, one of the Hewlett Packard processors used NMOS technology, and the Matsushita 32-bit MPU used considerably more aggressive design rules (1.0um) to get 372,000 transistors on a 92.0 sq. mm die. All but the AT&T CRISP chip (C-Machine Rational Instruction Set Processor) were implemented in double-layer metal. The AT&T device used three layers of interconnect, one of metal and two of polysilicon.

Clock rates ranged from 8 MHz to 30 MHz, providing performance ratings of between 2 mips (average) and 20 mips (peak). Pipelining features varied, with different devices using three to five stages. Increased performance was also achieved through various on-chip instruction and data caches, ranging in size from 256 bytes (the Hewlett Packard RISC processor), to 13 Kbytes (on the AT&T CRISP chip). Only one device, the Hewlett Packard NMOS device, lacked an on-chip cache. Memory Management Units (MMUs), and Translation Lookaside Buffers provided virtual memory support. Power dissipation ranged from 500mW to 10W for HP's NMOS device. Other popular features included on-chip support to facilitate testing, as well as ease of interface to coprocessors or floating point processors.

Clearly marking the advantages of systems orientation was this session, where five of the six 32-bit processors presented were designed by either captive systems houses (AT&T, Digital, and HP), or vertically integrated merchant suppliers (Matsushita), all of whom have tremendous in-house systems expertise and systems perspective, not to mention financial resources (HP is the smallest at $6 billion in revenue per year). The only exception was a 32-bit RISC chip presented by the Stanford University Center for Integrated Systems.

Digital Signal Processors and Image Processors

Here also, CMOS processing dominated, with typical design rules down between 1.2 and 1.5um. Each of the papers in this session contained special features designed to address high-throughput applications.

As with several of the more general-purpose 32-bit MPUs, the 60ns DSP from AT&T-Bell Labs puts an instruction cache on-board.

Two papers (Toshiba and another from AT&T-Bell Labs) described devices aimed at speech processing, which came to the fore about five years ago and has slowly been giving way to silicon advances.

In the CCD imaging session, Sony described a CMOS image processor designed for application in VCRs.

Big Companies-Big Impact

As was the case in other system-chip application areas discussed above, independent semiconductor houses played only a small role in this session. No papers were presented by independents. The devices from big companies are often defined and designed in response to an in-house need in the final product--such as Sony's image processor or AT&T-Bell Labs' requirements for speech processing in telecom applications.

Furthermore, most of the papers offered by the systems houses that have significant semiconductor capability (AT&T-Bell labs, Hitachi, Toshiba, etc.), all had multiple authorship, with major participation from different parts of the company: often the R&D section, the IC design section, and the applications lab. This fact does not bode well for independent semiconductor houses as the trend advances to greater systems solutions--they are likely to lack the financial resources and the in-house breadth of talent and expertise to create such chips in a timely manner.

For example, for the 15 Hitachi papers presented, 12 were joint efforts involving one or more of the following arms of the Hitachi organization:

- Hitachi Central Research Labs--Tokyo, Japan
- Hitachi Consumer Products Research Center--Yokohama, Japan

- Hitachi Device Development Center--Tokyo, Japan
- Hitachi Kanagawa Works--Kanagawa, Japan
- Hitachi Ltd.--Tokyo, Japan
- Hitachi Musashi Works--Kodaira, Japan
- Hitachi Omika Works--Ibaraki-Ken, Japan
- Hitachi Research Lab--Ibaraki-Ken, Japan
- Hitachi Takasaki Works--Gunma, Japan
- Hitachi VLSI Engineering Corp.--Tokyo, Japan

While this is certainly a testimony to one company's organization of the research and product development effort, it also gives strong evidence to the fact that designing today's complex, applications-oriented chips is a multidisciplinary effort requiring tremendous resources.

Special-Purpose Microprocessors

The session of special-purpose microprocessors included six papers. Hitachi presented a paper on a microprocessor with 2 Kbytes of on-chip EEPROM, which makes provision for data security through an on-chip encryption key in ROM. The chip is aimed at what is termed the smart-card market and packaging on a card can be accomplished through TAB. Parallel processing is an area of considerable interest and two of the session papers described processors with highly parallel architectures, one from Brunel University, England, and the other from Digital. The Brunel chip aims at image-processing applications and the chip set from Digital would implement a massively parallel structure. The largest machine configuration could contain 8K processors and execute at 2.6 trillion 4-bit operations per second. Applications suited to this approach include simulation problems, AI, and image and data base processing, which typically are not well handled by serial processors. Two papers describing chips optimized for AI applications were presented. NTT Electrical Communications Labs described a 32-bit LISP processor with a microcoded interpreter-oriented architecture. By electing to leave most of the memory off of the chip, this chip contains 80K transistors. An impressive 553K transistor, 32-bit LISP processor from TI also implements a microcoded architecture. The compiler views the chip as stack oriented. Among other features of the device are hardware support for memory management, six on-chip RAMs, pipelining, and ROM for self test. The processor was designed for a 30ns clock cycle. The project was funded in part by DARPA. A paper from Toshiba dealt with a chip set for digital TV. In order to package the two devices totalling 195K transistors in plastic packaging, 1.5 micron CMOS technology was used.

High-Speed Circuit Technology and Special-Purpose Accelerators

These two sessions comprised 11 papers dealing with very high performance circuit elements, embodying a wide range of technologies to address many special-purpose functions. While these papers didn't have nearly the systems orientation as those discussed above, they were certainly as intent on high throughput, albeit in much more tightly focused applications.

Josephson junctions made their annual appearance in a paper from Fujitsu, Ltd., describing a 900-gate Josephson 16b ALU. At previous ISSCCs, Fujitsu had also designed and fabricated an 828-gate 16 x 16b multiplier, and a 112-gate 8b shift register, both using Josephson junction technology.

The staff at Hitachi Central Research Labs described a very impressive 48ps gate-delay ECL technology that utilized a proprietary Self-aligned Edge Contact Technology (SELECT). The device was impressive not only for its performance, but because this performance was obtained through the use of some critical device tolerances as fine as 0.1um.

In the Special-Purpose Accelerators Session, the devices described were impressive not only for their high performance in special applications, but for their advanced circuit and process technology.

The staff at NTT Electrical Communications Labs described a Pipeline Sorting Chip measuring 37 x 21mm. Non-zero yield was made possible through the use of a three-tier hierarchical redundancy scheme that nearly doubles the chip size, and through the use of liberal 3um design rules.

MOVING THE PERIPHERAL ISSUES ON-BOARD

Total Cost Management of the Design, Manufacturing, Test, and Maintenance of VLSI Chips

The same systems trend that is taking place in the silicon is also taking place throughout the industry in the design effort. The new "system" is total cost management. Issues that had traditionally been secondary design criteria, peripheral to the performance-optimization issue, are steadily being pulled into the design equation. This has shifted design considerations from device performance alone to bona fide "total cost" issues such as (1) efficient use of designers, (2) reduced time-to-market, (3) control of the exponentially increasing cost of testing, and (4) methods of ensuring higher reliability in a complex systems environment. The problems addressed by the designer now give much more consideration to these formerly peripheral issues. This trend was apparent in much of what was presented at this year's ISSCC, both directly and implicitly.

CAD Trends

It was also evident that many designers have attempted to design custom-capability chips using standard cell libraries or gate arrays. The goal then becomes to maximize chip performance and minimize design time (and the use of design resources) within the limits posed by a given set of standard cells or blocks.

In these presentations, attention is paid to gate density, gate utilization, design time/manpower, and, of course, chip performance. But, the first three criteria are being weighted more heavily than before.

In the CAD and chip-design area, the trends evident at the ISSCC itself understate the actual overall trend taking place in the industry. Nine years ago, the CAD-intensive Custom Integrated Circuits Conference came into being, in part driven by the special CAD interests of this area. Much of the growth in activity and interest in the design area is spilling over into the dramatic growth of that conference. The CAD discussions at ISSCC generally have revolved around issues of general interest to design, and not limited to ASICs.

Added Consideration Being Given to Testability

With complex logical functionality comes increased difficulty in testing, problems in high power output, and the need for high pin-count packaging. Session 13 at this year's ISSCC was devoted to testing and packaging issues, but a large number of the papers in other sessions also addressed these same problems in the context of their own chips.

In the 32-bit Microprocessor session, every design incorporated some level of on-chip testability. In the memory sessions this has been going on, in another manner, through the incorporation of redundant circuits and ECC, but those designs, too, were shown to reflect much more concern for the test problem.

It is only with memories and simple well-defined functional building blocks that the problems of packaging are minimized. High pin-counts (the 32-bit MPUs all had 160 pins or more) and high power dissipation are major concerns for high-speed, high-throughput processors.

This trend, too, tends to favor the vertically integrated chip manufacturers, especially IBM, which have always placed great emphasis on packaging and interconnection issues to improve system performance.

In the sessions dealing with high-performance devices, there were several instances where the device could not be fully tested at the highest clock rate for which it was designed, because of the unavailability of adequate test equipment.

Efficient Use of Design Resource--Keynote Address

Computer-aided design issues have been an important part of the ISSCC for many years, either directly in the session presentations, or in the informal evening sessions. This year's keynote address, by Robert Brodersen, of the University of California at Berkeley, discussed "IC Design in a Restructured Semiconductor Industry," which provided a good overview for the whole conference by discussing the shifting importance of circuit perfection and design time; complex, system-oriented chips and primitive building blocks; and designing for manufacturability and testability. His thesis is that great advances in price performance in the next generation of computers will result more from improved computer architectures than from improvements taking place at the device and circuit level. This will include, on the design side, reduced time to delivery, and increased ability to customize circuits through use of CAD tools. On the systems side, progress will result through the use of parallel-processing capabilities or pipeline architectures.

ADVANCES IN PROCESSING: CIRCUIT ELEMENTS AND INCREASING CIRCUIT DENSITY

As always, there were a host of papers dealing with basic advances in the fundamental processing capabilities of the state of the art. As is generally recognized, memory products, mainly DRAMs, as well as fast and slow SRAMs, lead the way. The 1987 ISSCC was no exception. A total of 35 papers and three of the special evening sessions focused on pushing back the current limits of fine-line processing (now 0.7um in DRAMs, and a remarkable 0.1um in one high-speed processor paper), density (NTT's 16Mb DRAM sets the new standard), and speed (5 SRAMs with access times under 5ns).

This performance is never free, however, and the apparent process complexity (e.g., mask steps) and the attendant problems coming from continual scaling, will certainly generate new problems for the next wave of circuit designers to solve.

Dynamic RAMs

There were 10 papers describing DRAMs, plus an evening session on DRAM cell structures and technology. As a technology, NMOS has disappeared entirely for the first time, being replaced by CMOS, and interestingly, a 35ns BICMOS DRAM was described by Hitachi.

NTT described a 16Mb DRAM, which was built using a 0.7um, n-well CMOS process. A trench capacitor was used, and the cell capacitance, at 70fF, was kept well above the low threshold at which soft-error problems begin to appear. Newly developed Error Correction Circuitry (ECC) was developed, and the chip incorporated 2Mb of parity bits along with the 16Mb for data. The die measures 147.8 sq. mm, and ran off a 3.3V power supply.

All of the 4Mb DRAMs used a vertical capacitor structure, using either a trench, stacked capacitor, or corrugated cell. Also, every supplier has built flexibility into the designs to allow production of x1 or x4 configurations through mask or bonding options. As in several of the sessions, designers of the 4Mb DRAMs are beginning to bring the supply voltage from 5V to 3.3V, though 4Mb will likely be a mixture of both. Table 4 gives several specs of the DRAMs described at this year's ISSCC.

Table 4

ISSCC DYNAMIC RAM SUMMARY

Company	Product	Features
Fujitsu	4Mb	7.5 sq. um cell, uses stacked capacitor cell
Hitachi	1Mb	BICMOS, 35ns access speed
Hitachi	4Mb	
IBM	4Mb	3.3V power, uses 1Mb litho tools
Matsushita	4Mb	8.0 sq. um cell
Mitsubishi	4Mb	
NTT	16Mb	2Mb ECC, 3.3V power, 4.9 sq. um cell
Oki	4Mb	Pseudostatic or virtually static mode
Siemens	4Mb	
Toshiba	4Mb	60ns access speed

Source: Dataquest
April 1987

Static RAMs

There were a total of 15 papers dealing with static RAMS, six of which could be classified as "high speed" (a concept increasingly relative and application dependent), and seven that emphasized high density. Two others described static RAMs with specialty cache-memory functions. Of these 15 papers, 10 were delivered by Japanese authors and five by U.S. or European authors. Of the high-speed devices, two were CMOS (one of which was BICMOS with ECL outputs), three were GaAs, and one was ECL.

There were two new and advanced variants that sought to produce a more compact SRAM cell to ease the transition to high densities. One of these was a 512Kx8 (4Mb) design that could be used as either a pseudo-static or virtually static RAM. Presented by Oki, this device appeared in the DRAM session because it was an SRAM that utilized a single-transistor DRAM storage cell.

The other, a small-celled 256K true SRAM, continues to use a 4-transistor cell, but solved some of the scaling problems associated with either the 6-transistor cell or the 4-transistor cell with poly-load resistors, through the use of a special circuit.

Various versions of the DRAM approach have been available since about 1980 from Hitachi, Intel, Mostek, National Semi, Toshiba, and Zilog, but have never made the impact they might have under the right market conditions, or if marketed differently. The scalable 4-Tx cell presented by Hitachi, however, being more in the tradition of the movement from 6-Tx to 4-Tx cell in 1977/78, appears to offer a significant incremental improvement over existing devices, without the drawbacks of earlier pseudostatic and virtually static RAMs.

Both of the versions presented in the 1987 ISSCC continue to resolve some of the user unfriendliness of earlier offerings, and may gain a substantial share of the high-density SRAM market.

True 1Mb SRAMs were presented by Hitachi, Mitsubishi, Sony, and Toshiba, all using the traditional cell structure and circuitry. These devices represent the new state of the art in high density SRAMs, and their principal device parameters are listed in Table 5.

Table 5

ISSCC 1MB SRAM SUMMARY

Company	Product	Features
Hitachi	128Kx8	42ns, 3-poly process
Mitsubishi	128Kx8	34ns, 3-poly process
Sony	128Kx8	35ns access
Toshiba	128Kx8	25ns

Source: Dataquest
April 1987

On the high-speed end of the spectrum, GaAs supplied half of the papers, including a 5ns 16K device from Mitsubishi LSI Research and Development Labs. At this year's ISSCC, NMOS, as a technology for high-speed SRAMs, was absent for the first time (see Table 6).

Table 6

ISSCC FAST SRAM SUMMARY

Company	Product	Speed	Features
Fujitsu	8Kx8	5ns	ECL
Fujitsu	49K Tag Memory		Twin-well CMOS
Hitachi	64Kx1	7ns	BICMOS with ECL outputs
Hitachi	4K	1ns	GaAs
Mitsubishi	4Kx4	5ns	GaAs
Philips Rsch	1K	2ns	GaAs

Source: Dataquest
April 1987

Nonvolatile Memory

There was one formal session (seven papers) and an evening session, dealing with nonvolatile memory (NVM). In the formal session, the papers that drew the most interest were a 4Mb EPROM from Toshiba and a 128K "flash" EEPROM from SEEQ Technology. There were no bipolar NVM papers presented, no mask ROM papers presented, and surprisingly, no high-speed MOS ROM, EEPROM, or EPROM papers presented.

In the informal evening session on "Future Non-Volatile Memory Technologies," the panelists from AMD, Intel, and SEEQ all expressed great expectations for the future of the flash EEPROM, and an improved flash EPROM (testable and speed-sortable OTP) to garner a large share of what is now the traditional EPROM market, and partly served by the full-featured EEPROM market.

Toshiba's 4Mb EPROM is the first described of that density, and utilizes a 9 sq. um cell (versus about 20 to 25 sq. um for the smallest in general production today). In addition, Toshiba was able to address the speed-sort after packaging problem with special circuitry for OTPs. The 4Mb device uses 0.7um design rules and is a die measuring 5.86 x 14.92mm.

SEEQ's flash EEPROM is akin to a similar product described in the 1985 ISSCC by Toshiba, but never brought to market. The 128K device has a cell more closely related to an EPROM than to a full-featured EEPROM. What is gained in this approach is a much smaller cell size and die size, and lower cost, at the expense of bit-erase flexibility (The flash EE has bulk erase only) and extended durability (many erase-write cycles without failure). Although this device has been around in one form or another for some time without being marketed, there was considerable expectation at the evening session that a market does exist for such a device and that it should capture a considerable portion of the EPROM market because of its innate reprogramming capability.

GaAs Doubles Paper Count in 1987

At the ISSCC two years ago, one wag commented, "Gallium arsenide--technology of the future--always has been and always will be." It is interesting to note that GaAs IC Presentations this year numbered eight, compared to just four in 1986. Dataquest has identified 55 GaAs ventures today, most of which have begun during the past four years. Still, in 1986, the estimated GaAs IC market rested at $43 million--less than 0.2 percent of the total IC market for 1986. Though extremely fast GaAs memories have been presented at the ISSCC since 1982, few are believed to be currently designed into a commercial system, or are available as a standalone component on the merchant market. (As recently as 1983, however, the densest GaAs memory was 1K, compared to a 16K device at this year's meeting.)

Furthermore, the technical achievements of established technologies, and their kin--CMOS, ECL and BICMOS--march forward at tremendous pace, while the progress of GaAs is still confounded by myriad technical and economic problems limiting commercial application. If the systems-oriented trends apparent at this conference maintain their momentum--on-chip caches, parallel processing, reduced emphasis of optimized circuits and heavier emphasis on system optimization--GaAs technology could be further constrained in its economic applicability.

It remains to be seen whether GaAs will face ever-shrinking market opportunities after years of effort (like bubble memories), or will realize great economic and technical advances, such as we have just seen in superconducting materials, where tremendous progress has recently been made after years of unrewarded effort and hundreds of millions of dollars of investment.

SESSIONS FOR SPECIALIZED PRODUCT AREAS

There were many other formal sessions and evening sessions that dealt with important topics not in the mainstream of the major trends listed above, with technology barriers not often related to the major thrust of the industry, but nonetheless important to progress in their own application area. At the 1987 ISSCC, such areas included formal sessions on Telecom ICs, Networking, A/D Converters, CCD Imaging, and Wideband Amplifiers. CCD imaging and A/D converters have always been a part of the ISSCC program, and are essential front-ends to the advancing digital system that constitutes the core of focus for the rest of the ISSCC program.

Also, there were informal evening sessions that discussed Smart Power and Broadband Networks.

ISSCC TRENDS AND INDUSTRY TRENDS

Technology is clearly the cornerstone of today's semiconductor industry. Just as clearly, however, is the importance of business issues not related to the silicon issues, for example the increasingly active role played by governments in balancing or unbalancing the markets. The bath of red ink suffered by nearly every company over the past two years and the extensive layoffs during the same period, indicate that proper capital spending, improved forecasts of future market conditions, innovative product and marketing strategies, and sheer financial mass can be as important as leading-edge technology in determining the success or failure of today's semiconductor companies.

This year's ISSCC, with its systems orientation, and the dominance of well-financed suppliers with broad expertise, also serves to underscore the changing nature of the semiconductor business as it matures from being silicon-driven to being driven by systems issues and systems companies.

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Lane Mason

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Research Newsletter

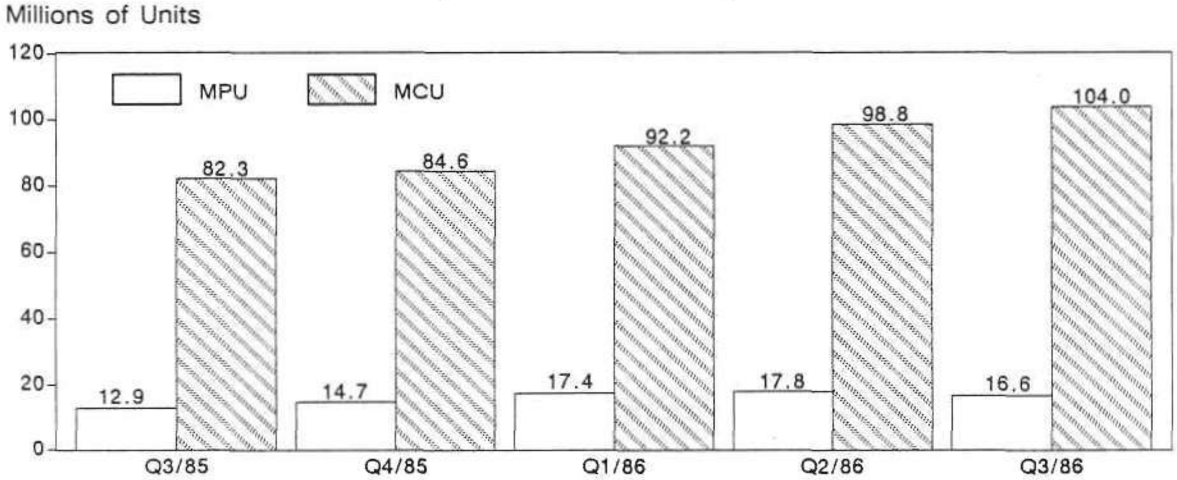
SIS Code: 1986-1987 Newsletters: April 1987-11

THIRD QUARTER 1986 MICROPROCESSOR AND MICROCONTROLLER UNIT SHIPMENT UPDATE

During the third quarter of 1986, worldwide microprocessor and microcontroller unit shipments increased by approximately 5.7 million units, or 5 percent, from second quarter 1986. Estimated shipments of all microcontroller devices totaled approximately 104 million units. Shipments of all MCU categories increased. Estimated shipments of all microprocessor devices totaled approximately 16.6 million units. Shipments of 8-bit MPUs decreased slightly in the second quarter over the prior quarter's shipments, whereas shipments of 16-bit MPUs were up considerably. Figure 1 shows MCU and MPU unit shipments from the third quarter of 1985 through the third quarter of 1986.

Figure 1

MICROCONTROLLER AND MICROPROCESSOR UNIT SHIPMENTS
THIRD QUARTER 1985 THROUGH THIRD QUARTER 1986
(Millions of Units)



Source: Dataquest
April 1987

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Table 1 shows the quarterly revenue for microcontrollers and microprocessors from the third quarter 1985 through the third quarter 1986.

Table 1

TOTAL MICROCONTROLLER AND MICROPROCESSOR REVENUE
THIRD QUARTER 1985 THROUGH THIRD QUARTER 1986
(Millions of Dollars)

	Q3/85	Q4/85	Q1/86	Q2/86	Q3/86
MCU	$260.0	$300.0	$321.0	$358.0	$359.0
MPU	96.0	104.8	122.0	136.0	143.0
Total	$356.0	$404.8	$443.0	$494.0	$502.0

Source: Dataquest
April 1987

Table 2 shows the change in total microcontroller unit shipments from the second quarter of 1985 through the third quarter of 1986.

Table 2

TOTAL MICROCONTROLLER UNIT SHIPMENTS
SECOND QUARTER 1986 THROUGH THIRD QUARTER 1986
(Thousands of Units)

	Q2/1986		Q3/1986		Percent
		Percent of		Percent of	Growth
MCU	Units	Shipments	Units	Shipments	Q2 to Q3
4-Bit	53,688	54.3%	58,057	56.0%	8.1%
8-Bit	45,038	45.6	45,521	43.9	1.1%
16-Bit	98	0.1	117	0.1	19.4%
Total	98,824	100.0%	103,695	100.0%	4.9%

Source: Dataquest
April 1987

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Table 3 shows the change in total microprocessor unit shipments from the second quarter of 1986 through the third quarter of 1986.

Table 3

TOTAL MICROPROCESSOR UNIT SHIPMENTS
SECOND QUARTER 1986 THROUGH THIRD QUARTER 1986
(Thousands of Units)

	Q2/1986		Q3/1986		Percent
MPU	Units	Percent of Shipments	Units	Percent of Shipments	Growth Q2 to Q3
8-Bit	15,132	85.2%	13,750	82.8%	(9.13%)
16-Bit	2,509	14.1	2,736	16.5	9.05%
Others	113	0.7	126	0.7	11.50%
Total	17,754	100.0%	16,612	100.0%	(6.43%)

Source: Dataquest
April 1987

Table 4 shows the change in the shipments of the leading 8-bit MPUs from the second quarter of 1986 through the third quarter of 1986.

Table 4

LEADING 8-BIT MICROPROCESSOR SHIPMENTS
SECOND QUARTER 1986 THROUGH THIRD QUARTER 1986
(Thousands of Units)

	Q2/1986		Q3/1986		Percent
Device	Units	Percent of Shipments	Units	Percent of Shipments	Growth Q2 to Q3
Z80	6,187	40.9%	4,951	36.0%	(20.00%)
8085	3,090	20.4	2,983	21.7	(3.46%)
8088	1,617	10.7	1,392	10.1	(13.90%)
6802	987	6.5	937	6.8	(5.07%)
6809	844	5.6	796	5.8	(5.70%)
Others	2,407	15.9	2,691	19.6	11.80%
Total	15,132	100.0%	13,750	100.0%	(9.13%)

Source: Dataquest
April 1987

Table 5 shows the changes in estimated shipments of 16-bit microprocessors from the second quarter of 1986 through the third quarter of 1986.

Table 5

16-BIT MICROPROCESSOR SHIPMENTS
SECOND QUARTER 1986 THROUGH THIRD QUARTER 1986
(Thousands of Units)

	Q2/1986		Q3/1986		Percent
Device	Units	Percent of Shipments	Units	Percent of Shipments	Growth Q2 to Q3
68000	673	26.8%	721	26.4%	7.13%
8086	515	20.5	586	21.4	13.80%
80286	497	19.8	583	21.3	17.30%
80186	337	13.4	395	14.4	17.20%
V30	160	6.4	170	6.2	6.30%
Z8000	172	6.9	117	4.3	(32.00%)
32016	89	3.5	94	3.4	5.60%
Others	66	2.6	70	2.6	6.10%
Total	2,509	100.0%	2,736	100.0%	9.05%

Source: Dataquest
April 1987

Table 6 shows the changes in estimated shipments of 8-bit microcontrollers from the second quarter of 1986 through the third quarter of 1986.

Table 6

8-BIT MICROCONTROLLER SHIPMENTS
SECOND QUARTER 1986 THROUGH THIRD QUARTER 1986
(Thousands of Units)

	Q2/1986		Q3/1986		Percent
Device	Units	Percent of Shipments	Units	Percent of Shipments	Growth Q2 to Q3
8049	6,970	15.5%	7,333	16.1%	5.21%
6805	7,108	15.8	7,010	15.4	(1.38%)
8051	4,119	9.1	4,455	9.8	8.16%
8048	3,698	8.2	3,703	8.1	0.14%
Others	23,143	51.4	23,020	50.6	(0.53%)
Total	45,038	100.0%	45,521	100.0%	1.07%

Source: Dataquest
April 1987

Table 7 shows market share by technology for 8-bit microcontroller and microprocessor devices from the third quarter of 1985 through the third quarter of 1986, and indicates slightly increased shipments of 8-bit CMOS microcontrollers.

During third quarter 1986, approximately 75.7 percent of all 8-bit CMOS MCU shipments and approximately 57 percent of all 8-bit CMOS MPU shipments were Japanese manufactured and shipped.

Table 7

MARKET SHARE BY TECHNOLOGY FOR MICROCONTROLLERS AND MICROPROCESSORS THIRD QUARTER 1985 THROUGH THIRD QUARTER 1986

Device	Tech.	Q3/85	Q4/85	Q1/86	Q2/86	Q3/86
8-Bit MCU	CMOS	20.4%	21.6%	21.5%	22.1%	21.6%
8-Bit MCU	NMOS	79.6	78.4	78.5	77.9	78.4
Total		100.0%	100.0%	100.0%	100.0%	100.0%
8-Bit MPU	CMOS	17.2%	19.3%	24.6%	23.1%	25.5%
8-Bit MPU	NMOS	82.8	80.7	75.4	76.9	74.5
Total		100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest
April 1987

DATAQUEST ANALYSIS

Dataquest estimates that revenue from microprocessor and microcontroller shipments for third quarter 1986 was $502 million, an increase of approximately 1.6 percent from the previous quarter.

Patricia Galligan

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a company of The Dun & Bradstreet Corporation

Research Newsletter

SIS Code: 1986-1987 Newsletters: April
1987-12

A WORLDWIDE IC PACKAGING UPDATE

OVERVIEW

The normal state of affairs in the semiconductor industry is to be in a "state of transition" or to have "reached a milestone." Or, something has occurred that will "revolutionize" the industry. Packaging of semiconductors is no exception.

Significant achievements in VLSI fabrication and design technologies have reached the point where concurrent improvements in die-level interconnection technologies are necessary for continued system performance. Of all the packaging and interconnection technology issues discussed, one issue readily agreed upon is that both users and suppliers of semiconductors are going through a demanding transitional phase of component packaging decisions--decisions that will have to be dealt with in the near future, as the industry approaches submicron geometries.

One very clear trend that we are seeing is that equipment manufacturers are using more and more VLSI devices. There is a sweeping desire to reduce space and cost through more condensed packaging and to automate as much as possible. To accomplish this, packaging technology must approach chip technology.

PACKAGE CONSUMPTION

Figure 1 shows the estimated worldwide integrated circuit (IC) package consumption for 1986. The estimates are based on Dataquest's worldwide IC consumption data and therefore show consumption by all packaged ICs. Japan captured 40 percent of packaged ICs in 1986, while U.S. market share dropped to approximately 33 percent and Europe came in at 17 percent. The remaining 10 percent not shown went to ROW.

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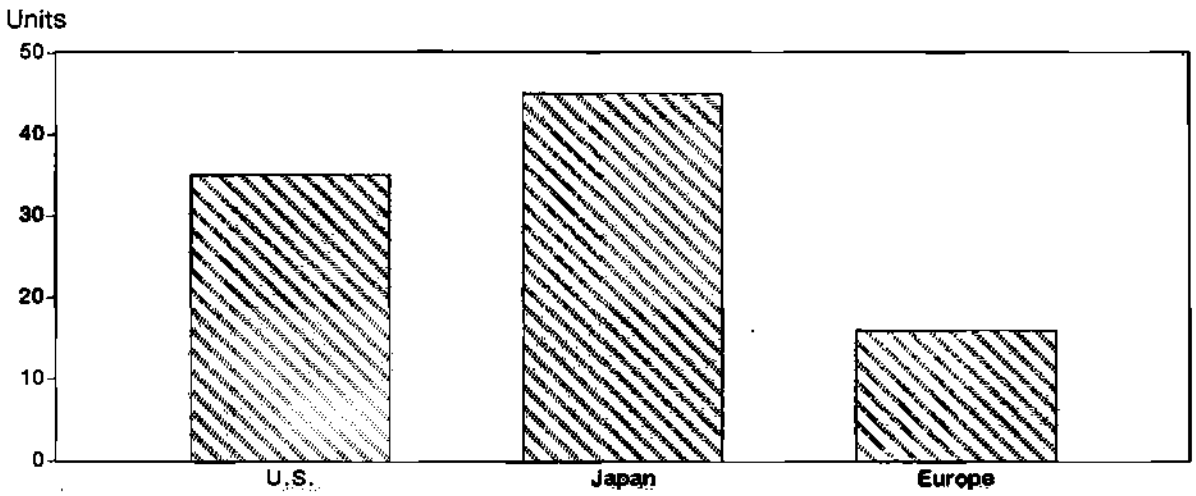
Figure 1

ESTIMATED 1986 WORLDWIDE PACKAGING TRENDS
(Units)



Source: Dataquest
April 1987

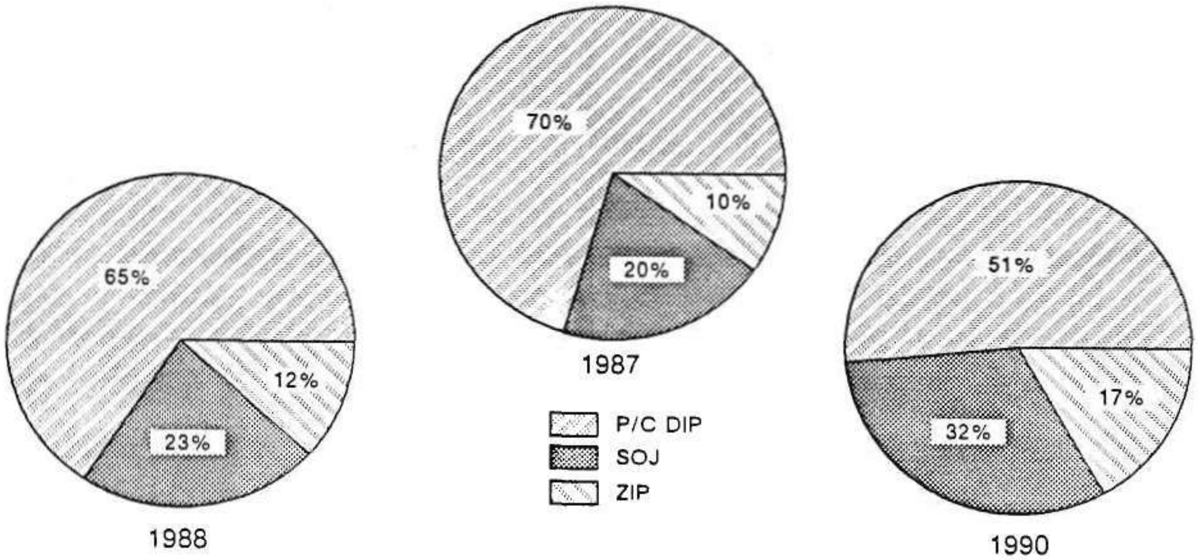
We expect that the Japanese will maintain their lead in the 1988 market using 44 percent of packaged ICs, with the United States holding approximately 38 percent, and Europe with 18 percent. By 1991, we anticipate that Japan will strengthen its lead to 45 percent, by virtue of its majority share of the consumer business, concerted efforts in the industrial sector, and its lead in automated assembly. At this point, U.S. market share will drop to 34 percent, and Europe's share will climb to 21 percent. While Europe is obviously not defeating its American and Asian competitors, we do expect it to modestly regain market share. At this time, we believe that European users are changing to surface-mount technology more readily than the American and Japanese users. Telecommunications and IC smart card applications, focusing on small-outline (SO) and tape-automated bonding (TAB) will provide Europe with the biggest growth opportunities for the next 10 years.

THE MEMORY ROLE

Over the last few years, memory devices have been on the leading edge of packaging technology due to density requirements. We have forecast that approximately 55 million 1 Mbit DRAMs will be shipped worldwide in 1987. As shown in Figure 2, 70 percent of those units will be shipped in either plastic or ceramic dual in-line packages (DIPs). By 1988, DIP package usage for DRAMs will shrink to 65 percent, while zig-zag in-line package (ZIP) and small-outline J-lead (SOJ) usage will grow. As we move into the 1990s, the SOJ package is expected to grow to 32 percent. High-density device architectures, led by smaller geometries and line widths, coupled with the desire to bring down costs while maintaining price competitiveness and building better and faster machines, will require the increased use of surface-mount technology (SMT).

Figure 2

ESTIMATED 1Mb DRAM PACKAGES



Source: Dataquest
April 1987

SMT ISSUES

Despite the many advantages, implementation of surface-mount (SM) packages into systems manufacturing is taking longer than anticipated. Surface-mount technology is still immature and as such the manufacturing infrastructure is not fully developed. Preferring the tested reliability of through-hole (TH) packages, users continue to mix SM/TH designs. Reliability of SM devices has not yet been proven and solder joint inspection is difficult. However, as shown on Table 1, concentrated use of SM devices is occurring in applications where small size and weight are the primary issues. As shown on Table 2, computers were the leading end-use segment for SMDs in the United States, in 1986. While cost reduction was the driving force, reliability continues to play a major role in acceptance of SMT. Europe led the United States in acceptance and usage of SMT in telecom applications; and by virtue of its command over the consumer market, Japan led the market with 10 percent of ICs packaged in SMT. As a comparison, Japan's Printed Circuit Association (JPCA) estimated that SM consumption in Japan reached 13 percent for ICs, and that over the next five years, ICs in SMT will grow to 33.9 percent in Japan.

Table 1

SURFACE-MOUNT TECHNOLOGY

Where?

- Consumer
- Automotive
- Disk storage
- Avionics, missiles, and space
- High-density memories
- Power supplies

Source: Dataquest
April 1987

Table 2

SURFACE-MOUNT TECHNOLOGY
END-USE SEGMENTS
1986

	Japan	Europe	United States
End Use	Consumer	Telecommunications	Computers
Driving Force	Small size	Reliability	Cost reduction/ reliability
Percent of ICs Consumed Worldwide	40%	17.7%	32.8%
Percent of ICs in SMT	10%	8.0%	4.0%
Dominant SMT Approach	TAB/QUAD/SO	SO	SO/CC/TAB

Source: Dataquest
April 1987

SUMMARY

At the present time, we believe that there is no single solution to future VLSI packaging problems. For the 1990s and beyond, we expect that package designs will continue to proliferate. Advanced multichip product designs will incorporate ASICs, use advanced circuit design techniques, and use advanced board assembly methods incorporating TAB and other multichip packages. While plastic packaging has its hermetic limitations, its high-volume, low-cost, high-performance, 40 pin-and-below characteristics will make it the dominant package by 1990.

Automated assembly will change the way that ICs and other components are packaged. TAB or some variation of this method of construction is the most likely packaging style for ICs in the 1990s. Chip-on-board (COB) has also made its way up the automated assembly ladder in consumer applications. From early single-chip digital watch applications, it is now being used in multichip applications such as copiers, facsimile, and IC cards.

REGIONAL ANALYSIS

If we use the premise that memory devices have been on the leading edge of packaging technology due to density requirements, then we can assume that Japan has a two-year lead on the industry and will gain overall leadership in packaging technology before the 1990s. With its vertically integrated structure, Japan can maintain closer technical and strategic cooperation among members of its packaging chain. Their command over the consumer market and surface-mount approach has given them a lead in packaging technology. There are already major efforts among equipment suppliers in Japan to develop automated assembly processes.

Despite major engineering efforts dedicated to designs, substrate and component materials, and assembly equipment, cooperation lags among members of the packaging chain in the United States. At times, cooperation seems better between U.S./Japanese partners than between U.S./U.S. alliances. The strong financial/technical megacorporate links of Japan are nonexistent in the United States. Outside of Texas Instruments and a few systems groups, everyone else has transported assembly offshore. Unlike Europe and Japan, there is very little academic research and cooperation. There is some hope in U.S. research consortiums, but cooperative efforts in packaging are weak. Finally, except for a few systems houses, the fear of capital investments in automated assembly technology has paralyzed many companies into making the decision to automate, a decision that could prevent them from staying on the competitive edge.

Mary A. Olsson

Dataquest
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Research Newsletter

SIS Code: 1986-1987 Newsletters: April
1987-14

BRINGING HOME THE BACON: NORTH AMERICAN FORECAST

SUMMARY

The semiconductor industry witnessed a promising surge in North American OEM bookings during the first quarter of 1987. Rising backlog and book/bill ratios above parity point to a strong first half 1987. Dataquest is raising the 1987 North American semiconductor consumption forecast to 15.1 percent growth.

The wary industry observer will note that while the first half of 1986 was also strong, the second half was flat, resulting in a disappointing annual consumption growth rate of only 6.2 percent in North America. Is there anything fundamentally different in 1987 suggesting better growth? Yes, there is. The underlying end-equipment industries are in better shape in 1987, especially the computer and communications industries that account for more than half of the North American semiconductor consumption. Analysis of historical trends shows that the rate of decline in the computer industry has been slowing since the last quarter of 1986. Inventory levels hit the bottom last December in both the computer and communications industries, and have now begun to rise.

North American semiconductor consumption grew only 6.2 percent in 1986, with the last quarter registering a 1.0 percent decline. We believe that the first quarter of 1987 turned out to be much better than what we expected, and that the bookings momentum and backlog should carry the industry through a strong second quarter. We anticipate slowing growth during the summer months and project the overall year to close 15.1 percent up, allowing the North American semiconductor vendors to bring home the bacon.

MONITORING OUR QUARTERLY INDUSTRY FORECASTS

Table 1 illustrates how we have been homing in on our quarterly forecast.

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Table 1

QUARTERLY INDUSTRY FORECAST: STAGGER CHART
NORTH AMERICAN SEMICONDUCTOR CONSUMPTION
(Millions of Dollars)

Forecast Date	Q1/86	Q2/86	Q3/86	Q4/86	Total 1986
June 1986	$2,315	$2,642	$2,687	$2,882	$10,570
Oct. 1986		$2,620	$2,641	$2,614	$10,219
Jan. 1987			$2,645	$2,650	$10,233
Apr. 1987				$2,621	$10,201

Forecast Date	Q1/87	Q2/87	Q3/87	Q4/86	1987
June 1986	$3,015	$3,234	$3,431	$3,664	$13,344
Oct. 1986	$2,562	$2,767	$2,969	$3,147	$11,445
Jan. 1987	$2,678	$2,845	$2,922	$3,087	$11,532
Apr. 1987	$2,732	$2,907	$2,982	$3,120	$11,741

Forecast Date	Q1/88	Q2/88	Q3/88	Q4/88	1988
June 1986					$16,574
Oct. 1986					$14,893
Jan. 1987	$3,265	$3,551	$3,666	$3,744	$14,226
Apr. 1987	$3,302	$3,578	$3,689	$3,757	$14,326

Source: Dataquest
April 1987

HISTORICAL TRENDS IN END EQUIPMENT

Dataquest's Semiconductor Applications and Markets (SAM) Service links semiconductor consumption to end-equipment production on an annual basis. For our quarterly industry forecast, we analyze the monthly data reported by the U.S. Department of Commerce to monitor the trends in bookings, shipments, and inventories in the computer and communications industries. While there are differences in industry and product definitions between the U.S. Department of Commerce data and Dataquest's data for end equipment, we believe that an aggregate level monthly trend analysis can provide useful insights into the industry dynamics.

The annualized growth rate, also known as "12/12," is an averaging mechanism that points out long-term trends, while smoothing out short-term and seasonal variations. 12/12 is simply the growth during the most recent 12-month period over a base period of the 12-month period immediately preceding the current period. Note that for the month of December, the annualized growth rate is identical to the calendar year growth rate.

Computer industry bookings and shipments declined at an increasing rate during 1986, with the annualized growth rate hitting rock bottom (negative 17 percent bookings, negative 13 percent shipments) during the fourth quarter. The rate of decline has been slowing since, and the trend suggests that the computer industry will register positive annualized growth by mid-year 1987. Average inventory levels fell to the lowest level of 8.8 weeks of average shipments in December 1986 from a peak of 14.5 weeks in March 1986 and are rising again.

The rate of growth in communications industry shipments and bookings followed a similar trend and bottomed out during 1986 (negative 3.0 percent bookings, 5.8 percent shipments), and the annualized growth rate in shipments should rise to 10.0 percent during the second half of 1987. Average inventory levels fell to the lowest level of 10.6 weeks of average shipments in December from a peak of 12.7 weeks last July, and are rising again.

According to SAM estimates, computer and data processing industry shipments will grow 10 percent in 1987, and communications industry shipments will grow 12 percent. This is consistent with the recovery trend that the U.S. Department of Commerce data suggests.

ASSUMPTIONS FOR THIS FORECAST

Book/Bill Stays above Parity

The book/bill ratio has been rising since October and should stay above or close to parity for the first half of 1987. This implies a healthy rise in backlog supporting shipments for the year.

Computer Industry Registers Positive Growth

Computer industry bookings and shipments bottomed in the fourth quarter of 1986. The rate of decline has been slowing since and the trend suggests that the computer industry will register positive growth by mid-year 1987.

Communications Industry Remains Healthy

Communications industry shipments bottomed in the fourth quarter of 1986, and the rising trend in shipments suggests growth topping 10 percent by late 1987, comparable to mid-1985 levels.

Other Economic Assumptions--1987

GNP is expected to grow about 3 percent in 1987, with about a 4 percent rise in the consumer price index; the interest rate will remain stable.

Capacity utilization should rise to 70 percent by year-end, with some product areas becoming capacity constrained.

THE FORECAST: MODERATE TURNING HEALTHY

Our quarterly forecast of North American semiconductor consumption for 1987 and 1988 is shown in Table 2.

Table 2
ESTIMATED NORTH AMERICAN SEMICONDUCTOR CONSUMPTION
(Millions of Dollars)

	1986	Q1/87	Q2/87	Q3/87	Q4/87	1987	% Chg. 1987
Total Semiconductor	$10,201	$2,732	$2,908	$2,982	$3,121	$11,743	15.1%
Total IC	$ 8,136	$2,200	$2,352	$2,418	$2,541	$ 9,511	16.9%
Bipolar Digital	$ 2,021	$ 498	$ 538	$ 561	$ 589	$ 2,186	8.2%
Memory	$ 335	$ 87	$ 94	$ 98	$ 103	$ 382	14.0%
Logic	$ 1,686	$ 411	$ 444	$ 463	$ 486	$ 1,804	7.0%
MOS Digital	$ 4,484	$1,289	$1,373	$1,402	$1,463	$ 5,527	23.3%
Memory	$ 1,560	$ 415	$ 440	$ 455	$ 475	$ 1,785	14.4%
Micro	$ 1,262	$ 362	$ 390	$ 395	$ 419	$ 1,566	24.1%
Logic	$ 1,662	$ 512	$ 543	$ 552	$ 569	$ 2,176	30.9%
Linear	$ 1,631	$ 413	$ 441	$ 455	$ 489	$ 1,798	10.2%
Discrete	$ 1,649	$ 426	$ 446	$ 452	$ 463	$ 1,787	8.4%
Optoelectronic	$ 416	$ 106	$ 110	$ 112	$ 117	$ 445	7.0%

	1986	Q1/87	Q2/87	Q3/87	Q4/87	1987	% Chg. 1987
Total Semiconductor	$11,743	$3,302	$3,578	$3,689	$3,757	$14,326	22.0%
Total IC	$ 9,511	$2,700	$2,947	$3,050	$3,125	$11,822	24.3%
Bipolar Digital	$ 2,186	$ 631	$ 690	$ 710	$ 716	$ 2,747	25.7%
Memory	$ 382	$ 107	$ 113	$ 116	$ 118	$ 454	18.8%
Logic	$ 1,804	$ 524	$ 577	$ 594	$ 598	$ 2,293	27.1%
MOS Digital	$ 5,527	$1,564	$1,728	$1,797	$1,861	$ 6,950	25.7%
Memory	$ 1,785	$ 497	$ 548	$ 575	$ 593	$ 2,213	24.0%
Micro	$ 1,566	$ 453	$ 501	$ 523	$ 541	$ 2,018	28.9%
Logic	$ 2,176	$ 614	$ 679	$ 699	$ 727	$ 2,719	25.0%
Linear	$ 1,798	$ 505	$ 529	$ 543	$ 548	$ 2,125	18.2%
Discrete	$ 1,787	$ 479	$ 501	$ 506	$ 498	$ 1,984	11.0%
Optoelectronic	$ 445	$ 123	$ 130	$ 133	$ 134	$ 520	16.9%

Source: Dataquest
April 1987

LONG-TERM OUTLOOK

We project a healthy 22.0 percent rebound in North American semiconductor consumption in 1988. This rebound is contingent on sustained growth in the North American computer and communications industries during 1988. We anticipate a flattening or a slight decline in 1989, corresponding to a general economic recession. This will be followed by double-digit growth rates in the years 1990 through 1992, rising to a peak 17.5 percent growth in 1992.

We expect MOS logic and microcomponents to remain steady high-growth areas, registering 15 percent to 20 percent long-term growth during the 1990 through 1992 period. MOS memories will grow at a slightly lower rate, followed by bipolar logic and linear product categories.

DATAQUEST ANALYSIS

Dataquest projects 15.1 percent growth in U.S. semiconductor consumption in 1987. We are off to a good start with a strong first quarter. The rising backlog and book/bill trend point to a strong first half. Projected recovery in the computer and communications industries should sustain semiconductor consumption through the rest of 1987 and rebound in 1988.

Howard Z. Bogert
Joseph K. Borgia

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Electronic Whiteboard

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European Telecommunications

Gallium Arsenide

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Manufacturing Automation

Office Systems

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Home Markets for PCs in Europe

The IBM 3270 Market: 1986 and Beyond

Korean Semiconductor Industry Analysis

Diskettes—The Market and Its Requirements

Imaging Supplies Distribution Survey

Directory Products

I.C. Start-Ups—1987

SpecCheck—Competitive Copier Guide

SpecCheck—Competitive Electronic Typewriter Guide

SpecCheck—Competitive Electronic Whiteboard Guide

The DQ Monday Report

Future Products

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  Semiconductor Application Markets—Military

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- Focus Reports

  The IBM 3270 Market: 1987 and Beyond

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For further information about these products, please contact your Dataquest sales representative or the Direct Marketing Group at (408) 971-9661.

Dataquest

Conference Schedule

1987

Semiconductor Users/Semiconductor Application Markets	February 4–6	Saddlebrook Resort Tampa, Florida
Copying and Duplicating	February 23–25	San Diego Hilton Resort San Diego, California
Imaging Supplies	February 25–26	San Diego Hilton Resort San Diego, California
Electronic Printer	March 23–25	Silverado Country Club Napa, California
Imaging Supplies	March 25–26	Silverado Country Club Napa, California
Computer Storage	April 6–8	Red Lion Inn San Jose, California
Japanese Semiconductor	April 13–14	The Miyako Kyoto, Japan
Color Conference	April 24	Red Lion Inn San Jose, California
European Telecommunications	April 27–29	The Beach Plaza Hotel Monte Carlo, Monaco
CAD/CAM	May 14–15	Hyatt Regency Monterey Monterey, California
Graphics/Display Terminals	May 20–22	San Diego Hilton Resort San Diego, California
European Semiconductor	June 4–5	Palace Hotel Madrid, Spain
European Copying and Duplicating	June 25–26	The Ritz Hotel Lisbon, Portugal
Telecommunications	June 29–July 1	Silverado Country Club Napa, California
Financial Services	August 17–18	Silverado Country Club Napa, California
Western European Printer	September 9–11	Palace Hotel Madrid, Spain
Manufacturing Automation	September 14–15	San Diego Hilton Resort San Diego, California
Business/Office Systems and Software	September 21–22	Westford Regency Hotel Littleton, Massachusetts
Asian Peripherals and Office Equipment	October 5–8	Tokyo American Club Tokyo, Japan
Technical Computers	October 5–7	Hyatt Regency Monterey Monterey, California
Semiconductor	October 19–21	The Pointe Resort Phoenix, Arizona
Office Equipment Dealers	November 5–6	Hyatt Regency Monterey Monterey, California
Military IC	November 12	Hotel Meridien Newport Beach, California
Electronic Publishing	November 16–17	Stouffer Hotel Bedford, Massachusetts
Asian Information Systems	November 30–December 4	Tokyo, Japan
CAD/CAM Electronic Design Automation	December 10–11	Santa Clara Marriott Santa Clara, California

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Research Newsletter

SIS Code: 1986-1987 Newsletters: April
1987-13

256K DRAM PRODUCTION CUTBACKS ACCELERATE 1MB DESIGNS

OVERVIEW

A rush of events in the first quarter appear to be producing a 256K DRAM shortage. Early in the year, the U.S. Department of Commerce accused certain Japanese companies of violating the U.S.-Japanese semiconductor trade arrangement. As a penalty, sanctions will be imposed on a variety of Japanese products, unrelated to semiconductors, such as television sets, laser printers, and disk drives. Prior to the penalties, MITI announced 11 percent cuts in 256K DRAM production in the second quarter of 1987, beyond the estimated 23 percent cut in the first quarter.

As a result, reports of a drying gray market have been coming in. Lead times in the United States have stretched out from ex-stock to 6 to 8 weeks for the more generic, Japanese-made 256K DRAMs. Several new personal computers were announced by IBM, which has reportedly been ordering large volumes of 256K DRAMs for its new PC series. Devices in PLCC packages, or with 100 nanosecond access times or faster, currently have lead times of 12 weeks that are stretching out to 16 weeks.

ESTIMATING THE POTENTIAL DEGREE OF SHORTAGE

Japanese manufacturers accounted for 82 percent of total 256K DRAM factory shipments in 1986. If these manufacturers reduce their production levels to 118 million units in the second quarter, as reported, and keep it flat through the year, their share of worldwide production will be only 56 percent. However, 1987 is projected to be the highest unit demand year for 256K DRAMs, growing to 850 million units, as shown in Figure 1.

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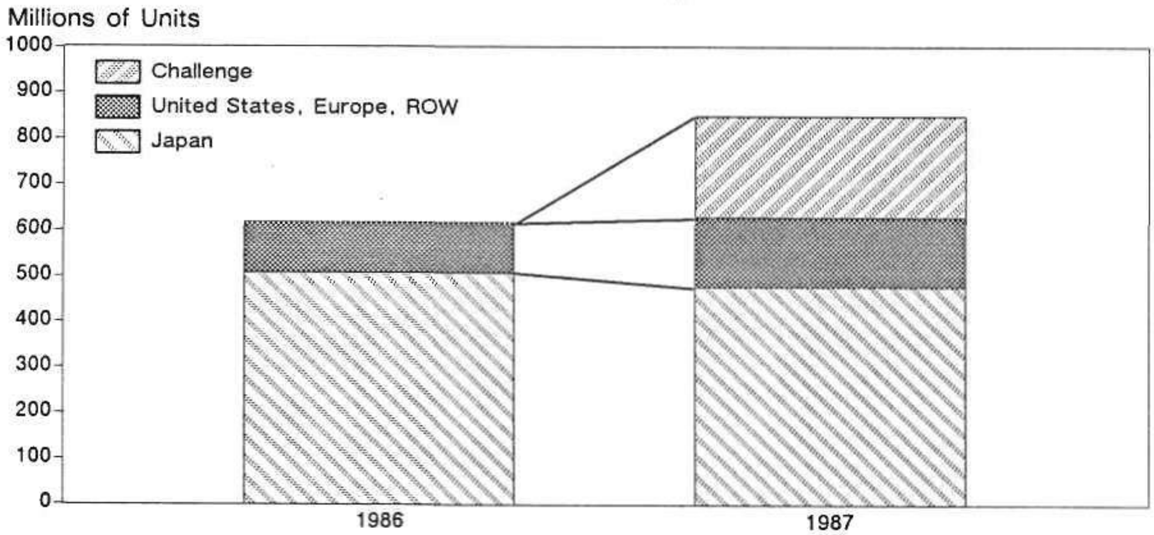
Figure 1

256K DRAM REGIONAL PRODUCTION
JAPAN VERSUS UNITED STATES, EUROPE, ROW



Source: Dataquest
April 1987

It is important to appreciate the magnitude of these production cuts. To meet the remaining 44 percent estimated demand in 1987, the combined production of U.S., Korean, and European firms must more than triple from 1986 rates. From these regions the high-volume producers are Texas Instruments, Samsung, and AT&T. It is not likely that they can produce to these levels by the end of the year. Given the production cutbacks and lack of non-Japanese capacity to fill the void, Dataquest estimates the year's shortage potential to be over 200 million units.

HOW LONG WILL THE SHORTAGE LAST?

Dataquest believes that extended lead times will be a fact of life at least through the third quarter. Bookings tend to grow as lead times increase. We estimate that it will take at least three months for Japanese companies to begin to return to increased production, if at all. The U.S., Korean, and European firms will face the same production lag. However, the high demand for high-speed or surface-mount DRAMs may remain high, keeping lead times of these parts extended through the year.

Another factor increasing the odds of a long-lasting shortage is that Japanese firms, and even some U.S. firms, may not be motivated to increase their production. The 256K DRAM cycle has matured and demand is expected to begin waning in 1988, with the price-per-bit crossover with the 1Mb DRAM estimated to be in the beginning of 1988. Many Japanese as well as U.S. firms may also want to encourage more 1Mb DRAM usage with the shortage and rising prices of 256K DRAMs.

Prices will certainly increase in this scenario. In fact, the high foreign market value prices in the United States will finally be validated, if not liked. The U.S. and Korean firms will likewise increase their prices with the shortage of parts and the lack of gray market competition. Dataquest estimates that average prices in the United States will increase to $2.35 by the middle of the year, from a first quarter average of $2.05. Prices in Europe and Asia are also expected to rise, alleviating the price pressures in those regions.

DATAQUEST ANALYSIS

It is still uncertain if Japanese companies will adhere to MITI's instructions. However, MITI's control of export licenses has been effectively used as a tool to convince them. If the companies comply, then the scenario mentioned above has a high likelihood of occurrence, which is even now obvious to Japanese manufacturers. The market will then accelerate 1Mb design-ins immediately and 1Mb purchases by the end of the year, to gain better availability and cost-effectiveness.

This situation points to the importance of long-term vendor-buyer relationships and of having a balanced supply of components from selected regions of the world. The DRAM buyer market that has been experienced for the last two years may be coming to a close. With supplies for this part tightening, communication lines between buyers and vendors must be finely tuned so that ship schedules do not become affected. The procurement systems set up over the past years will be put to the test for these parts. With supplies of the 1Mb DRAM increasing, the crossover to this part from the 256K DRAM may be accelerated, thus alleviating some of the pressure. It appears that one of the results of the semiconductor agreement is for supplies of parts to be controlled so that "fair prices" can be had by all.

Victor de Dios

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Research Bulletin

SIS Code: 1986-1987 Newsletters: April
1987-15

WORLDWIDE SEMICONDUCTOR INDUSTRY FORECAST

Dataquest projects worldwide semiconductor consumption to rise 18.2 percent in 1987 and 20.7 percent in 1988, measured in U.S. dollars. When comparing these growth rates with the 25 percent growth in 1986, one must bear in mind the effect of the rising yen in the valuation of 1986 consumption.

The most significant assumptions for this forecast are for a turnaround in the U.S. computer industry by midyear and for growth in semiconductor consumption picking up in Japan in the third quarter. The year 1988 is expected to be a "boomlet," followed by flattening in 1989. The regional breakdown of our long-term forecast is presented in Table 1.

Table 1

ESTIMATED WORLDWIDE SEMICONDUCTOR CONSUMPTION
(Billions of U.S. Dollars)

	1986	1987	1988	1989	1990	1991	1992
North America	$10.2	$11.7	$14.3	$14.3	$16.0	$18.3	$21.5
Japan	12.4	14.2	16.7	16.7	19.0	22.8	27.5
Europe	5.5	6.8	8.1	8.2	9.2	10.8	12.9
Rest of World	2.9	3.9	5.1	5.2	5.9	7.0	8.6
Worldwide Total	$31.0	$36.6	$44.2	$44.4	$50.1	$58.9	$70.5

Source: Dataquest
April 1987

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The estimated worldwide quarterly semiconductor consumption by product categories is shown in Table 2.

Note on Currency Exchange Rates: The yen exchange rates used in the valuation are 237 in 1985, 167 in 1986, and 154 in the first quarter of 1987. Similarly, the European basket exchange rates used in the valuation are 154 in 1985, 150 in 1986, and 131 in the first quarter of 1987. The shifts in currency exchange rates have a significant effect on the valuation of world consumption. Our quarterly forecast is based on constant exchange rates as of the first quarter. To account for currency movements since then, the dollar values may be ratioed appropriately.

Joseph Borgia

Table 2

ESTIMATED WORLDWIDE SEMICONDUCTOR CONSUMPTION
(Millions of U.S. Dollars)

	1986	Q1/87	Q2/87	Q3/87	Q4/87	1987	% Chg. 1987
Total Semiconductor	31009	8595	8982	9369	9722	36667	18.2%
Total IC	23601	6615	6954	7291	7590	28449	20.5%
Bipolar Digital	4321	1163	1225	1269	1307	4963	14.9%
Memory	675	182	194	202	206	783	16.1%
Logic	3646	981	1031	1067	1101	4180	14.6%
MOS Digital	13064	3844	4060	4293	4490	16687	27.7%
Memory	4338	1266	1326	1415	1484	5491	26.6%
Micro	3661	1052	1124	1197	1264	4637	26.7%
Logic	5065	1526	1610	1681	1742	6559	29.5%
Linear	6216	1608	1669	1729	1793	6799	9.4%
Discrete	5818	1565	1602	1636	1671	6474	11.3%
Optoelectronic	1590	415	426	442	461	1744	9.7%

	1987	Q1/88	Q2/88	Q3/88	Q4/88	1988	% Chg. 1988
Total Semiconductor	36667	10198	10866	11404	11794	44261	20.7%
Total IC	28449	7999	8566	9018	9366	34948	22.8%
Bipolar Digital	4963	1375	1490	1562	1616	6042	21.7%
Memory	783	212	225	232	237	905	15.6%
Logic	4180	1163	1265	1330	1379	5137	22.9%
MOS Digital	16687	4795	5176	5496	5749	21216	27.1%
Memory	5491	1593	1738	1863	1948	7142	30.1%
Micro	4637	1345	1433	1516	1576	5870	26.6%
Logic	6559	1857	2005	2117	2225	8204	25.1%
Linear	6799	1829	1900	1960	2001	7690	13.1%
Discrete	6474	1717	1792	1854	1888	7251	12.0%
Optoelectronic	1744	482	508	532	540	2062	18.2%

Source: Dataquest
April 1987

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Research Newsletter

SIS Code: 1986-1987 Newsletters: April
1987-16

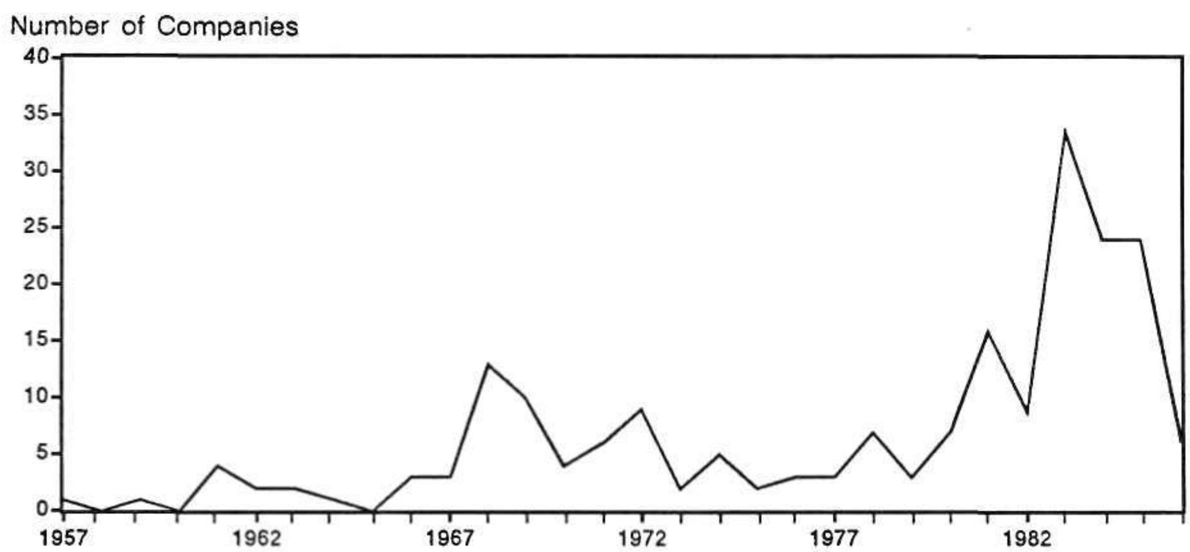
START-UP COMPANIES EXPANDING

This newsletter is the first in a series of quarterly updates on recent activities of start-up semiconductor companies. This information supplements I.C. Start-Ups 1987, a new Dataquest directory of semiconductor start-ups, which was published in October 1986. The newsletters will include information on new companies formed, initial and additional rounds of financing, significant company announcements, and new alliances.

Figure 1 illustrates the activity in company formation between 1957 and 1986.

Figure 1

FORMATION OF COMPANIES
1957-1986



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MAJOR DEVELOPMENTS

Start-up activity continues at a strong pace. Seven companies, formed in 1986, have emerged. Dataquest expects the number to grow as companies raise initial financing and complete their initial product offerings.

We have noted also that many of the start-ups are experiencing extraordinary growth. In 1986, Cypress Semiconductor approximately tripled its sales from $18 million in 1985; Samsung and UMC doubled their sales from $95 million and $33 million, respectively, in 1985. Many other companies increased revenue by 25, 30, or 50 percent.

Major developments for start-up companies include the following:

- Start-up companies have attracted $73.6 million in additional financing since the publishing of I.C. Start-Ups 1987 in October 1986.
- VLSI Technology acquired Visic, Inc.; Custom MOS Arrays and its sister company, California Micro Devices, merged activities.
- Start-ups have expanded with the formation of subsidiaries in Asia and additional manufacturing facilities in the United States and Europe.
- Several start-ups have also announced reorganizations and changes of presidents and CEOs, indicating business expansion.
- Many new alliances have been formed, involving a total of 33 companies.

Table 1 lists the semiconductor companies formed in 1985 and 1986.

Table 1

START-UP COMPANIES

Companies Formed in 1986

Company	Location	Product
Gazelle Microcircuits	Sunnyvale, CA	GaAs digital
Graphics Communications	Japan	Graphics chips
Innovative Silicon Technology	Italy	ASICs
MemTech	Folsom, CA	Bubble memory
Solid State Technologies	San Jose, CA	Bipolar memory
Taiwan Semiconductor Mfg. Corp.	Taiwan	Foundry
Telcom Devices	Newbury Park, CA	GaAs opto

(Continued)

Table 1 (Continued)

START-UP COMPANIES

Companies Formed in 1985

Company	Location	Product
ABM Semiconductor, Inc.	San Jose, CA	AlGaAs Opto
ACTEL Corporation	Sunnyvale, CA	ASICs
Acumos, Inc.	San Jose, CA	CMOS ASICs
Advanced Linear Devices	Sunnyvale, CA	Linear
American Information Technology	Cupertino, CA	MPUs
Anadigics, Inc.	Warren, NJ	GAas A/D converters
BT&D Technologies, Inc.	United Kingdom	Optoelectronics
Catalyst Semiconductor	Santa Clara, CA	Memory
Chips & Technologies	Milpitas, CA	Micros
Dolphin Integration	Europe	ASICs
European Silicon Structures	West Germany	ASICs
GAIN Electronics	Somerville, NJ	GaAs
Hittite Microwave Corp.	Massachusetts	GaAs
Intercept Microelectronics	San Jose, CA	ASICs
Level One Communications	Folsom, CA	Linear
Orbit Semiconductor	Sunnyvale, CA	Foundry
Sahni Corporation	Sunnyvale, CA	Closed (1986)
Saratoga Semiconductor	Cupertino, CA	Memory
Spectrum Semiconductor	Canada	ASICs
III-V Semiconductor	Arizona	GaAs
Tachonics Corporation	Bethpage, NY	GaAs
Topaz Semiconductor	San Jose, CA	DMOS ICs
Triad Semiconductor Intl.	Colorado	Memory
Wolfson Microelectronics	United Kingdom	ASICs

Source: Dataquest
April 1987

NEW COMPANIES

American Information Technology

American Information Technology (AIT), a start-up company in Cupertino, California, was formed in 1985. AIT has recently raised additional financing, is in its development stage, and will be releasing information on its activities later this year.

Gazelle Microcircuits, Inc.

Gazelle was founded in the summer of 1986 by ex-GigaBit Logic executives Andy Graham and David McMillan. In January 1987, Jerry Crowley, vice chairman and founder of Oki Semiconductor, left Oki to head the start-up. Gazelle is located in Sunnyvale, California, and was recently financed by Hambrecht & Quist and Kleiner, Perkins, Caufield & Byers. The company also has floated 900,000 shares of preferred stock at $1 a share and currently is putting together another round of financing. Gazelle will concentrate on very high speed digital ICs for military, telecommunications, and EDP applications.

Graphics Communications Technology

Ascii Inc., a Japanese software house, established a graphics start-up called Graphics Communications. Graphics Communications will be 70 percent financed by the joint MITI/MPT (Ministry of Posts & Telecommunications) Key Technology Research Promotion Center and 30 percent by 11 companies, including Iwasaki Communications, Mitsui Corporation, and Okura Electric. Ascii will maintain a 5 percent share in the venture, which will be headed by Ascii vice president, Kazuhiko Nishi.

Innovative Silicon Technology

Innovative Silicon Technology (IST) is a spin-off of SGS that was formed in May 1986 and is headed by Piero Martinotti and others from Motorola. SGS transferred the assets of its ASIC activities to IST, which will use a 1.5-micron, double-layer metal and direct-write on E-beam. It is providing gate arrays in one and one-half weeks and standard cells in two weeks. IST is planning a new R&D facility, fab, and operations, separate from SGS, that will be located northeast of Milan, Italy. Products are expected in 1987.

MemTech

MemTech was formed to acquire Intel's bubble memory operation. In February 1987, Intel signed the final purchase agreement covering the sale of Intel's magnetics operation to MemTech. The final sale terms provide for the transfer of Intel bubble memory manufacturing and test equipment, inventory, product designs, personnel, and manufacturing and quality specifications to MemTech for an undisclosed price. Operations will remain in Folsom, California.

MemTech is affiliated with Helix Systems & Development, Canoga Park, California, a bubble memory systems manufacturer. MemTech is headed by Richard H. Loeffler, formerly chairman and chief executive of Helix, and William H. Almond, the former head of Eaton's microlithography division. MemTech offers a complete bubble memory product line that includes 1- and 4-megabit bubble memory components and support circuitry, bubble memory boards, subsystems, and a cassette product, all available in a variety of temperature ranges.

Solid State Technologies

Solid State Technologies is a 1986 start-up located in San Jose, California. The company was founded by George W. Brown, presently serving as president, and Marshall Wilder, vice president of operations, both from Advanced Micro Devices. Initially, Solid State Technologies plans to offer high-performance bipolar memory products. It is presently in its developmental stage and will be releasing more information in a few months.

Taiwan Semiconductor Manufacturing Corp.

Taiwan Semiconductor Manufacturing Corp. (TSMC) has been set up as a foundry operation that will produce a wide variety of ICs. Taiwan's Executive Yuan, or legislature, has earmarked monies from its Development Fund for a 48 percent stake in the new company. N.V. Philips will take a 27.5 percent share in the $150 million investment in TSMC.

Chips are now being produced at the company's initial fab, which is capable of producing 10,000 6-inch wafers per month. In the second phase, which will be completed in 1988, it will be able to produce 30,000 1.5-micron, 6-inch wafers per month.

Telcom Devices Corp.

Telcom Devices was formed in early 1986 to offer indium gallium arsenide (InGaAs) photodiodes and indium gallium phosphide (InGaP) light-emitting diodes. Telcom Devices is a subsidiary of Opto Diode Corp. (ODC) and is operating from ODC's facilities in Newbury Park, California. The two companies share clean room and manufacturing space. Larry Perillo, formerly with Rockwell, is director of optoelectronics materials. Telcom Devices started volume production of its first product in May 1986, an InGaAs PIN photodiode for fiber-optic applications.

FINANCING

Table 2 lists by company the funding raised in the fourth quarter of 1986 and the first quarter of 1987.

Table 2

ADDITIONAL START-UP FINANCING

Company	Date	Round	Amount	Sources
Anadigics Inc.	Nov. 1986	2	$10.0M	Century IV Fund; Englehard Corp.; Memorial Drive Fund; Metropolitan Life Insurance Co.
California Devices Inc.	Oct. 1986	3	$ 3.9M	Alan Patricof Assoc.; Partners; Brentwood Assoc.; Dougery, Jones & Wilder; Edelson Technology; Hook Partners; InnoVen Group; John Hancock Ventures; Lambda Fund; Merrill Lynch Venture; Oxford Partners; J.F. Shea & Co.; Xerox
Cirrus Logic Inc.	Nov. 1986	3	$ 4.5M	Brentwood Assoc.; Institutional Venture Partners; Kuwait & Middle East Financial; Nazem & Co.; New Enterprises Assoc.; NY Life Insurance; Robertson, Colman & Stephens; Technology Venture
Elantec Inc.	Dec. 1986	4	$ 7.8M	Harvard Mgmt.; Cypress Fund; Morgan-Holland; New England Capital; Riksa Trust; Sequoia Capital; St. James Venture Capital Fund; U.S. Venture Partners; CEI; and others
European Silicon Systems	Nov. 1986	Equity	$ 9.0M	Banque International a Luxembourg; European Investment Bank
Krysalis Corp.	Dec. 1986	1	$ 3.0M	Columbine; Crosspoint Venture Partners; Meadows Resources; OSCCO Ventures
Laserpath Corp.	Dec. 1986	2	$ 4.5M	Crosspoint Venture Partners; Emerging Growth Partners; GE Venture Capital; Wolfensen Assoc.

(Continued)

Table 2 (Continued)

ADDITIONAL START-UP FINANCING

Company	Date	Round	Amount	Sources
Performance Semiconductor Inc.	Nov. 1986	1	$10.0M	Advanced Technology Ventures; Albion Venture Fund; Asset Mgmt.; Brentwood Assoc.; DSV Partners; Harvard Mgmt.; IAI Venture Partners; North Star Ventures; Northwest Venture Capital; Reynolds Creek Ltd. Partnership; L.F. Rothschild, Unterberg Towbin; Taylor & Turner; U.S. Venture Partners; VenWest Partners
Seeq Technology Inc.	Oct. 1986	Private placement post IPO	$ 6.0M	Bridge Capital; GE Venture Capital; Hillman Ventures; John Hancock; Kleiner, Perkins, Caufield & Byers
Sensym Inc.	Aug. 1986	3	$ 1.5M	Becton & Dickinson
Vitesse Electronics Corp.	Feb. 1987	2	$10.0M	Sequoia Capital and others
Xilinx Inc.	Jan. 1987	3	$ 3.4M	Fleming Ventures Ltd.; Hambrecht & Quist; Kleiner, Perkins, Caufield & Byers; Interfirst Venture; Interwest Partners; Matrix Partners; Morgan Stanley; Rainier Venture Partners; Security Pacific Venture Capital; J. H. Whitney

Source: Dataquest
April 1987

COMPANY ANNOUNCEMENTS

Acrian Inc.

Acrian Inc. has named Gary Irvine president and chief operating officer. Jack Harris remains as chairman and chief executive. Mr. Irvine, formerly president of EH Electronics, will be responsible for new products and market expansion as well as possible acquisitions by the company.

Adaptec, Inc.

Adaptec announced plans to open a subsidiary in Singapore in the first quarter of 1987 to manufacture surface mount controllers. The new company, called Adaptec Manufacturing (Singapore) Private Ltd., plans to begin pilot production in April and full production in early summer.

Altera Corporation

Altera entered the military market with its EPLDs, offering the first products to meet Class B specifications of MIL-STD-883 Rev. C--the EP310 and EP1210.

California Devices Inc.

Douglas Ritchie has been elected chairman of the board of CDI in addition to his responsibilities as president and chief executive officer. Wilmer R. Bottoms, the former chairman, has been named vice chairman.

Custom MOS Arrays

Custom MOS Arrays has merged with California Micro Devices (CMD). CMD was incorporated in 1980 to acquire the assets of a thin-film company. No changes in personnel assignments are planned. Handel Jones, formerly president of Custom MOS Arrays, will be the president and chief operating officer of the new combined company.

Cypress Semiconductor Corporation

Cypress announced that it will file a registration statement with the SEC to offer 4,400,000 shares of common stock. The proceeds will be used as working capital and to increase its capital base.

Harris Microwave Semiconductor

Harris Microwave Semiconductor has transferred its CAE tools developed for CMOS digital ASICs in Melbourne, Florida, to its GaAs operation in Milpitas, California. The company has set up a commercial GaAs standard cell operation.

Integrated Device Technology Inc.

Leonard C. Perham, former vice president and general manager of IDT's SRAM Division, has assumed the duties of president and chief operating officer of Integrated Device Technology Inc. John Carey remains as chief executive officer and chairman of the board.

International Microelectronic Products Inc.

Barry Carrington, president, has been promoted to chief executive officer from chief operating officer. Mr. Carrington succeeds George W. Gray, who remains IMP's chairman.

Krysalis Corporation

Franc R.J. deWeeger has joined Krysalis as president and chief executive officer. Joseph T. Evans, who was a Krysalis cofounder and served as the company's president, now becomes vice president of research and engineering. Mr. deWeeger was previously at ASM International, where he served as president since 1984; he remains on the ASM America board of directors. Before that, he spent two years as president of Zilog, Inc.

Lattice Semiconductor Corporation

Lattice announced that Rahul Sud resigned as president and Jay McBride resigned as general manager. C. Norman Winningstad, chairman of the board, is acting CEO. Lattice also announced that Rahul Sud, Jay McBride, S. Robert Breitbarth, and Kishan C. Sud resigned from Lattice's board of directors.

Linear Technology Corporation

LTC has established a Japanese company to strengthen its services to its Japanese customers. The company is called Linear Technology K.K. and is wholly subscribed by the U.S. parent. Robert Swanson has been appointed president, and Atsushi Nakata has been appointed general manager.

LSI Logic Corporation

LSI Logic has reorganized into four strategic business units with separate profit and loss responsibilities. The four units and vice presidents heading them are: Components and Technology, Cy Hannon; Engineering Services, Ven Lee; Software and Computer Services, Jim Koford; and Military/Aerospace, Norm Chanoski. Each of the four vice presidents will report to George Wells; each unit will be supported by decentralized sales, marketing, purchasing, finance, and MIS staff.

LSI Logic also plans to offer part of its European affiliate, LSI Logic Europe, on London's second-tier Unlisted Securities Market (USM). More than 80 percent is owned by the parent company, with the remainder held by local private investors, insurance companies, and other financial interests. The most visible industrial investor in LSI Logic Europe is Sulzer Brothers AG, a Swiss engineering firm.

In West Germany, LSI Logic Europe is building a mass production assembly and test facility in Braunschweig, which will form part of the corporation's worldwide capacity. It should be operational later this year, acting as a subcontractor to the U.S. parent company.

Micron Technology, Inc.

Micron has placed approximately 3,500,000 shares of common stock with certain foreign institutional investors at a price of $4.375 per share in a private placement assisted by Montgomery Securities.

Samsung Semiconductor Inc.

Samsung announced that it is building a new facility in San Jose, California, which will house its headquarters, R&D operations, and research fab. Included in the new 80,000-square-foot facility will be a 12,000-square-foot fab equipped with 6-inch wafer processing equipment.

Seeq Technology Inc.

Monolithic Memories Inc. purchased a 16 percent equity in Seeq Technology for $4 million. The two companies also have agreed to a four-year joint product and technology program to develop CMOS PLDs. Seeq received MIL-STD-883 Rev. C Class B specifications for its products.

Sierra Semiconductor Corporation

Sierra Semiconductor announced Stephen Forte as president of its new European joint venture, Sierra Semiconductor B.V., formed in June 1986 in the Netherlands.

Silicon Systems Inc.

Stephen E. Cooper, formerly senior vice president and general manager of the Microperipheral Division of Silicon Systems, succeeds Carmelo J. Santoro as president and chief operating officer. Mr. Santoro remains as chairman and chief executive officer.

Telmos Inc., Universal Semiconductor Inc., and Zytrex

Investment Management International Inc. (IMI), the finance group that acquired Zytrex last spring, has acquired Universal Semiconductor and the assets and product rights of Telmos Inc.

Vitesse Electronics Corp.

The Vitesse Electronics' Integrated Circuit Division raised $10 million and is now an independent company, called Vitesse Semiconductor Corporation. Dr. Louis R. Tomasetta, former president of the IC Division, is president and CEO of the new company. Vitesse Semiconductor will remain in the 70,000-square-foot existing facility and will use the new funding to develop additional products and expand into higher-volume production.

VLSI Technology, Inc.

VLSI Technology's Government Products Division in Phoenix, Arizona, has been certified for production of devices that are fully compliant with MIL-STD-883C.

VLSI Technology completed the acquisition of Visic, Inc. Visic will maintain its own board of directors, which will include members of both Visic and VLSI Technology. Products designed and developed by Visic will be manufactured in the VLSI Technology facility and marketed under the VLSI name.

VLSI Technology's ASIC operation is now a separate division, joining the memory, logic, and government divisions. Former vice president of design and technology, Douglas G. Fairbairn, has been promoted to the new position of vice president and general manager of the new ASIC Division. He will continue to report to both chairman Alex Stein and president Henri Jarrat.

Xicor, Inc.

Xicor announced that it has completed MIL-STD-883C Class B qualification for its X28256 EEPROM device. This qualification affects all versions of the X28256 in the 32-pad leadless chip carriers.

Table 3 lists some recent alliances involving start-up companies.

Michael Boss
Penny Sur

Table 3

ALLIANCES INVOLVING START-UP COMPANIES

Company	Date	Comments
Altera WaferScale Sharp	Jan. 1987	Altera and WSI agreed to a 5-year technology exchange to develop new user-configurable logic products; Sharp will manufacture the products using WSI's process.
Chips Ascii Corp.	Sept. 1986	Chips & Technologies and Ascii, a major software company in Japan, will start a new company to develop communication products. Chips will design the products; manufacturing will be done by companies in Japan. Chips and Ascii will hold equal shares of the majority interest in the new venture.
Chips NSC	Nov. 1986	National Semiconductor will second source Chips & Technologies CMOS ICs in exchange for fabrication services. National is Chips' first U.S. source.
Cirrus Logic Silicon Systems	Oct. 1986	Cirrus Logic and Silicon Systems will exchange controller and buffer manager functions and mutually second source the ASICs. Both chips will be processed in 2-micron CMOS.
Crystal Asahi Chemical	Jan. 1987	Asahi Chemical acquired an 8 percent share in Crystal Semiconductor for about $4 million. Asahi will provide foundry services in exchange for a license to all of Crystal's existing products and to be its principal distributor in the Far East. Both companies will develop new products.
Custom Silicon NCR	Feb. 1987	NCR has licensed CSi's standard cell library, including 342 TTL macrocells and microcomputer building blocks of up to 5,863 gates. CSi's library was built from NCR's existing library, which CSi licensed.
ES2 N.V. Philips TI	Feb. 1987	Texas Instruments Ltd. of England and Philips International N.V. will offer accelerated prototyping for the SystemCell Library of standard cells in cooperation with ES2. The SystemCell Library is the result of a collaborative relationship between TI and Philips who provide high volume manufacturing and standard prototyping.

(Continued)

Table 3 (Continued)

ALLIANCES INVOLVING START-UP COMPANIES

Company	Date	Comments
ICT Asahi Chemical	Jan. 1987	Asahi Chemical Industry will receive technology from ICT (International CMOS Technology) and will also market its EEPROMs.
IDT VTC, Inc.	Jan. 1987	VTC will second source Integrated Device Technology's FCT product line of TTL-compatible CMOS logic devices.
iLSi Sumitomo Corp.	Dec. 1986	Sumitomo licensed ASIC design technology from Integrated Logic Systems Inc. (iLSi); in addition to royalty payments, iLSi has gained rights to use any foundries Sumitomo uses.
IMP Micro Linear MBB	Aug. 1986	International Microelectronic Products and Micro Linear have agreed to transfer ASIC design know-how to Messerschmitt-Bolkow-Blohm GmbH over a three-year period.
Lattice SGS	Feb. 1987	Lattice Semiconductor signed a technology agreement with SGS Semiconductor, giving SGS a license to second source Lattice's GAL products. SGS will manufacture GAL products for Lattice, and both companies will cooperate on the design of future PLD products.
Seeq MMI	Nov. 1986	Monolithic Memories purchased a 16 percent equity in Seeq for $4 million. The companies also agreed to a 4-year joint product and technology program to develop CMOS PLDs.
Seeq Motorola	Dec. 1986	Seeq and Motorola agreed to work on a multimillion-dollar EEPROM technology project.
XTAR Fairchild	Sept. 1986	Fairchild agreed to second source XTAR's 2-chip set graphic MPU.

Source: Dataquest
April 1987

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Research Bulletin

SIS Code: 1986-1987 Newsletters: April 1987-17

IBM'S PERSONAL SYSTEM/2: DOORS ARE STILL OPEN FOR DRAM MERCHANT VENDORS

The introduction of the IBM Personal System/2 line of personal computers is certainly welcome news to semiconductor MOS memory manufacturers. However, the closeness of this announcement to press exposure on IBM's 4Mb DRAM has led to speculation that IBM intends to use only its internally produced DRAMs in the new computers. This newsletter addresses that issue.

PERSONAL SYSTEM/2 ON-BOARD DRAM REQUIREMENTS

At first glance, the speculation seems well founded. There are two single in-line modules (SIMs) attached to the motherboard through two 30-pin connectors. Each SIM has a 512Kx9 organization and contains six DRAMs. Dataquest believes that four of the DRAMs are 1Mb devices with 256Kx4 organizations and that two of the DRAMs are 256K devices with 256Kx1 organizations. Despite the proliferation of surface-mount devices everywhere else in the system, the DRAMs are in pin-grid array (PGA) packages.

The standard SIMs in the market are in 256Kx9 or 1Mbx9 organizations and hold DRAMs in surface-mount packages--plastic-leaded chip carriers (PLCCs) for 256K DRAMs and small-outline J-lead (SOJ) for 1Mb DRAMs.

DATAQUEST ANALYSIS

Dataquest believes that IBM's on-board main memory approach does not exclude external DRAM vendors. The economics dictate that having multiple sources of DRAMs ensures more competitive pricing and uninterrupted supply. Competition with other vendors also fosters efficiency and technological excellence in IBM's semiconductor operations.

Technically, the 512Kx9 SIM does not pose any barriers to other merchant market vendors. The 30-pin connector is standard and can be used for 256Kx9 and 1Mbx9 modules available in the market.

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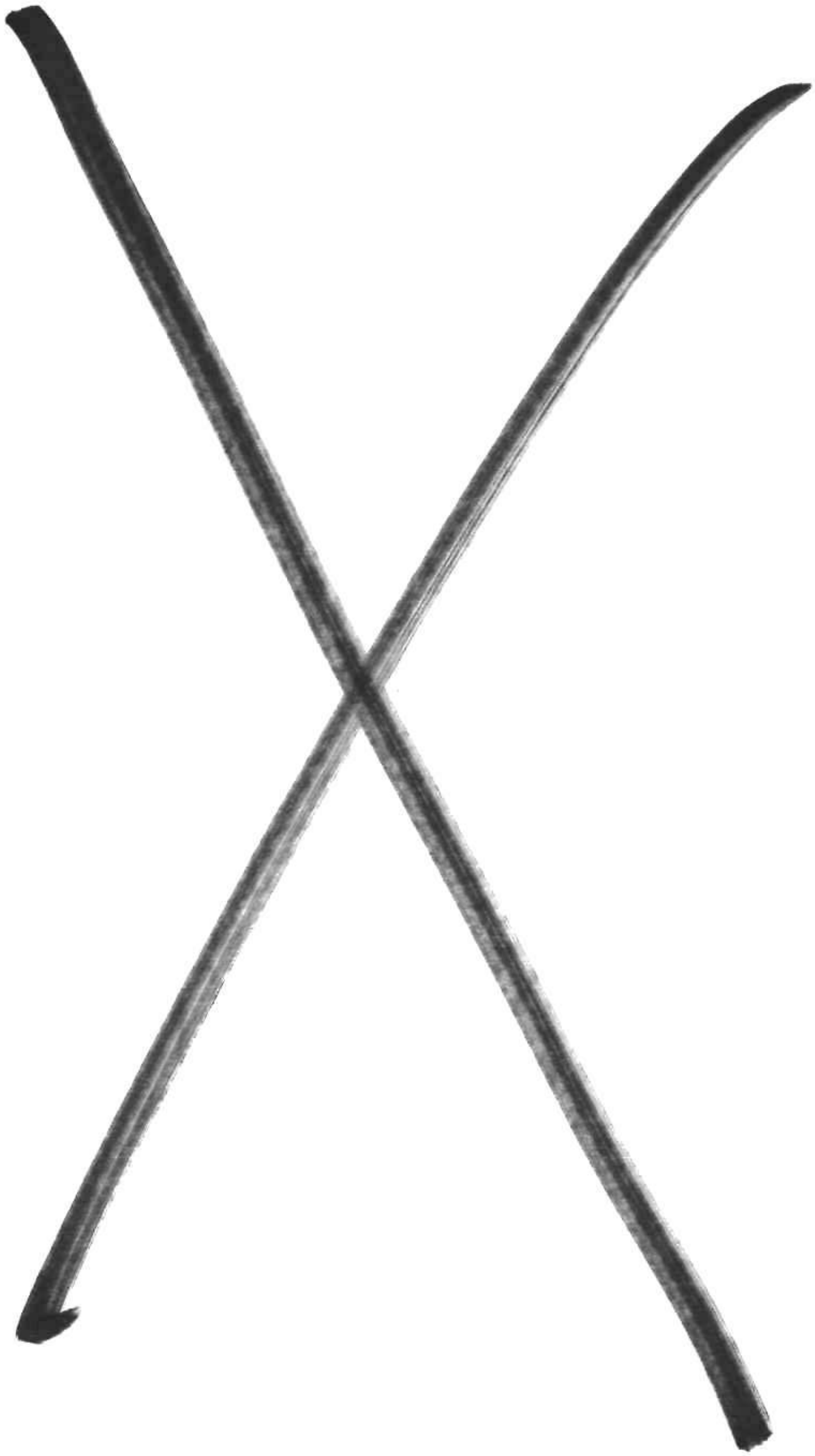
The SIM approach is not new. Many competing computer manufacturers use the same approach because of the inherent benefits: minimal board space use, ability to configure system memory in the late assembly stages, and field upgradability. Several vendors build SIMs, including Hitachi, NEC, Texas Instruments, and Toshiba.

The PGA package does not pose any barriers, since vendors can use surface-mount devices in their place. Dataquest believes that IBM has long been using PGA packages for other systems. It has become a fairly inexpensive package and its use in the new personal computer line leverages IBM's assembly capacity for this package. We believe that the use of surface-mount packages instead of PGAs would also be welcome by IBM.

SIMs using 256K DRAMs are experiencing long lead times because of the limited availability of PLCC packages and the turnaround time in mounting DRAMs on the SIM. At present, SIMs have lead times of as much as 12 weeks, which may extend to 16 weeks as 256K DRAMs become scarcer. The turnaround time for modules from Japan is averaging six to eight weeks. This situation may have contributed to IBM's decision to increase reliance on its internal operations.

Although the doors are open to other DRAM vendors, this SIM approach enhances the competitiveness of IBM's internal DRAM operations. IBM has been ahead in the development of 1Mb DRAMs and has now found an inexpensive approach to SIM production using a leveraged PGA package. Although IBM's sufficient capacity of PGA packages and 1Mb DRAMs could constrain the DRAM market, we do expect other DRAM merchant vendors to support IBM's new personal computer market.

Victor G. de Dios



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Research *Bulletin*

SIS Code: 1986-1987 Newsletters: May 1987-18

AMD AND MMI JOIN FORCES: LOOK OUT, PLD MARKET!

Jerry Sanders, chairman and CEO of Advanced Micro Devices (AMD) and Irwin Federman, president and CEO of Monolithic Memories (MMI), have announced an agreement in principle to merge their two companies. Under the agreement, MMI will convert each of its 21.8 million shares of outstanding common stock into 0.875 shares of AMD common stock. With the final transaction awaiting the approval of the shareholders of each company, as well as regulatory approvals, the merger would allow MMI to operate as a wholly owned subsidiary of AMD.

On the basis of worldwide market share, the merger leaves AMD still in 12th place ranking based on 1986 revenue. AMD's sales for the year were $629 million, whereas MMI's were $210 million. Combined, their $839 million in total semiconductor revenue places them right behind National Semiconductor's 1986 sales of $990 million.

The real story, in terms of market share clout, is the impact of the combined AMD/MMI on the worldwide supply of programmable logic devices (PLDs). The share of market that Fujitsu and Fairchild would have enjoyed in bipolar digital logic pales in comparison with the dominance that AMD and MMI will boast in PLDs. In 1986, MMI's PLD revenue was $140 million, while AMD's was $32 million. Their combined $172 million PLD revenue represents nearly 56 percent of the 1986 worldwide PLD market--which Dataquest believes will expand at a compound annual growth rate (CAGR) of nearly 23 percent between 1987 and 1992.

As a pioneer in bipolar PLD technology, MMI's trademarked PAL family of programmable logic devices has gained the company 51 percent of the worldwide bipolar PLD business. The future, however, belongs to CMOS. With an estimated CAGR of 48.4 percent between 1987 and 1992, the use of CMOS PLDs is growing steadily and will surpass the sales of bipolar PLDs by 1991.

Despite a recent alliance with Seeq Technology of San Jose, California, MMI has been late to establish itself in the CMOS market. MMI's CMOS PLD revenue in 1986 totaled $5 million, 15 percent of that market, giving it the second-place position behind start-up Altera Corp. During 1986, MMI strategically used legal recourse to set up barriers to CMOS PLD start-ups, suing both Lattice Semiconductor and Altera for infringing on its PAL architecture. Both cases have been settled out of court for undisclosed royalties.

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Aggressive protection of its patents may help maintain MMI's position as a market share leader in PLDs, but it does nothing to address the fact that innovations in programmable logic are emanating from sources other than MMI, a fact that must greatly concern MMI's management. MMI's brief foray into another avenue of the ASIC business, gate arrays, has proven unproductive. Barely six months after announcing its intention to enter the gate array business, MMI pulled the plug, explaining that "...the potential return does not match the business opportunities that exist in other areas, specifically field-programmable products."

In light of these concerns about MMI's future, the logic of its merger with AMD may at first seem bewildering. Although MMI ran behind the CMOS PLD leader in 1986, AMD wasn't even in the race. Nor does AMD figure in any aspect of the ASIC market except for its bipolar PLD line. With an estimated $100 million in the bank, MMI could surely underwrite its own entry into CMOS. Given its difficulties up to now, however, the merger with AMD is probably the more effective long-term alternative.

To begin with, the merger gives MMI a CMOS capability today. AMD's two wafer fabs in Austin, Texas, have a combined potential for more than 12,000 starts per week in 6-inch CMOS wafers. Fab 15 is capable of operation using 1.7-micron CMOS, whereas Fab 14 can work down to 1.2-micron geometries. MMI can now enter the CMOS PLD arena with substantial manufacturing potential, without draining its corporate war chest through a costly investment in facilities. Also, MMI could conceivably leverage some CMOS process expertise through its equity investments in both Seeq Technology and Cypress Semiconductor.

For AMD, the merger brings into the corporate fold a company whose 1986 revenue grew 22 percent over 1985 (AMD's grew only 2.3 percent), with $100 million cash on hand. In so doing, it places itself in the driver's seat of today's PLD market, with an excellent chance of maintaining a strong position in the CMOS era. There is also some synergy from the viewpoint of AMD's customers. AMD's popular bit-slice microprocessor, the AMD 2900, is frequently used with a sprinkling of MMI PALs surrounding it. The merger further combines AMD's strength in OEM sales with MMI's distribution-oriented sales force. AMD's alliance with Sony for joint development in next-generation IC products also fits well with MMI's strong performance in the Japanese market. MMI has just been granted registration rights for its PAL line by the Japanese patent office.

Quite often in analyzing a merger, there is a temptation to speculate that the weaknesses of one company drove it into the arms of a suitor. As Dataquest has pointed out many times, however, alliances and consolidations are going to be an inescapable part of the changing semiconductor industry landscape. In the AMD/MMI merger, we see two companies whose assessment of the industry environment has led them to the conclusion that they can better guarantee their future success in tandem rather than solo. AMD and MMI are not unique in this point of view--even as Jerry Sanders and Irwin Federman announced the union of their companies, two major European semiconductor manufacturers, SGS of Italy and Thomson of France, were making a similar announcement half a world away.

Michael J. Boss
Andrew M. Prophet

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Research Bulletin

SIS Code: 1986-1987 Newsletters: May
1986-19

NATIONAL AND LATTICE ANNOUNCE PLD AGREEMENT

In the wake of the merger between Advanced Micro Devices (AMD) and Monolithic Memories Inc. (MMI), the programmable logic device (PLD) market has yet another new force to contend with--an alliance between National Semiconductor and Lattice Semiconductor. As of early this afternoon (May 4), the two companies have announced the signing of a licensing, codevelopment, and manufacturing agreement for high-speed CMOS electrically erasable programmable logic devices, commonly referred to as E^2PLDs.

Under the terms of the agreement, National will have the right to manufacture and market Lattice's family of CMOS E^2PLDs, produced under the trademarked name of GAL (Generic Array Logic). The alliance combines National's substantial CMOS capability with Lattice's innovative field-programmable logic technology. National is also the world's third largest PLD supplier, with 1986 revenue of $33.5 million--approximately 11 percent of the total PLD market.

While the National/Lattice tie-up certainly does not have the same impact on today's PLD market as last week's announced merger between AMD and MMI, the potential of the alliance is clearly aimed at the future of PLDs: CMOS applications. With an estimated CAGR of 48.4 percent between 1987 and 1992, the use of CMOS PLDs is growing inexorably, and may surpass the sales of bipolar PLDs by 1991, as shown in Table 1.

The Lattice CMOS GAL devices are *pin-for-pin-compatible* with MMI's bipolar PAL (programmable array logic) family, which currently accounts for roughly half of the PLD market. This fact caused Lattice some grief when MMI sued the Beaverton, Oregon-based company along with another CMOS PLD supplier, Altera Corp., for infringement of MMI's patents on the PAL architecture. Both suits have since been settled out of court.

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Table 1

PRELIMINARY 1986
WORLDWIDE CONSUMPTION OF PROGRAMMABLE LOGIC DEVICES BY TECHNOLOGY
(Millions of Dollars)

	1985	1986	1987	1988	1989	1990	1991	1992
Total PLD	235.3	308.3	417.0	582.6	764.0	917.8	1,058.6	1,160.8
MOS (CMOS)	10.3	34.3	87.0	187.4	305.8	416.6	538.2	625.5
Bipolar	225.0	274.0	330.0	395.3	458.2	501.2	520.4	535.3

Source: Dataquest
May 1987

Dataquest believes that the market for CMOS PLDs will ultimately surpass the market for bipolar PLDs, as CMOS PLDs combine the inherent power-saving advantages of CMOS with speeds that compete favorably with bipolar. Lattice's niche in the CMOS PLD market is its E^2 technology, which, in addition to the above advantages of CMOS, also allows for greater ease of reprogramming than the more conventional EPROM approach based on ultraviolet-erasable cells. Dataquest also believes that, at just under a $15 million market in 1986, the reprogrammable segment of the PLD business will grow to $300 million by 1992--nearly 26 percent of the total PLD market, of which electrically erasable PLDs will be the technology of choice.

The alliance with National is a further indication of the improving health of Lattice, whose 1986 revenue totaled approximately $10 million. Less than six months ago, Lattice's future seemed very uncertain. With the MMI lawsuit hanging over its head, the company experienced difficulty in securing additional venture capital. Following the resignation of its founder and CEO, Rahul Sud, and its vice president of operations, funding once more materialized. Lattice has not yet appointed a new president.

Dataquest believes that, with the MMI lawsuit out of the way, Lattice will see an operating profit this year. In early March, Lattice signed a second-source agreement with SGS of Italy (who merged last week with Thomson of France), giving the GAL line entry into the European market. In addition to adding National as a second source, Lattice is currently receiving high-quality GAL devices through a foundry agreement with Seiko Epson of Japan.

Neither National Semiconductor nor AMD are strangers to the PLD market. Rather than join forces at this time with a PLD heavyweight, as did AMD in its merger with MMI, National has instead formed a link with a scrappy contender for the fast-growing CMOS segment of the market. In so doing, National gains an innovative E^2 technology. Lest the significance of National's intentions in the ASIC arena be misunderstood, keep in mind that at the Custom Integrated Circuit Conference (CICC) beginning today in Portland, Oregon, National is expected to deliver from five to seven papers--the most from any single company in attendance.

Michael J. Boss
Andrew M. Prophet

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Research *Bulletin*

SIS Code: 1986-1987 Newsletters
1987-23

HEWLETT-PACKARD BUILDS FOR WEITEK:
A NEW BUSINESS METHODOLOGY?

INTRODUCTION

Certainly the concept of partnership between suppliers and customers is not necessarily unique. However, an important trend may be surfacing as these relationships gravitate toward agreements of a somewhat different nature. A case in point is that of Weitek and Hewlett-Packard. Weitek has signed an agreement with HP to not only supply the Weitek 2264/65 math coprocessors for inclusion in specific HP system products, but also to obtain manufacturing capacity of packaged products. This research bulletin examines the implications of the agreement between HP and Weitek.

DATAQUEST ANALYSIS

Although strategic alliances are commonplace, this one between HP and Weitek is exceptional in that HP will, in effect, function as both customer and foundry to Weitek. Whereas Weitek has the design expertise, HP has its own manufacturing expertise, which is vital in scaling the devices over time and volume. In this situation, a healthy, established manufacturing line will greatly benefit both Weitek and HP. From a design standpoint, Weitek's current devices and knowledge of arithmetic processing will clearly benefit several of HP's existing product lines in addition to future designs. Additionally, future Weitek coprocessors could fit neatly into HP's ongoing systems work.

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Implications

The Weitek chips are targeted exactly at some of the applications HP is currently involved in. Dataquest believes, however, that HP might desire to enter other high-end computational market segments to further enhance its presence. Weitek, on the other hand, will certainly benefit from the expertise provided by HP in both manufacturing and applications feedback. As alliances go, this situation provides Weitek with a very effective way to stay on the leading edge of circuit design through design, evaluation, and test feedback from HP's experienced engineering staff. Additionally, the capacity of HP's 1.2 micron CMOS fab will assure Weitek of making its other commitments.

Every company has its key accounts, but a relationship of the type between HP and Weitek clearly reduces the risk factor in many ways. First, the customer is a large, established company that will probably not cease to exist as would a much smaller start-up. Secondly, when a company's customer is also its foundry, communications are greatly simplified as both parties have a mutual interest in success. This relationship then becomes much more of a marriage because so many activities are shared.

Does the agreement between HP and Weitek signify the beginning of a trend? Perhaps. Success in today's market is largely based on knowing what the other partner is doing in the supplier/customer relationship and keeping communication open and flexible. Other HP divisions may desire to establish similar alliances with suppliers if a technology trade is possible and something as valuable as production capacity can be offered in exchange for products. Moreover, as niche IC suppliers look for methods to expand and establish a long-term customer base, this type of alliance could be one of the best options available.

Brand A. Parks

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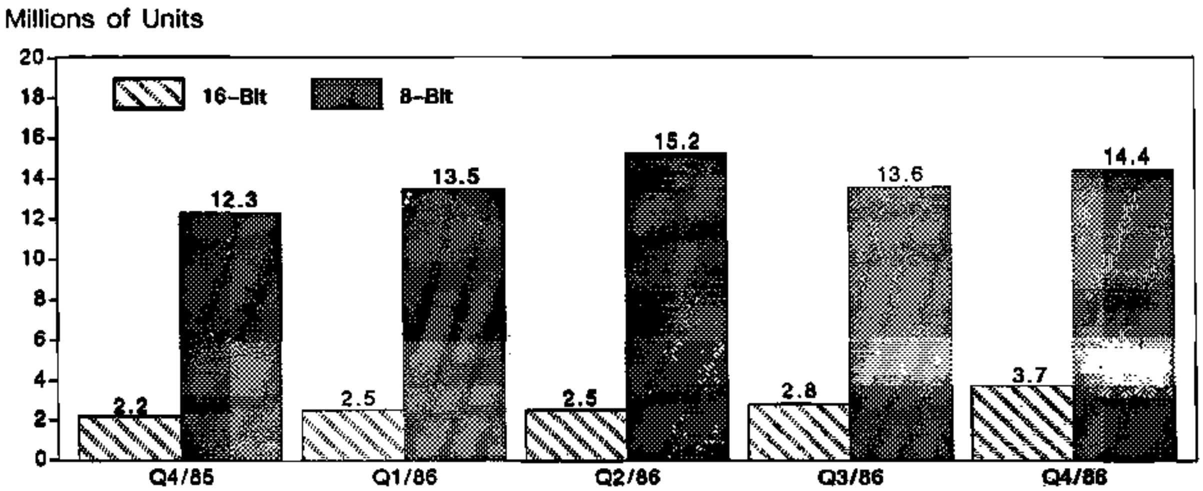
Figure 2

8- AND 16-BIT MICROPROCESSOR UNIT SHIPMENTS
FOURTH QUARTER 1985 THROUGH FOURTH QUARTER 1986
(Millions of Units)



Source: Dataquest
August 1987

Table 3 shows the change in shipments of the leading 8-bit MPUs from the third quarter of 1986 through the fourth quarter of 1986, and Table 4 shows the changes in estimated shipments of 16-bit microprocessors from the third quarter of 1986 through the fourth quarter of 1986.

Table 3

LEADING 8-BIT MICROPROCESSOR SHIPMENTS
THIRD QUARTER 1986 THROUGH FOURTH QUARTER 1986
(Thousands of Units)

	Q3/1986		Q4/1986		Percent
Device	Units	Percent of Shipments	Units	Percent of Shipments	Growth Q3 to Q4
Z80	5,411	39.7%	6,343	44.1%	17.2%
8085	2,290	16.8	2,103	14.6	(8.2%)
8088	1,530	11.2	1,502	10.5	(1.8%)
6802	910	6.7	954	6.6	4.8%
6809	796	5.8	759	5.3	(4.6%)
Others	2,091	19.8	2,724	18.9	1.2%
Total	13,628	100.0%	14,385	100.0%	5.6%

Source: Dataquest
August 1987

Table 4 shows the changes in estimated shipments of 16-bit microprocessors from the third quarter of 1986 through the fourth quarter of 1986.

Table 4

16-BIT MICROPROCESSOR SHIPMENTS
THIRD QUARTER 1986 THROUGH FOURTH QUARTER 1986
(Thousands of Units)

	Q3/1986		Q4/1986		Percent
Device	Units	Percent of Shipments	Units	Percent of Shipments	Growth Q3 to Q4
80286	590	21.2%	1,210	32.4%	105.1%
68000/10	751	26.9	736	19.7	(2.0%)
8086	625	22.4	673	18.0	7.7%
80186	425	15.2	556	14.9	30.8%
V30	170	6.1	240	6.4	41.2%
Z8000	101	3.6	135	3.6	33.7%
32016	77	2.8	91	2.4	18.2%
Others	50	1.8	92	2.5	84.0%
Total	2,789	100.0%	3,733	100.0%	33.8%

Source: Dataquest
August 1987

Table 5 shows the market share changes in 8- and 16-bit MPU shipments (not consumption) by geographical region from fourth quarter 1985 through fourth quarter 1986.

Table 5

MARKET SHARE BY REGION FOR 8- AND 16-BIT MICROPROCESSORS
FOURTH QUARTER 1985 THROUGH FOURTH QUARTER 1986

	Region	Q4/85	Q1/86	Q2/86	Q3/86	Q4/86
8-Bit MPUs	United States	37.3%	40.7%	51.5%	47.5%	48.8%
	Japan	55.0	41.0	38.1	43.5	40.9
	Europe	7.7	12.3	10.4	9.0	10.3
	Total	100.0%	100.0%	100.0%	100.0%	100.0%
16-Bit MPUs	United States	73.6%	64.5%	73.4%	73.1%	73.6%
	Japan	22.0	29.0	17.9	19.3	18.8
	Europe	4.4	6.5	8.7	7.5	7.6
	Total	100.0%	100.0%	100.0%	100.0%	100.0%

Source: Dataquest
August 1987

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Research Newsletter

SIS Code: 1987 Newsletters: August
1987-32

HOW IS 1987 SHAPING UP?
UPDATES FROM MOTOROLA, NATIONAL, INTEL, AND AMD

From July 29 through August 11, 1987, Motorola, National, Intel, and AMD have all held either financial analysts' meetings or shareholders' meetings. This newsletter provides a brief outline of the major topics addressed at those meetings.

MOTOROLA, INC.

Financial Summary

Jim Norling, executive vice president and general manager of Motorola's Semiconductor Products Sector, and Tommy George, senior vice president and assistant general manager, gave a joint presentation at Motorola's July 29 securities analysts' meeting. Net sales for the corporation were up 9.3 percent in the company's second quarter, which ended in June, over the same period a year ago, increasing from $1,499 million to $1,639 million. Semiconductor revenue, which is not broken out on a quarterly basis, increased 13 percent. Orders were up 19 percent and operating earnings were up in the second quarter over the same period a year ago. For the first half of 1987, the backlog was up 14 percent over last year. Because of Motorola's broad portfolio of products, the company believes that it has achieved a balanced performance over the past 12 months. Demand was quite good and the company performed well financially.

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Discussion

Motorola has deliberately moved to balance its product portfolio in order to avoid over-exposure in any one market segment. The emphasis is on keeping commitments to its customers to support Motorola's aim of being a preferred supplier. Some of the key points addressed by the speakers were:

- Market conditions were characterized as exhibiting strong demand with the exception of commodity military products for which demand was soft.

- Pricing for CMOS gate arrays and analog products is still under pressure.

- Motorola will resume fabrication of DRAMs in 1988, using one facility in the United States and one located in Europe.

- Although lead times are out somewhat, they are below 13 weeks and Motorola is managing the order entry process closely.

Microcomponents

The 68030, Motorola's next-generation 32-bit microprocessor, achieved first silicon in April, and initial deliveries, which are scheduled for the fourth quarter, are expected to be on target. The 68020 is gaining increased acceptance in the PC and multiuser environment where the traditional distinctions between PCs and workstations are dwindling. The issue of providing for MS-DOS capability has been addressed through a company called Insignia Solutions, which offers a software solution to emulate the 8088 on a 68020-based machine running a UNIX or derivative operating system. The DSP56000 is ramping up well.

ASICs

In July, the company announced its ECLiPS ECL logic family, which has package gate speeds of 300ps and internal gate speeds of 70ps. This family is targeting the next-generation computers, ATEs and superminis, among other applications. General sampling will occur this month. A number of new product announcements were made in the ASIC arena, including Motorola's new 10,000-gate ECL array and a new family of high-density CMOS arrays with up to 100,000 gates. Some BIMOS arrays will be released for customer options and the family will be extended to include arrays of up to 100,000 gates. The 6805 from Motorola's standard cell library has been well received and more analog capability, as well as low-density EEPROM, will be added by mid-1988. In 1988, the company also plans to:

- Offer its standard cell library to 1.5-micron geometries in CMOS

- Include a 16-bit microprocessor

- Offer BIMOS 1.5-micron capability

Outlook

Motorola is focusing strongly on improving its manufacturing competitiveness, which it views as strategically important to compete globally. It also has a major customer service initiative under way. It views its relationship with Toshiba as very important and proceeding well. The company is also engaged in a joint development program with IBM to supply the printed circuit board for the new broadband RF modem for PS/2 and earlier PC models. Motorola is developing ISDN components in conjunction with Northern Telecom.

The company expects to see the order rate continue along current levels. No major changes are anticipated and demand is expected to remain in line with consumption. Computer and consumer area bookings were up, demand from the automotive segment was up moderately, industrial applications were up slightly, and communications were slightly down. Distribution orders are up across the board, but military orders are soft.

Motorola has experienced higher orders internationally, particularly from the Pacific Rim countries, i.e., Japan and the Asia Pacific countries. It has witnessed strong microcontroller and microprocessor activity in Japan. For example, Canon has designed the 68HC11 and some custom discrete products into its camera line. Motorola's reception in Japan has been warmer although it remains to be seen how much of the quote activity will translate into orders. In general terms, the company's view of the world economic outlook is that the U.S. economy will remain positive but subdued, the economies of Western Europe and Japan will stay weak, and the Asia Pacific economy will continue with strong growth. Worldwide semiconductor growth is anticipated to be in the 14 to 17 percent range.

NATIONAL SEMICONDUCTOR

Financial Summary

At National's July 30 financial analysts' meeting, it reported that for the fiscal year 1987, which ended in May, net sales were $1,868 million, up 26.4 percent over the prior year. The company earned profits of $8.1 million for the fourth quarter, but recorded a net loss of $24.6 million for the year. Semiconductor sales were up 16.6 percent to $977.0 million. The Information Systems Group also experienced significant revenue growth, increasing 53.2 percent to $891.0 million with modest profit growth.

Discussion

Charlie Sporck, National Semiconductor's president and CEO, dealt with some of the issues that National sees and its strategy for the future. National does not focus on the market; instead, it is strategic and customer-driven. For this reason, quality is an important facet of National's approach and its current defect level is below 50 PPM. With companies everywhere reducing their vendor bases, a ship-to-stock strategy, which

National supports, is more cost-effective. Product development is too expensive to go it alone anymore so National has aligned itself with partners that have different areas of expertise. National's packaging standard is supported by Delco and Motorola. The following key points were made regarding the business climate:

- Mainframe computer group sales were particularly strong.
- National's Datachecker, which is based on the 32000 family, is making major inroads into the West European market.
- Shipments are not significantly impacted by the summer slowdown.
- Logic prices in Europe are very competitive although in most cases they have stabilized.

Components

National recently produced the first internal sample of its 32532 32-bit microprocessor. Although National has looked at the RISC architecture from a research perspective, it does not offer a product in this area. The company does not really participate in the PC market with its 32-bit microprocessor product offering. The company has recorded some significant design wins in the embedded controller area and reference was made to the recent Canon design-win in next-generation laser printers.

A significant element in National's return to profitability resulted from the fact that:

- In 1987, 78 new semiconductor products were introduced, 70 of which were proprietary.
- Of the top 25 revenue-producing products, 84 percent were proprietary.

Systems

National Advanced Systems (NAS) is laboring under considerable price pressure due to the IBM price cut. It is, however, expected that Hitachi, National's hardware supplier, will adjust its prices to compensate for the IBM announcement. NAS targets the mid- and large-size computer, board-level engineering, and scientific markets.

Outlook

National is experiencing increasing demand from international markets for system products. The company continues to be frustrated by the restrictive trading practices in Japan and sees a need for the matter to be addressed more forcibly. Based on the strength of its backlog for product, Mr. Sporck was optimistic about the future and said that this year's industry growth could come in at the 20 percent level. The company will make modest R&D investments in fiscal year 1988, primarily in the semiconductor area.

The Arlington, Texas, facility has facilities for three fabs. Currently, one 20,000-square foot module is operational and is focusing on gate arrays as a lead in to cell array technology. Because of the growing percentage of proprietary products in its portfolio, and because more than 50 percent of those products are sole-sourced, National's average selling prices (ASPs) are expected to increase.

INTEL CORPORATION

Financial Summary

At the Intel analysts' meeting convened on July 31, Bob Reed, Intel's CFO and vice president of finance stated that Intel has warrants under registration in order to generate cash in the third quarter of 1987. Intel had positive cash flow in the second quarter but it perceives a need to generate cash for its anticipated expansion in 1988, and believes that the time is ripe because of the positive economic conditions. Originally, Intel had put capital expenditure at between $200 million and $250 million for 1987, but it now looks more like between $275 million and $300 million, and more than $300 in 1988. Intel's immediate needs are for testers for the 80386, but both front and back-end operations will get an infusion of funds.

Discussion

Microcomponents

Larry Hootnick, senior vice president of sales and marketing, reported that the order momentum indicates a continued strong year ahead. Orders in the second quarter were strong, although the book-to-bill was lower than in the first quarter. The mix in the second quarter was good. However, this is based on what can be shipped, so that the book-to-bill would be higher if Intel were to book all orders regardless of its ability to meet the demand. Intel's major customers do not want long lead times--they want Intel to reserve capacity for their orders and meet its commitments, not have months of backlog.

- The average range for backlog is 2.8 to 3.5 months and lead times are stretching out, although none are greater than 6 months.
- MPU orders are very strong. The 80286 shows no signs of slipping or slowing down.
- It is expected that 1988 pricing for the 80286 will be the same as 1987 pricing.

- MCU bookings are strong and units are accelerating because PC demand is strong. Demand is broad-based in all areas, such as PCs and automobiles.

- EPROMs have been drifting upward in price, especially OEM prices, but this is a very competitive market.

There is rapid movement from 8-MHz 80286 parts to 10 and 12-MHz 80286 parts and to PLCC packaging. About 95 percent of 80286 shipments were at 8 MHz in 1986, and more than 50 percent will be at speeds greater than 8 MHz in 1987. The clone manufacturers are pushing to get to the higher speeds. Intel is capacity constrained for the faster parts and probably will not be able to supply full demand until some time during the first half of 1988. Intel cannot meet the demand for UV EPROMs and, therefore, as a service to its customers, it has subcontracted out production of this product to Mitsubishi. In the ASIC arena, Intel is playing catch-up. Its agreement with Texas Instruments is important to Intel's ASIC strategy, although no microprocessor cells have yet been traded.

Systems

Les Vadasz, senior vice president of Systems, presented a talk on the systems side of Intel's business, which provides the building blocks for microcomputer systems. Systems revenue is growing, although not at the same pace as that of components. This is a strategically important business and represents about $0.5 billion in revenue. The 3,000-member Systems Group is based in Portland, Oregon, with manufacturing facilities in Singapore, Puerto Rico, and Portland. Its business comprises development tools, the bus and board-level products, and networking, and is built on Intel's microprocessor foundation with technology and manufacturing capability, OEM, and retail channels to service its customers. The PC product line, which is called Above Board, is aimed at the problem of the system's memory limitations. Intel believes that it participates in 68 percent of the total board market, where Multibus I and PC bus are winners. Networking is increasingly important and Intel's solution is OpenNET. Through FASTPATH, the user in the LAN environment can be connected to an IBM S370 mainframe or to a computer from Digital Equipment Corporation. Currently, the systems business is in controllers and embedded and desktop applications, but Mr. Vadasz sees the systems business moving on to small computers, midsize systems, mainframes, and supercomputers.

Outlook

Intel expects to increase its output of the 80286 and the 80386 to meet demand by some time in the first half of 1988. The 80386 is currently manufactured in Livermore, California, and in Israel, and is expected to come on-line in Aloha, Oregon, later this year. Production in Fab 9, Rio Rancho, New Mexico, is expected to commence sometime around the second quarter of 1988. The PC market is booming and all other areas are doing well. Demand from North America has rebounded and seems to be coming from the PC, factory automation, and automotive sectors. Western Europe is experiencing the slowest growth, probably due to low participation in the PC market. Japan is showing strength for local PC consumption. The Asia Pacific area is a major region for PC manufacturing with many subcontractors and North American suppliers moving offshore, particularly to Taiwan and Korea.

ADVANCED MICRO DEVICES

Financial Summary

AMD held its annual shareholders' meeting on August 11. The major item on the agenda was ratification of the AMD/MMI merger, whereby MMI would become a wholly owned subsidiary of AMD. For the company's most recent quarter ending in June, AMD's first fiscal quarter for 1988, sales were $192.4 million, an increase of approximately 13 percent over the prior quarter. Profits for the quarter were recorded at just over $4 million, which compares favorably with the losses of $3.3 million for the previous quarter.

Discussion

AMD offers 41 products in CMOS. The company has achieved acceptable yields on some CMOS EPROMs. The Sony process initially will be installed in the Sunnyvale fab.

Microprocessors

The 29000 RISC microprocessor is aimed at workstation suppliers, but the larger piece of the target market will be embedded controllers. Other applications, such as laser printer engines, high-speed communications controllers, and desktop publishing, are expected to gravitate toward the 29000.

It looks like there has been excessive ordering from the PC market although tempering has already begun. AMD expects the 80286 to dominate this market for the next few years. Summer business was somewhat flat, but still large.

- First silicon on the 29000 has been achieved.

- No comment was made about the Intel/AMD suit except to say that AMD has been in compliance with the mutually entered upon agreement.

Merger

AMD's merger with Monolithic Memories, Inc. (MMI), was approved and will close within a few days. Some resulting accounting procedural charges may be put through in the third quarter. Although employee reductions are not planned, they may be a necessity in areas where duplication exists.

MMI is running close to capacity, and will take up some of AMD's unused capacity. This will allow the company to grow faster than the industry. Jerry Sanders, AMD's chairman and CEO, said that this combination will provide a major revenue-generating opportunity in bipolar PLAs.

Outlook

AMD's capital spending for 1988 was originally targeted at $130 million, but, given the new "brawny" AMD, Mr. Sanders could not comment on what the amount would be under the new structure. A major issue for the future is what effect the Intel lawsuit will have on AMD. AMD's arbitration proceedings against Intel are set for September 8. Intel's recently announced suit against AMD follows on the heels of the product announcements made on August 10 by AMD and Chips & Technologies, when AMD announced a 16-MHz 80286, and Chips & Technologies introduced a 16-MHz 80286 chip set. AMD has been a credible second source for the popular 80286 and wants to gain access to Intel's 80386, among other products. Intel, for its part, says that AMD has not complied with the original 1982 agreement and wants to revoke AMD's license for the 80286 and certain other devices. The implications for AMD are serious, but the matter was not dwelt on at the shareholders' meeting.

Patricia Galligan

Mark your calendars now!

Semiconductors' Midlife Crisis

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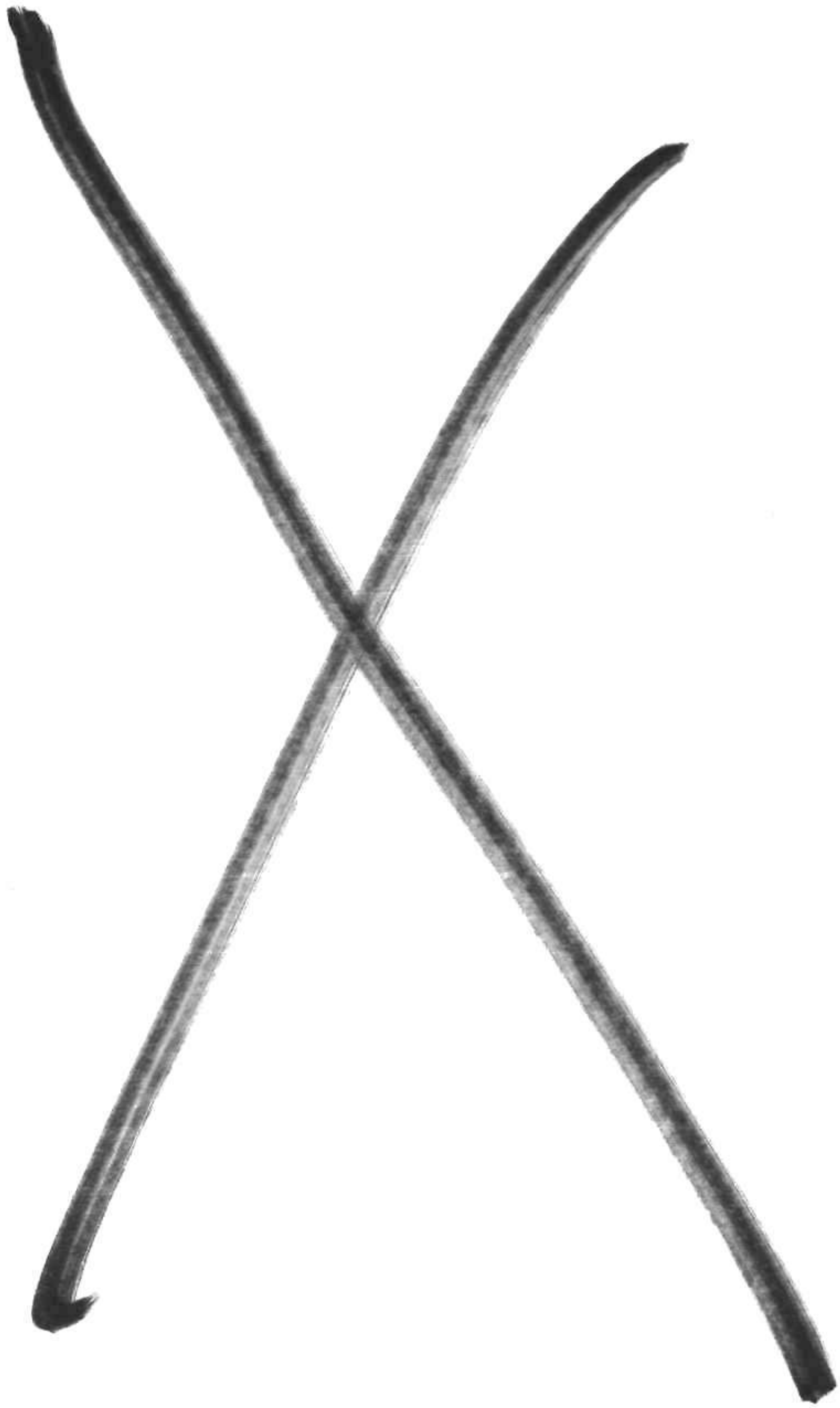
Conference Schedule

1987

Western European Printer	September 9–11	Palace Hotel Madrid, Spain
Computer Products	September 21–22	The Westford Regency Inn Westford, Massachusetts
Asian Information Systems	October 5–9	Tokyo American Club Tokyo, Japan
Technical Computers	October 5–7	Hyatt Regency Monterey Monterey, California
Semiconductor	October 19–21	The Pointe at Squaw Peak Phoenix, Arizona
Office Equipment Dealers	November 5–6	Hyatt Regency Monterey Monterey, California
Electronic Typewriter	November 6	Hyatt Regency Monterey Monterey, California
Electronic Publishing	November 16–17	Stouffer Hotel Bedford, Massachusetts
Asian Semiconductor and Electronics Technology	December 7	Asiaworld Hotel Taipei, Taiwan, ROC

1988

Semiconductor Users/ Semiconductor Application Markets	February 22–24	Westin St. Francis Hotel San Francisco, California
Copying and Duplicating	March 7–9	The Pointe at Squaw Peak Phoenix, Arizona
Imaging Supplies	March 9–10	The Pointe at Squaw Peak Phoenix, Arizona
Telecommunications	March 16–18	Pier 66 Hotel and Marina Fort Lauderdale, Florida
Electronic Printer	April 5–7	Hyatt Regency Monterey Monterey, California
Imaging Supplies	April 7–8	Hyatt Regency Monterey Monterey, California
Japanese Semiconductor	April 11–12	Tokyo, Japan
Computer Storage	April 18–20	Silverado Country Club Napa, California
European Semiconductor	June 8–10	Gleneagles Hotel Auchterarder, Scotland
Display Terminals/Graphics and Imaging	June 13–15	Hyatt Regency Monterey Monterey, California



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Research Newsletter

SIS Code: 1987 Newsletters: October
1987-39

HAPPY BIRTHDAY TRANSISTOR! HAPPY BIRTHDAY ASICS!

SUMMARY

This is a newsletter about history—an ASIC history. It is a chronology of a maturing industry, a story that is still unfolding, a story that invites your input. For, like all chronologies, it needs to be augmented as new facts emerge.

AN ASIC CHRONOLOGY

As we pause to reflect on the 40th birthday of the semiconductor at this year's Dataquest Semiconductor Industry Conference, we should reflect on the history of custom ICs as well. Our clients probably register no surprise when we say that the origins of the ASIC closely parallel the history of the semiconductor industry as a whole. As fledgling suppliers struggled to make standard products, they also saw the need for custom transistors. In 1958, a bright young Texas Instruments engineer, Jack Kilby, invented the first IC. It stands to reason that other venturesome souls would follow with the development of custom ICs. Although the early history of ASICs is yet to be uncovered, we believe that it will coincide with the overall growth of semiconductors.

We believe that our clients will find Table 1 an interesting reflection on ASIC chronology. It is a history filled with surprising developments that seemed to languish for years, in contrast with other developments that altered the course of the entire semiconductor industry immediately. Who would have thought that a set of 23 ASICs developed in 1964 would debut as the world's first all-electronic calculator, launching one of the largest consumer markets ever seen? Or that a custom 4-bit calculator chip designed by Intel would mark the origins of the microprocessor revolution? Or that despite recent press coverage, the true origins of gate arrays and cell-based ICs (CBICs) can be traced back as far as 1968?

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Table 1

ASIC Chronology

Year	Major Event	Company	Comments
1964	Full custom set of 23 chips developed for the first all-electronic calculator	General Micro Electronics (GME)	Metal gate PMOS technology
1965	Metal gate PMOS standard-cell library developed	GME	Library was developed under a contract to the U.S. government
1968	First commercialization of PMOS standard cells	American Micro Systems (AMI) (now called Gould Semiconductors), General Instrument, RCA	Library consisted of paste-up cells
1968	First bipolar gate arrays developed, called Micro Matrix	Fairchild, Honeywell	
1970	Custom shift register developed for a rotating-drum memory	AMI	66-bit shift register
1971	First MOS gate arrays announced	Fairchild	Developed for Philips of France as a 400-gate display data communication system
1972	First linear gate arrays developed	Ferranti, Interdesign	Called the Monochip series
1972	Custom 4-bit micro-processor architecture developed to compete in calculator market	Intel	Product emerges as the first commercial micro-processor, the 4004
1972	Single-chip calculator announced	Texas Instruments	Developed for Bowman Calculator (selling price $150.00)
1974	First scientific calculator appears	Hewlett-Packard	7-chip set called the first electronic slide rule

(Continued)

Table 1 (Continued)

ASIC Chronology

Year	Major Event	Company	Comments
1974	ASIC suppliers experience enormous boom as electronic calculators become common		
1974	One of earliest "commercial" CMOS gate arrays appears	International Micro-circuits (IMI)	IMI pioneers design and manufacture of gate arrays
1974	Fujitsu produces 100-gate ECL gate array	Fujitsu	First applications were in Fujitsu's computers
1974	First commercial PLD introduced	Intersil	Called Integrated Fuse Logic (IFL)
1975	Price of calculator drops sharply as first $10 machine appears		Believed that during this era, more than 10 percent of all IC consumption and more than 95 percent of MOS consumption is ASIC
1975	Signetics introduces an IFL	Signetics	Signetics grows to become a major PLD supplier
1976	Major recession in semiconductor industry; many companies exit market		Calculator suppliers also experience a major collapse
1976	Digital Equipment introduces minicomputer built with gate arrays	Digital Equipment	Texas Instruments, Signetics, and Digital act as the foundries--code name is COMET
1977	Fujitsu introduces 3,900-gate CMOS gate array	Fujitsu	First Japanese company to make a major commitment to gate arrays
1977	Fujitsu starts producing standard cells up to 10,000 gates	Fujitsu	

(Continued)

Table 1 (Continued)

ASIC Chronology

Year	Major Event	Company	Comments
1978	First start-up company to focus on gate arrays emerges	California Devices	A Silicon Valley-based design center
1978	First third-party design center using gate array emerges	Master Logic	
1978	First Programmable Array Logic (PAL) is introduced	Monolithic Memories (MMI)	MMI later becomes dominant PLD supplier
1979	VLSI Technology founded	VLSI Technology	
1979	Dataquest estimates ASIC worldwide consumption exceeds $1 billion	Dataquest	Roster of ASIC suppliers begins to expand rapidly
1981	NCR enters CBIC market	NCR	NCR decides to use its CBIC capability in merchant marketplace
1981	LSI Logic founded	LSI Logic	Original product was ECL gate array but later switched to CMOS
1981	Toshiba introduces gate array with 5,000 gates	Toshiba	CMOS--3-micron, 2-layer metal
1982	Apollo announces Domain family of CAD work-stations	Apollo Computer	Apollo sets new standard in workstation performance
1982	Toshiba announces GaAs gate array	Toshiba	
1982	The term ASIC introduced at the Dataquest conference	Dataquest	Term introduced in speech by Howard Bogert
1983	First sea-of-gates array announced	California Devices	The company uses CMOS silicon gate terminology

(Continued)

Table 1 (Continued)

ASIC Chronology

Year	Major Event	Company	Comments
1983	First commercial silicon compiler	VLSI Technology	
1983	CMOS becomes technology of choice for ASIC users	Dataquest	CMOS consumption surpasses bipolar
1983	AT&T Technologies announces CBIC merchant library	AT&T Technologies	The company takes its captive CBIC technology merchant
1983	AMD introduces PLD whose architecture sharply departs from PAL PLDs	AMD	22V10 is announced in late 1983 and later grows to be one of most popular PLDs
1983	Texas Instruments introduces 3-micron CBIC family	Texas Instruments	
1983	Number of ASIC suppliers continues to expand rapidly	Dataquest	By end of 1985, Dataquest identifies more than 100 ASIC companies
1984	First CMOS-UV PLD appears	Altera	Offers the ability to replace many PALs
1984	As lead time for standard logic stretches, many users shift to gate arrays		Lead times are short for gate arrays
1985	Gate array consumption surpasses $1 billion mark	Dataquest	ASIC market forecast to be 25 percent of all IC consumption by 1990
1985	First EECMOS PLDs introduced	Lattice Semiconductor	
1985	First RAM-based PLD introduced	Xilinx	

(Continued)

Table 1 (Continued)

ASIC Chronology

Year	Major Event	Company	Comments
1986	Term cell-based IC (CBIC) introduced	Dataquest	Dataquest introduces the term CBIC to encompass standard cells, block cells, and compliable cells
1986	Core Microprocessor becomes popular among CBIC suppliers	Dataquest	Core processors such as 2901, 65C02, and 80C51 become common in cell libraries
1986	First EE CBIC library	Sierra Semiconductor	
1986	Another major Japanese company announces CBIC product line	NEC	
1987	MITI requests Japanese suppliers to unbundle NRE and production	MITI	The request applies only to ASICs to be exported
1987	Two major PLD suppliers merge	AMD & MMI	Combined revenue after merger puts AMD over 50 percent of the total PLD consumption in 1986

Source: Dataquest
October 1987

INPUT IS INVITED

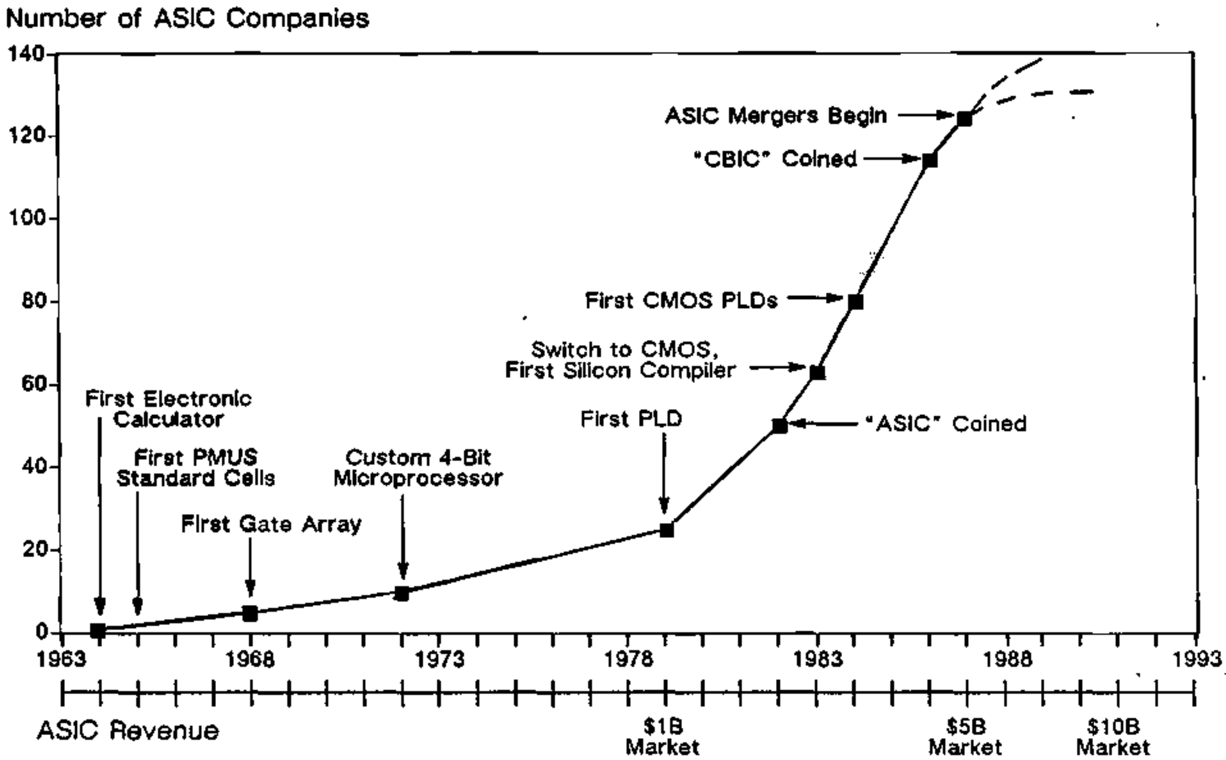
Chronologies are never complete, nor is the information in Table 1. Chronologies are living documents, constantly changing. What is shown here is a collection of important events as identified by key industry sources and Dataquest researchers. We invite all readers to contribute items from their own experience or knowledge of noteworthy milestones, along with comments, on the form provided at the end of this newsletter. Dataquest will continue to expand and amend the ASIC chronology.

IS THE ASIC INDUSTRY MATURING?

In some ways, the ASIC industry is maturing, and in others it is still growing. Buried in the Table 1 chronology is a dramatic expansion in the number of ASIC suppliers. Figure 1 shows that when the total market reached $1 billion in the late 1970s, this was a critical turning point. With the introduction of VLSI, the emergence of the microprocessor, and the ability to make complex logic, there was an explosion of CAD tools that in turn made gate arrays and CBIC cost effective. These CAD tools were far cheaper than anything that preceded. Low-cost CAD made it possible for a wider number of engineers to design with ASICs, which altered the ASIC market forever. This meant that the barriers to entry were lowered, and the industry experienced a sharp rise in suppliers due to market expansion as the figure shows.

Figure 1

Growth of ASIC Suppliers



Source: Dataquest October 1987

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However, in the last year we have noticed a slowing in the rate of new suppliers, especially in the most mature sectors of the gate array market. This phenomenon is also true for the bipolar PLD segment, where the number of suppliers has declined as a result of consolidation by the recent mergers of Fairchild with National and Monolithic Memories with Advanced Micro Devices. This consolidation suggests that some ASIC segments may be entering a maturing phase where the number of suppliers has stopped growing and may be declining. Other portions of the ASIC market are still growing. These exceptions are CMOS PLDs and CBICs. Another portion of the ASIC arena that is expected to grow is suppliers that concentrate on quick-turnaround chip designs (i.e., in less than two weeks). Certainly PLDs are uniquely suited to what Dataquest calls Quick-ASIC, but we continue to believe that semiconductor manufacturers and equipment suppliers will look for ways to shorten the development cycle.

In the final analysis, certain segments, such as gate arrays and bipolar PLDs, will enter a maturing phase, while CMOS PLDs and CBICs will experience rapid growth both in consumption and supplier base.

DATAQUEST SUMMARY

We hope that the valiant courage, the pioneering spirit, and even the highly visible failures will continue. These are what make our industry really grow. Let us hope that as ASIC matures, its joints do not stiffen and its brain does not thicken!

Andrew M. Prophet

Submit your historical ASIC event to Dataquest

Year: ____

Major event: ______________________________

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Company: ______________________________

Comments: ______________________________

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Research Newsletter

SIS Code: 1987 Newsletters: October
1987-41

WORLDWIDE SEMICONDUCTOR SHIPMENTS FORECAST

Dataquest projects the healthy growth in worldwide semiconductor shipments to continue into 1988. Worldwide semiconductor shipments are estimated to rise 23.9 percent in 1987 and 23.7 percent in 1988, measured in U.S. dollars. The long-term forecast (see Table 1) shows a mild recession in 1989 followed by the resumption of growth from 1990 through 1992.

Semiconductor shipments to North America showed surprising strength this year with a good first half and a better than expected summer quarter. Though the bookings momentum has slowed, a rising order backlog and book-to-bill ratio above parity point to a strong recovery. The North American semiconductor market is estimated to rise 21 percent in 1987 and 23 percent in 1988. Our optimism is based on the projected acceleration in U.S. computer and communications equipment production, with equipment growth topping 15 percent in 1988.

The Japanese forecast for 1987 is now a positive 1 percent measured in yen, recovering from a disastrous first quarter that registered a 7.1 percent decline. The Rest of World (ROW) region experienced phenomenal growth during the first half of 1987 and is projected to grow 68.2 percent this year and 41.4 percent in 1988. The ROW growth is attributed to the continued transfer of electronic equipment manufacturing to ROW by U.S. and Japanese companies and the development of local markets in the Asia-Pacific region. The ROW semiconductor market is projected to become 17 percent of the worldwide market by 1992, matching Europe.

The estimated worldwide quarterly semiconductor shipments by product categories are shown in Table 2.

Joseph Borgia

Table 1

Estimated Worldwide Semiconductor Shipments
(Billions of U.S. Dollars)

	1987	1988	1989	1990	1991	1992
North America	12.3	15.2	14.9	16.8	19.2	22.6
Japan	14.4	17.3	17.3	19.5	22.8	27.3
Europe	6.8	8.1	8.2	9.2	10.8	12.9
Rest of World	4.9	6.9	7.0	8.3	10.3	12.9
Worldwide	38.4	47.5	47.4	53.8	63.1	75.7

Source: Dataquest
October 1987

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Table 2

Estimated Worldwide Semiconductor Shipments
(Millions of U.S. Dollars)

	1986	Q1/87	Q2/87	Q3/87	Q4/87	1987	% Change 1987
Total Semiconductor	$31,009	$8,408	$9,578	$10,013	$10,431	$38,430	23.9%
Total IC	$23,601	$6,478	$7,425	$ 7,795	$ 8,135	$29,833	26.4%
Bipolar Digital	$ 4,321	$1,130	$1,266	$ 1,343	$ 1,422	$ 5,161	19.4%
Memory	675	176	185	192	197	750	11.1%
Logic	3,646	954	1,081	1,151	1,225	4,411	21.0%
MOS Digital	$13,064	$3,713	$4,302	$ 4,552	$ 4,733	$17,300	32.4%
Memory	4,338	1,176	1,365	1,453	1,532	5,526	27.4%
Micro	3,661	1,060	1,225	1,265	1,300	4,850	32.5%
Logic	5,065	1,477	1,712	1,834	1,901	6,924	36.7%
Linear	$ 6,216	$1,635	$1,857	$ 1,900	$ 1,980	$ 7,372	18.6%
Discrete	$ 5,818	$1,519	$1,690	$ 1,749	$ 1,805	$ 6,763	16.2%
Optoelectronic	$ 1,590	$ 411	$ 463	$ 469	$ 491	$ 1,834	15.3%
Exchange Rate Yen/$	167	153	142	142	142	145	(13.2%)
Exchange Rate ECU/$	146	129	126	127	127	127	(12.9%)

	1987	Q1/88	Q2/88	Q3/88	Q4/88	1988	% Change 1988
Total Semiconductor	$38,430	$10,908	$11,667	$12,252	$12,715	$47,542	23.7%
Total IC	$29,833	$ 8,536	$ 9,159	$ 9,625	$ 9,999	$37,319	25.1%
Bipolar Digital	$ 5,161	$ 1,461	$ 1,536	$ 1,606	$ 1,654	$ 6,257	21.2%
Memory	750	201	211	220	228	860	14.7%
Logic	4,411	1,260	1,325	1,386	1,426	5,397	22.4%
MOS Digital	$17,300	$ 5,060	$ 5,500	$ 5,826	$ 6,085	$22,471	29.9%
Memory	5,526	1,634	1,777	1,873	1,934	7,218	30.6%
Micro	4,850	1,396	1,536	1,631	1,707	6,270	29.3%
Logic	6,924	2,030	2,187	2,322	2,444	8,983	29.7%
Linear	$ 7,372	$ 2,015	$ 2,123	$ 2,193	$ 2,260	$ 8,591	16.5%
Discrete	$ 6,763	$ 1,856	$ 1,960	$ 2,054	$ 2,121	$ 7,991	18.2%
Optoelectronic	$ 1,834	$ 516	$ 548	$ 573	$ 595	$ 2,232	21.7%
Exchange Rate Yen/$	145	142	142	142	142	142	(2.1%)
Exchange Rate ECU/$	127	127	127	127	127	127	(0.2%)

Note: This table was previously entitled "Estimated Worldwide Semiconductor Consumption."

Source: Dataquest
October 1987

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Research *Bulletin*

SIS Code: 1987 Newsletters: October
1987-42

NATIONAL SEMICONDUCTOR AND SEEQ ANNOUNCE "FLASH" AGREEMENT

National Semiconductor Corporation and Seeq Technology Incorporated have announced the signing of a four-year exclusive technology licensing and manufacturing agreement for high-density CMOS Flash EEPROMs.

Under the terms of the agreement, both companies will share technology and marketing rights to a new family of Flash EEPROM products. The agreement includes Seeq's existing 128K device along with that company's proposed 512K and 1Mbit densities and the 256K density from National. This alliance combines Seeq's EEPROM technology with National's substantial CMOS capability and manufacturing expertise.

Flash EEPROMs were first introduced to the market by Toshiba in 1985. The Flash construction implements an EPROM-like process and design approach. Seeq's Flash EEPROM technology uses a 1.5-micron, N-well CMOS process. The Flash requires a 12V power supply for programming and erasing and 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. Typical erase time is 1 second to erase the entire memory. The cell structure permits merging of the bit selection transistor with the floating-gate transistor.

Although the Flash EEPROM cell is approximately 5 to 10 percent larger than the comparable UVEPROM cell, we believe that the Flash product's benefits to the user will offset the penalty in cell size. The new products will be offered in comparable UVEPROM high densities, at only one to two times the cost of the UVEPROMs. They will have on-board programming capability, with reprogrammability and bulk erase time of less than 1 minute. In addition, they will require half the test time of UVEPROMs and will use low-cost plastic packages that are pin compatible with UVEPROMs.

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DATAQUEST ANALYSIS

Dataquest believes that the market for Flash EEPROMs will ultimately erode the commodity UVEPROM market. From a cost-effectiveness standpoint, we expect the Flash products to not only emulate UVEPROM products in density and speed, but also to achieve price-per-bit parity with UVEPROM products by late 1989. While sales from initial Flash product offerings have been negligible in 1987, we expect Flash to be a strong contender for a sizable share of the $1.5 billion EPROM market in 1990. A further discussion of Flash technology, other competitors, and market size will be available in a forthcoming Dataquest newsletter.

This alliance with National is a further indication of the improving health of Seeq Technology. After suffering serious financial setbacks during the industry recession in 1985 and 1986, Seeq returned to profitability in 1987. Dataquest believes that this merger is a very positive event for both Seeq and National, and that its importance should not be underestimated. Seeq and National now have the potential to establish a set of de facto standards for the Flash products that we expect will be introduced in the very near future by competitors. We believe that an alliance such as this will be a profitable one for both Seeq and National and an essential alliance for continued survival in worldwide markets.

Mary A. Olsson

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SIS Code: 1987 Newsletters: October

THE SEMICONDUCTOR INDUSTRY FACES MIDLIFE CRISIS

SUMMARY: DATAQUEST HOSTS AN INDUSTRY BIRTHDAY PARTY

The semiconductor industry has attained middle age, and Dataquest is throwing a birthday party. On October 19-21, the Semiconductor Industry Group proudly hosts its annual Semiconductor Conference at The Pointe at Squaw Peak in Phoenix, Arizona.

As might be expected, the mood surrounding the conference is one of celebration. The worldwide semiconductor industry has now clearly begun its recovery from two years of recession. Dataquest believes that the dollar value of world semiconductor consumption in 1987 will grow nearly 24 percent over 1986, to a total of more than $38 billion. We expect this growth to continue in 1988, with semiconductor consumption increasing by another 24 percent to $47.5 billion.

Why Midlife Crisis?

While attaining middle age certainly entitles one to reflect on the past, it is a rite of passage that demands facing the future as well. With industries as with individuals, confronting the remainder of one's life from the perspective of full adulthood can be at once profound and intimidating. For this reason, the Dataquest Semiconductor Industry Group has chosen the theme of "midlife crisis" for its upcoming conference.

What has the semiconductor industry learned from the past four decades? How have the structure and identity of the industry changed? How will these changes affect the future of the semiconductor business? This newsletter identifies some of the major transformations facing the semiconductor industry as it looks toward the next 40 years, and in doing so offers some insight into the Dataquest Semiconductor Conference agenda.

THE PAST AS PROLOGUE

Forty years ago, three Bell Laboratories scientists invented the point contact transistor, and the semiconductor industry was born. Eight years later, Texas Instruments began to manufacture silicon transistors on a commercial scale, ushering in a new era in electronics. In 1958, less than three decades ago, a Texas Instruments scientist named Jack Kilby and a Fairchild scientist named Bob Noyce independently developed the integrated circuit. At that time, worldwide semiconductor sales totaled $352 million.

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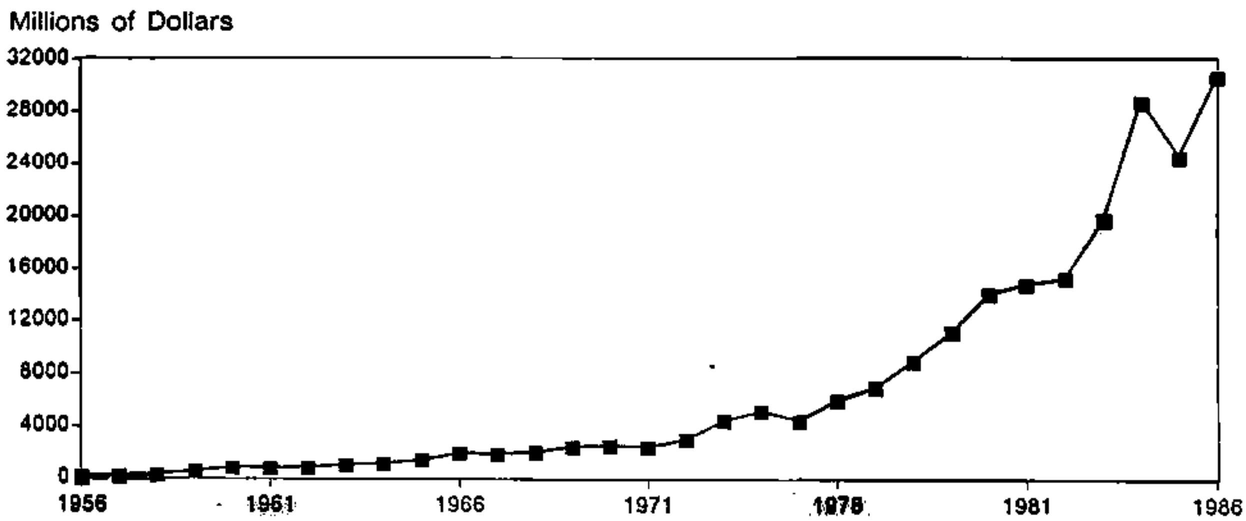
The growth of the semiconductor industry, as illustrated by Figure 1, has been nothing less than phenomenal. While this growth has slowed over the years, Dataquest believes that the world's demand for semiconductors will continue to expand at a compound annual growth rate of 14 to 16 percent into the 1990s. If the worldwide semiconductor market were to continue to grow at its historical exponential rate for the next 40 years, semiconductor consumption in the year 2027 would reach $22.6 trillion! Such an extrapolation obviously overstates the potential market. Considering that semiconductor consumption by the electronic equipment industry currently accounts for approximately 5 percent of its total sales, a $22.6 trillion semiconductor market would require a $452 trillion electronic equipment industry to support it!

Figure 1

Historical Worldwide Semiconductor Consumption



Source: Dataquest
October 1987

GROWTH: IS THERE LIFE AFTER THE PERSONAL COMPUTER?

Going through a midlife crisis often elicits the question, "Have I lived through the best years of my life?" During the past two years, Dataquest has heard a number of variations on this theme from semiconductor industry leaders. Clearly, growth in many semiconductor end markets is slowing down (Table 1). Nevertheless, the outlook for semiconductor consumption in major electronic equipment segments remains positive (Table 2).

Table 1

Estimated Compound Annual Growth Rates for Selected North American Electronic Equipment Segments (Based on Total End-User Revenue)

Segment	CAGR 1982-1986	CAGR 1987-1991
Single-User Enhanced Computers	156.1%	30.0%
Personal Computers	42.8%	8.7%
Electronic Typewriters	49.4%	(7.0%)
Rigid Disk Drives	20.3%	3.6%
Computer Storage	15.9%	4.8%
CAD/CAM Workstations	38.7%	7.6%
Telecom Equipment	14.0%	8.2%

Source: Dataquest
October 1987

Table 2

Estimated North American Semiconductor Consumption by Application Market (Millions of Dollars)

	1984	1985	1986	1987	1990	CAGR 1985-1990
Total Semiconductor	$13,139.0	$9,607.0	$10,201.0	$11,743.0	$15,998.0	10.7%
Data Processing	6,031.0	3,715.0	3,948.0	4,553.0	6,326.0	11.2%
Communications	2,057.0	1,357.0	1,505.0	1,731.0	2,491.0	12.9%
Industrial	2,107.0	1,561.0	1,608.0	1,890.0	2,555.0	10.4%
Consumer	970.0	698.0	732.0	830.0	1,138.0	10.3%
Military	1,276.0	1,488.0	1,560.0	1,777.0	2,176.0	7.9%
Transportation	698.0	788.0	848.0	962.0	1,312.0	10.7%

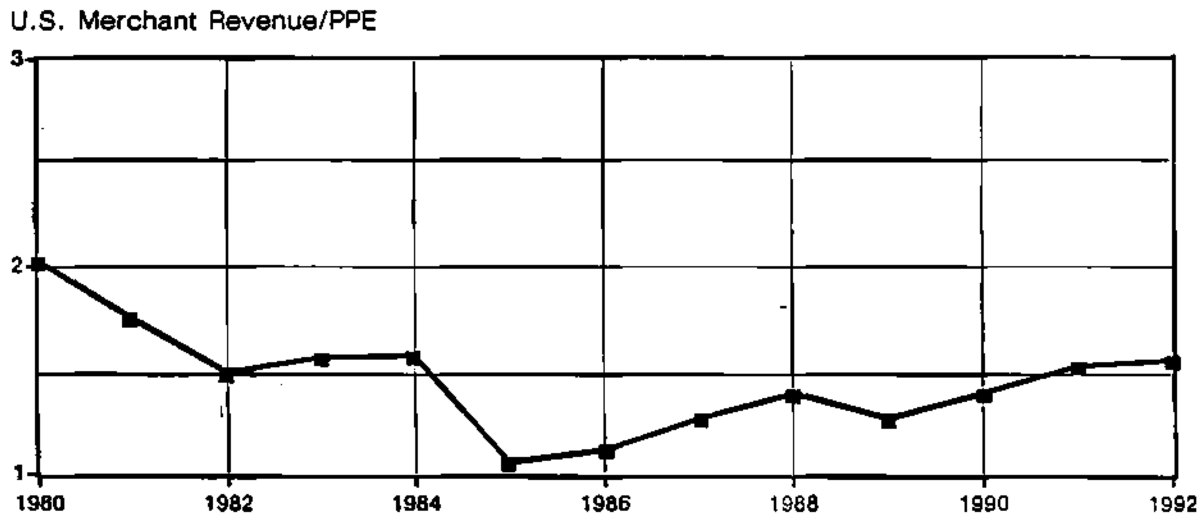
Source: Dataquest
October 1987

The Mixed Blessings of Commodities

As the industry continues to mature, it will continue to play the role of both creator and supplier to new end markets. But will these new markets offer the growth potential of the hand-held calculator and personal computer? If the industry has learned from its turbulent adolescence, it must seek out high-growth markets while avoiding the boom/bust pattern of its past. The blessings of commodities markets, as illustrated in Figure 2, have been mixed to say the least.

Figure 2

Estimated Revenue/Property, Plant, and Equipment Ratio
Worldwide Installed Base



Source: Dataquest
October 1987

During the last decade, semiconductor manufacturers have invested heavily in capital equipment to shrink line geometries and increase capacity, while the price per function of semiconductor products has decreased at a rate unprecedented in any industry. Aggravated still further by overcapacity in the face of the most recent electronics industry slump, the industry's return on its investments has been the stuff of a venture capitalist's nightmare. As the industry faces the next 40 years, semiconductor manufacturers must reflect on their profligate youth and find new ways of adding value to their products and black ink to their bottom lines.

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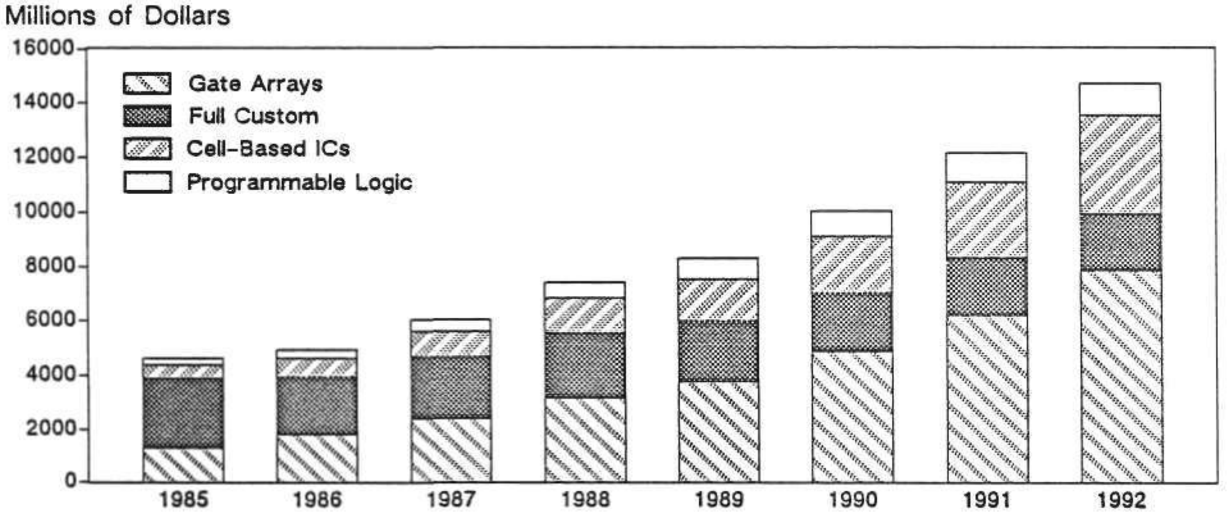
FROM JELLY BEANS TO VADs: HOW THE INDUSTRY ADDS VALUE

Experiencing a midlife crisis often brings about a changed perception of who one is and the values one holds. The forecast growth in consumption of ASIC devices (Figure 3) reflects a fundamental shift in the way semiconductor manufacturers and end users perceive the adding of value by the chip industry.

Figure 3

Estimated Worldwide ASIC Consumption



Source: Dataquest October 1987

The Third Wave

The ASIC business is creating a new duality within the semiconductor industry—the distinction between adding value through the low-cost manufacturing of "jelly bean" commodity products and adding value through addressing applications' needs through semicustom design. The industry's increasing applications focus, combined with production overcapacity, CAD tool advances, and venture capital, has created a "third wave" of semiconductor start-up activity—the emergence of "value-added designers" (VADs).

Out of the 127 start-ups that Dataquest has observed between 1977 and 1986, 42 are ASIC companies—half of which offer cell-based design capability. There are another 25 start-ups in the microcomponents area, the majority of which are devoted to applications such as communications, keyboard display, mass storage, and other special functions. In the growing market for digital signal processing (DSP), 9 companies have come into existence, with many more expected. In all, nearly 60 percent of the latest crop of start-up companies are now competing in an environment that stresses value-added design.

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CONSOLIDATION AND RESTRUCTURING

The semiconductor industry's changing perception of how value is added has been a contributing factor to the dramatic restructuring of many major U.S. suppliers during the past year. The following are some notable examples of this restructuring:

- In 1986, 75 percent of Fairchild's semiconductor revenue came from standard logic products. Prior to its acquisition by National Semiconductor, Fairchild's corporate strategy envisioned 75 percent of 1995 revenue coming from customer-specific and application-specific products.

- As a result of its acquisition of Monolithic Memories Inc., Advanced Micro Devices' (AMD) largest semiconductor revenue segment is now in the ASIC category.

- Intel and Texas Instruments (TI) joined forces a few months ago to jointly pursue the building of cell libraries around successful standard products. In its annual report, TI stressed the importance of applying systems expertise to silicon in achieving its corporate goals.

MANAGING CAPACITY: THE IMPORTANCE OF DOING MORE WITH LESS

Decreasing line geometries, the benefits of economies of scale, and cost-effective production will continue to be key issues in the semiconductor industry. In addition to these issues, however, the growing applications focus of the industry and the necessity to improve profitability will drive changes in the industry's view of manufacturing.

During a recent analysts' meeting, National Semiconductor's president and CEO, Charlie Sporck, stated that during the current recovery, his company would buy capacity from its competitors rather than invest solely in its own.

The hesitancy to dedicate brick and mortar to less proprietary areas is also evident in Intel's recent decisions to to satisfy rising demand in its memory markets through foreign sources. So far this year, Intel has entered into a DRAM agreement with Samsung and an EPROM agreement with Mitsubishi, while building its own capacity to meet the demand for 80286 and 80386 microprocessors.

The $600 Million Dollar Fab

The strategic use of capacity in 1987 is just the tip of the iceberg of manufacturing issues. Based on trends that we have observed recently, the revenue that a future state-of-the-art wafer fab will be able to generate will represent a significant barrier to market entry by the year 2000. In order to justify building a fab in 1980, a strategic planner had to find $35 million dollars worth of business. By the year 2000, this number will rise to approximately half a billion dollars!

Table 3, below, makes some rather conservative assumptions: an optimum fab operating level of 14,000 wafers per four-week period and a CAGR in revenue per square inch of 1 percent between 1985 and 2000. It is also assumed that the industry will be using 10-inch wafers by 1995 and 12-inch wafers by the year 2000.

Table 3

Estimated Revenue per Wafer Fab
(Millions of Dollars)

	1980	1985	1990	1995	2000
Wafer Size	100mm	150mm	200mm	250mm	300mm
Revenue/In.^{2}*	$15.50	$ 19.91	$ 20.93	$ 21.99	$ 23.11
Revenue/Fab	$35.00	$102.00	$191.00	$314.00	$476.00

*Assumes CAGR of 1 percent from 1985 to 2000.

Source: Dataquest
October 1987

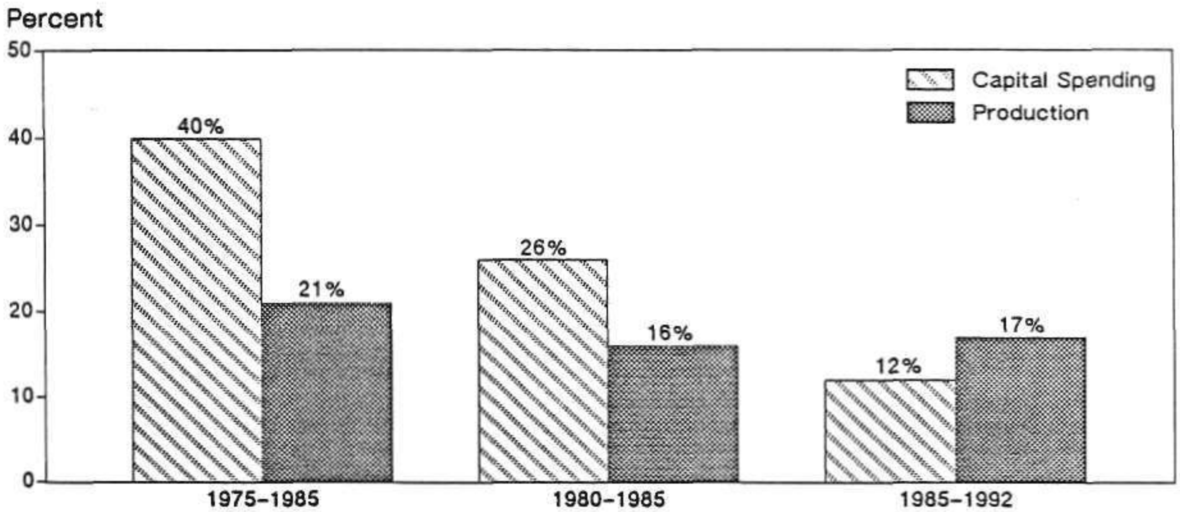
If one takes a slightly more aggressive forecasting posture and assumes an operating rate of 20,000 12-inch wafers per four-week period, the revenue potential of a single fab rises to more than $670 million—a level of revenue higher than AMD's total semiconductor sales in 1985. Looking ahead, semiconductor manufacturers will not only have to be concerned with how many clients buy their products, but perhaps with how many will do foundry in their facilities as well.

The "Fab in a Box"

As the semiconductor industry finds ways of doing more with less, Dataquest also believes that its capital investments will diminish in relation to productivity improvements, as illustrated in Figure 4. The need for broad product line suppliers to meet smaller, faster turnaround orders without throwing away profit will result not only in increased foundry relationships, but in the creation of smaller, more highly automated fabs. Dataquest analysts already see evidence of systems no larger than two telephone booths that are capable, using laser pantography, of performing the final metallization layers on already-packaged semicustom chips. The proliferation of such systems in design centers could make the "fab in a box" a reality.

Figure 4

Estimated Capital Spending versus Production



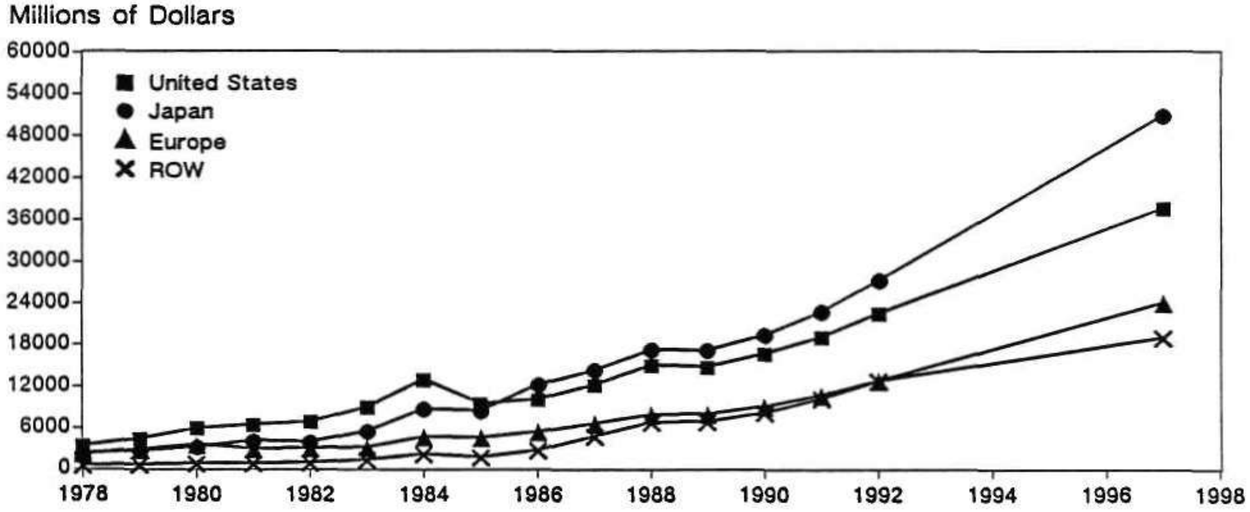
Source: Dataquest
October 1987

HOLDING ON TO WHAT YOU'VE GOT: MARKET SHARE IN A GLOBAL INDUSTRY

In the past 40 years, the U.S. semiconductor business has passed through the euphoria of being a brave new economic order, to arrive at the anguish of being yet another beleaguered U.S. industry under pressure from the Japanese juggernaut. U.S. semiconductor manufacturers now face a future in which they no longer possess the home field advantage—in 1986 the Japanese semiconductor market became the largest in the world, and is likely to remain so for the foreseeable future (see Figure 5).

Figure 5

Estimated Semiconductor Consumption by Region



Source: Dataquest
October 1987

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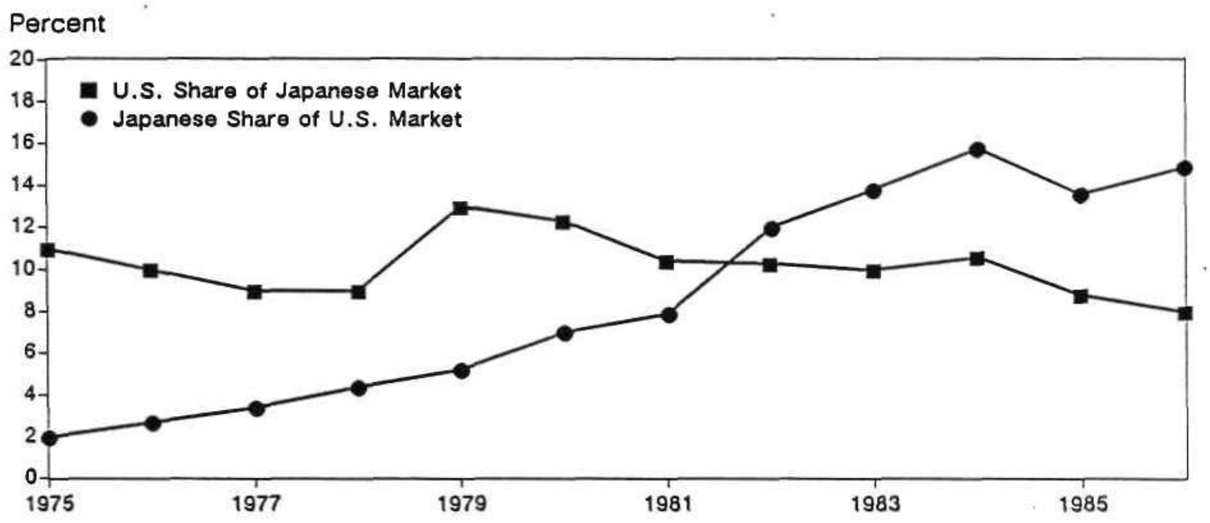
Market Access: The New Battle Cry

With trade tensions subsiding over the issue of semiconductor dumping, access to the Japanese market looms large in the minds of U.S. semiconductor manufacturers—and the U.S. Department of Commerce. Since the late 1970s, however, the U.S. share of the Japanese semiconductor market has diminished, while Japan's share of the U.S. market has increased (see Figure 6).

Figure 6

Japan's Share of the U.S. Semiconductor Market versus U.S. Share of Japan's Market



Source: Dataquest
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A Tale of Two Markets

While changes in currency exchange rates and the imposition of trade sanctions will have some impact on U.S. competitiveness vis-a-vis Japan, a fundamental problem remains for U.S. semiconductor suppliers: the Japanese electronic equipment market is a very different one from that of the United States. Dataquest believes that in 1987, the Japanese consumer electronics industry will account for nearly 39 percent of all semiconductor devices consumed in Japan. By contrast, the consumer segment will represent only 7.1 percent of the U.S. semiconductor market. With Japan's shift to offshore production in the wake of the rising yen, U.S. suppliers may be able to increase their share of the Japanese market and still find their percentage of the world market in decline.

The Role of Intellectual Property

Possessing technology has been an assumed prerequisite to entry into the semiconductor market. In the past, start-up companies with brilliant technology have floundered because they could not transition from the role of innovator into the role of world class manufacturer. The cost of making this transition has proved to be as much of a barrier to market entry as the possession of technology itself.

More recently, however, the industry has experienced the proliferation of alliances between U.S. start-up companies and Asian semiconductor manufacturers. Through second-source agreements and technology exchanges, smaller semiconductor companies in the United States have the potential to become more significant competitors. Of greater concern to established U.S. companies is the fact that in the process, overseas competitors with deep pockets may acquire technology cheaply and with it, access to U.S. distribution channels.

As the semiconductor industry turns increasingly to the creation of new products through cell-based design technology, another emerging intellectual property issue concerns the migration of standard products into alterable cells. Ultimately, the burden of protecting one's investment in standard products rests on patents and mask-level copyrights. Just how these protections will apply to cell-based libraries has yet to be tested through litigation.

THE POLITICS OF SEMICONDUCTORS

Just as the semiconductor industry's view of itself has changed in the past four decades, so too has its role in the geopolitical arena of world trade and national defense. For better or for worse, the semiconductor industry has become politicized. The Pentagon's Defense Science Board found that the U.S. semiconductor industry enjoys a lead in only three of 25 semiconductor technologies surveyed. This conclusion played a major role in raising the U.S. government's consciousness on the strategic importance of the domestic semiconductor industry and the need to establish Sematech as a vehicle for shared investment in generic manufacturing technology.

The imposition of trade sanctions against Japan by the Reagan administration have come about as a direct result of the U.S.-Japan semiconductor trade agreement. In its role as protector of the U.S. semiconductor industry, the federal government has sought to put an end to unfair trade practices and force greater access to Japan's markets.

Conflicting Interests

The extent to which the U.S. government can champion the cause of the semiconductor industry, however, has been called sharply into question. Given the current dependency of U.S. electronic equipment manufacturers on Japanese memory IC suppliers and the necessity of the U.S. electronic equipment industry to compete globally, trade legislation must carefully weigh the interests of a $12 billion U.S. semiconductor industry against those of a $234 billion U.S. electronic equipment industry.

The current situation regarding DRAM pricing highlights the conflict above. In its attempts to satisfy the U.S. government's concerns over predatory pricing, Japan's Ministry of International Trade and Industry (MITI) has created production controls and pricing guidelines affecting 256K and 1Mb DRAMs. As a result, Dataquest believes that by the fourth quarter of 1988, the cost of a 150ns 256K DRAM will be $3.00 (100,000 units/year volume), and that current DRAM pricing will delay a 4X price-per-bit crossover from the 256K to the 1Mb DRAM until the end of next 1988. In the meantime, Dataquest is observing consternation among a number of U.S. electronic equipment manufacturers over the supply/demand disparity that they perceive in the 1Mb DRAM market.

The complexity of the relationships between government, semiconductor suppliers, and end users will continue to grow as the newly industrialized countries of the world enter the competitive fray. In just the past few months, the International Trade Commission and the U.S. Customs Department have been pulled into intellectual property disputes between major U.S. semiconductor manufacturers and Asian competitors.

FACING MORTALITY

One of the more sobering aspects of midlife crises is facing one's mortality—the recognition that one's life is finite. The issue of mortality confronting the semiconductor industry is whether or not clear technological alternatives to etching circuits in silicon exist on the horizon.

At this time, the most obvious alternative to current silicon-based technology is the rapid progress being made in superconductive materials. In June of this year, Dataquest analysts attended the International Workshop on Novel Mechanisms of Superconductivity sponsored by the University of California at Berkeley. Several physicists at the conference expressed the belief that it might be possible to build simple superconducting devices within two to three years by layering superconducting thin films onto new substrate materials.

Death by Success

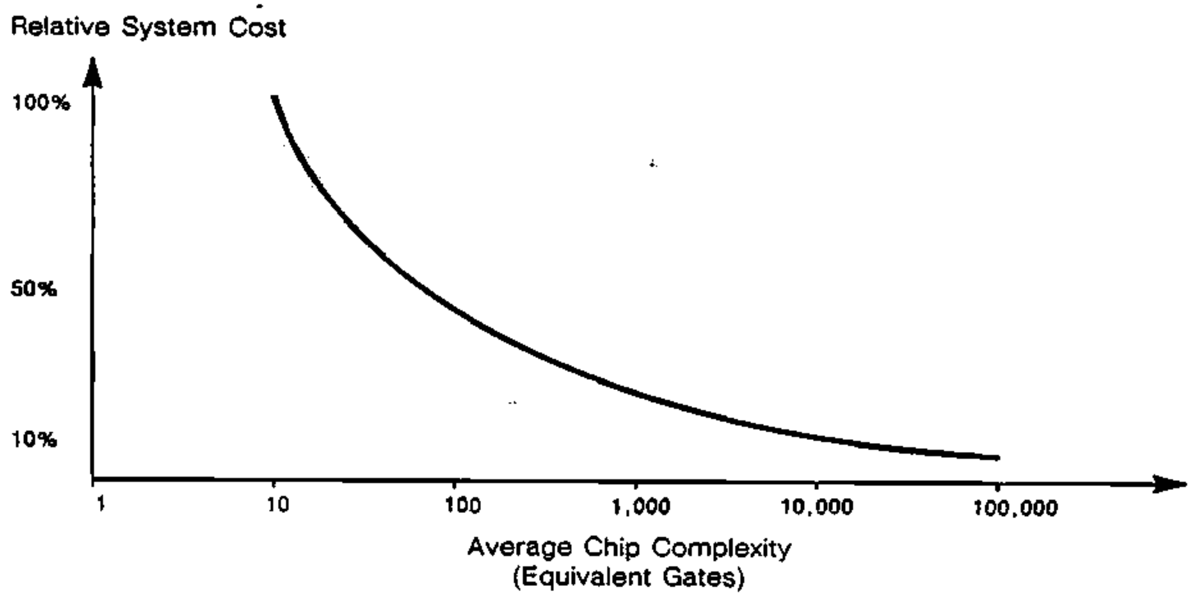
The demise of the semiconductor industry as we know it, however, may not come about through a technological revolution, but rather through tendencies already in the "genes" of the industry. The semiconductor industry could very well become a victim of its own success.

As suggested by Figure 7, the trends toward higher chip complexities, coupled with decreasing cost per function, have benefited end users and semiconductor manufacturers alike by endowing electronic equipment markets with greater elasticity of demand. Semiconductor chip sets are a current example of the industry's success in creating more powerful, less expensive systems through the continuing consolidation of ICs.

The sinister side of the industry's genius, however, has to do with the ultimate impact on the value of one's total available market when the potential exists to replace more than $20 worth of semiconductor devices with a $1 gate array. The semiconductor industry has now entered into a race between innovation and cannibalization. During 1987, we believe that semiconductor manufacturers will deliver as many gates of logic through gate array products as they will through standard logic products (Figure 8).

Figure 7

System Cost as a Function of Average Chip Complexity



Source: Bogert/Thomas Research

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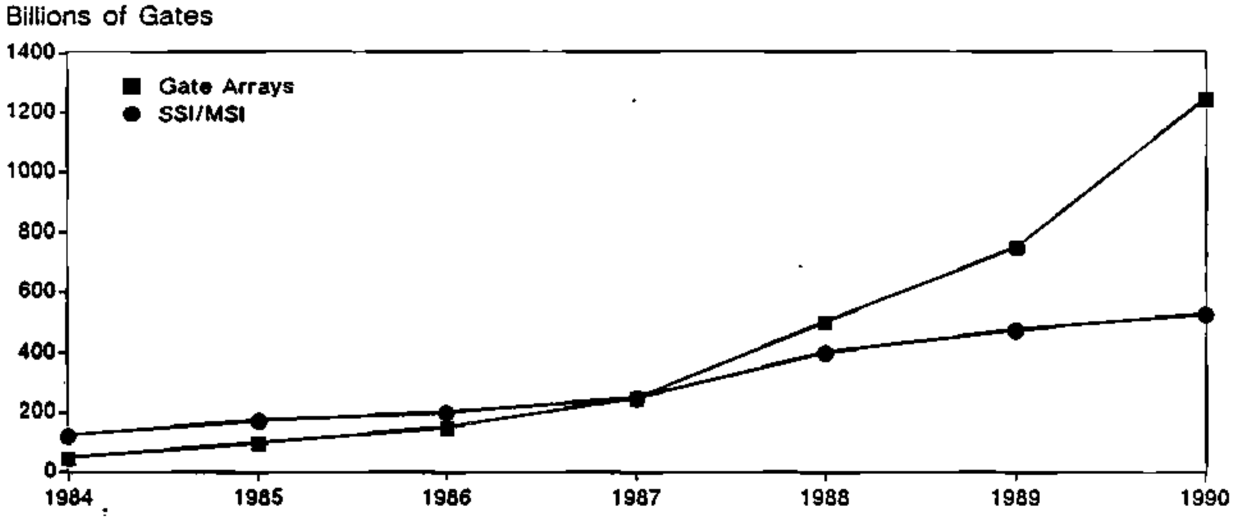
Figure 8

Expected Impact of Gate Arrays
on Semiconductor Logic Function Shipments



Source: Dataquest
October 1987

A BILLION TRANSISTORS ON A CHIP?

It has been predicted that by 1990 the semiconductor industry will be able to place a billion transistors on a chip. The following are a few examples of the kind of computing power this would make available to end users:

- 128 megabytes of RAM
- 1,000 VAX CPUs
- 20 Cray 2 CPUs
- 10 VAXs with memory
- 1/40 of a Cray 2 with memory

But can electronic equipment markets keep pace with the capability of the semiconductor industry to deliver higher levels of integration in silicon at lower costs per function? In a recent interview with Dataquest, Dr. K. Odagawa, the "founding father" of Toshiba's CMOS technology, observed, "Now that the ability to place more than one million transistors on a chip is a routine production event, the capability to design and process . . . far exceeds the technical requirements at this time. Market application is now the driving element."

What Business Are We In?

In the past four decades, it seems beyond belief that the semiconductor industry could have passed from the invention of the discrete transistor to envisioning the incorporation of a billion transistors on a single piece of silicon. During this transition, the industry has changed from a supplier of integrated circuits to a creator of integrated systems. In facing the next four decades, the success of the industry will depend on how it responds to this new role.

Perhaps the lessons of the steel industry apply here. The downfall of the U.S. steel industry may fundamentally have been that U.S. steel makers saw themselves in the business of producing steel, and were therefore buried by offshore competitors who could provide this service at a lower cost. Japanese steel makers, by comparison, see themselves as being in the business of supplying core materials. Faced with competition from the Pacific Rim, many of Japan's steel manufacturers have broadened their definition of core materials to include substances other than steel—such as silicon.

The future of the semiconductor industry may similarly depend on just what kind of business chip manufacturers see themselves participating in. If it is the business of etching circuits on silicon, the industry will sooner or later face its demise. If, on the other hand, chip manufacturers define their business as the consolidation of integrated systems, there is seemingly no limit to the industry's horizons.

Michael Boss