1993 SUBSCRIPTION RESEARCH SERVICE

SEMICONDUCTORS WORLDWIDE

What you'll need to know in 1993.

What are the major emerging semiconductor technologies? Which companies are leading the development of these technologies?

Semiconductor market drivers go beyond new applications. New hardware and software techniques as well as system standards effect new directions in the design and use of semiconductors. Dataquest's focus report, *Emerging Semiconductor Markets and Technologies*, will provide an assessment of some of these market forces and examine how the semiconductor suppliers are responding. Specific issues and opportunities to be discussed include neural networks, fuzzy logic, DSP, personal communications, and smart power.

What are the trends in high-density VLSI packaging?

The demands of high-performance systems integration over the next decade will cause a dramatic shift in interconnect technology from the traditional dual in-line package (DIP) to advanced surface-mount technology (SMT) packages. Dataquest's focus report, *Semiconductor Packaging Trends*, will help you evaluate your own semiconductor capital and R & D spending on new package development by providing a comprehensive five-year forecast by package type.

What impact will digital signal processing products have on the consumer, computer, and control markets?

DSP processors are permeating all types of applications, from tuning to control. Dataquest's focus report, *Digital Signal Processing Technology, Products, and Markets* will identify recent developments in DSP technology and their impact on systems development trends.

Do analog ICs and discrete devices have a future in electronics?

"Smart" products require a lot of power control, environmental sensing, and data conversion around the digital "brains". Since control is useless without a sensor and signal processor to measure results, the need for an analog interface to the physical world continues to grow. These applications drive the movement toward more ASIC solutions with mixed analog and digital functions. Dataquest's 1993 *IndustryTrends* report will help you understand the changing mix of analog, digital, mixed-signal, discrete, and optoelectronic semiconductors.

PRODUCT COVERAGE

Analog ICs
...
ASICs
...
Consumer ICs
...
Discretes
...
Memories
...
Microcomponents
...
Mixed-Signal ICs
...
Optoelectronics
...
Power ICs
...
Smart Power ICs
...
Telecommunications ICs

1993 RESEARCH HIGHLIGHTS

Semiconductor packaging trends
...
Digital signal processing technology, products, and markets
...
Emerging semiconductor markets and technologies
...
Audio/video markets and their impact on ICs
...
Analog and mixed-signal IC trends

Dataquest

Worldwide

Semiconductor Group

SEMICONDUCTORS WORLDWIDE: What you'll need to know in 1993.

INDUSTRYTRENDS REPORT

Comprehensive product and technology forecasts and application market trends in the global semiconductor market with detailed quantitative data.

This report gives a top-level view of the products, markets, companies, trends, and technologies of the global semiconductor industry. The industry will be examined from a supply side as well as a demand side, and from a regional market as well as a global market perspective. Special attention will be paid to market and technology trends in analog ICs and emerging technologies.

MARKET STATISTICS

- ***Semiconductor Market Share, Worldwide and North American***
  Market share by company for total semiconductors, total integrated circuits, bipolar digital, TTL/other bipolar digital, ECL bipolar digital, bipolar memory, bipolar logic, MOS digital, N/PMOS digital, CMOS digital, BiCMOS digital, MOS memory, MOS microcomponents, MOS logic, analog ICs, discrete semiconductors, and optoelectronic semiconductors.
- ***North American Wafer Fabrication Facilities***
  Pilot and production fab lines by company, location, fab name, products produced, process technology, minimum line width, wafer diameter, estimated wafer capacity, square feet of clean room, and clean room class.
- ***Semiconductor Consumption and Shipment Forecast***
  Five-year revenue forecasts by region for total semiconductors, total integrated circuits, bipolar digital, bipolar memory, bipolar logic, MOS digital, MOS memory, DRAMs, SRAMs, nonvolatile memory, other memory, MOS micro, microprocessors, microcontrollers, micro-peripherals, MOS logic, ASICs, custom logic, standard logic, analog ICs, monolithic, hybrid, discrete semiconductors, transistors, diodes, thyristors, other discrete, and optoelectronic semiconductors.

FOCUS REPORTS

- ***Semiconductor Packaging Trends***
  This report will provide comprehensive information that is qualitative as well as quantitative on the critical trends and major opportunities in semiconductor packaging. The report will also address the special issues involved in multichip module packaging.
- ***Digital Signal Processing Technology, Products, and Markets***
  This report will analyze the impact of DSP on systems development trends in the consumer, computer, and control markets.
- ***Emerging Semiconductor Markets and Technologies***
  This report will examine from a global and regional perspective the underlying technology trends and recent developments in neural networks, fuzzy logic, and DSP.

VENDOR PROFILES

Detail of organizational structure, product portfolio strengths and weaknesses, and strategic directions of major semiconductor manufacturers.

Companies scheduled to be profiled:

- Analog Devices
- National Semiconductor

ADDITIONAL RESEARCH RESOURCES

INQUIRY SUPPORT AND MONTHLY SUMMARIES: year-long direct access to semiconductor analysts and monthly summaries of representative inquires.

DATAQUEST ALERTS: news and analysis delivered by fax and *Dataquest Online* for fast breaking developments.

DATAQUEST PERSPECTIVES: timely analysis and commentary on industry events and issues.

DATAQUEST ONLINE: access to semiconductor service databases and publications. Clients will be billed separately by CompuServe for connect time.

INFORMATION RESOURCE CENTERS: access to extensive printed and on-line data in San Jose, Boston, UK, France, Germany, and Japan.

SEMICONDUCTOR CONFERENCES: the industry's preeminent semiconductor conferences held in the U.S., Europe, Japan, and Asia.

PROGRAM DELIVERABLES

IndustryTrends Report

...

Market Statistics

...

Focus Reports

...

Vendor Profiles

...

Inquiry Support and Monthly Summaries

...

Dataquest Alerts

...

Dataquest Perspectives

...

Dataquest Online

...

Information Resource Centers

...

Semiconductor Conferences

Dataquest

a company of
The Dun & Bradstreet Corporation

Corporate Headquarters
1290 Ridder Park Drive
San Jose, CA 95131-2398
Phone: 408-437-8000

Denham (UK) Office
Roussel House, Broadwater Park
Denham, Uxbridge
Middlesex UB9 5HP, England
Phone: (+44) 895-835050

Tokyo Office
Shinkawa Sanko Building
1-3-17, Shinkawa, Chuo-ku
Tokyo 104, Japan
Phone: (+81) 3-5566-0411

Dataquest®

Dataquest

Semiconductors

Semiconductors

DQ

1993 Index

Program: Semiconductors
Product Code: SCND-WW-IX-9303
Publication Date: February 28, 1994

Dataquest®

Semiconductors

Semiconductors

1993 Index

Program: Semiconductors
Product Code: SCND-WW-IX-9303
Publication Date: February 28, 1994

Dataquest Index

Semiconductors Worldwide

January - December 1993 | February 28, 1994

How to Use This Index

This is a cumulative index of key industry terms, companies, and products for 1993 core and segment issues of *Dataquest Perspectives* (DP), *MarketTrends* (MT), *IndustryTrends* (IT), *Inquiry Summaries* (IS), *User Wants and Needs* (UW), *Focus Reports* (FR), and *Vendor Profiles* (VP) documents. A key at the bottom of each page indicates the product abbreviations. Entries are followed by the date of publication and the page number(s). Product names are listed under the company that manufactures or publishes the product. General information about a company itself is found under the full company name. Each citation indicates only the beginning page of a discussion of a topic (the range of page numbers is not cited). Most Dataquest documents issued during 1993 appear in this index. A Table of Contents for 1993 Dataquest publications listing each issue number, title, and date is included at the end of the index. Article titles are listed for the *Dataquest Perspectives*. Some cover dates have been duplicated on the same type of document. To help locate an index entry, we have added an indicator after the date and before the page number that identifies the issue number. An example of this would be DFAX-EU-MT-9301 (Europe) and DFAX-EU-MT-9306 (Spain) both dated May 31, 1993. The index entry would be like this:

Facsimile
  market share by shipments
  Europe (1992), DFAX-EU-MT (May 31):[01]3
  Spain (1992), DFAX-EU-MT (May 31):[06]3

The [01] indicates DFAX-EU-MT-9301 and the [06] indicates DFAX-EU-MT-9306.

Note: The following abbreviations identify products associated with the Semiconductors Worldwide group.

ASIC-WW	ASIC Worldwide	SEMI-JA	Semiconductors Japan
MCRO-WW	Microcomponents Worldwide	SEMI-WW	Semiconductors Worldwide
MMRY-WW	Memories Worldwide	SEMM-WW	Semiconductor Equipment, Manufacturing, and Materials Worldwide
SAMM-WW	Semiconductor Application Markets Worldwide		
SCND-WW	Semiconductors Core Binder	SPSG-WW	Semiconductor Procurement Worldwide
SEMI-AP	Semiconductor Asia/Pacific		

A

B

C

D

E

F

G

H

I

J

K

L

M

N

O

P

Q

R

S

T

U

V

W

X

Y

Z

Table of Contents

Semiconductors Core Binder

Inquiry Summaries

IndustryTrends

Perspectives

ASICs Worldwide

Perspectives

MarketTrends

Dataquest®

a company of
The Dun & Bradstreet Corporation

Corporate Headquarters
Dataquest Incorporated
1290 Ridder Park Drive
San Jose, California 95131-2398
United States
Phone: 01-408-437-8000
Facsimile: 01-408-437-0292

Dataquest Incorporated
550 Cochituate Road
Framingham, Massachusetts 01701-9324
United States
Phone: 01-508-370-5555
Facsimile: 01-508-370-6262

Invitational Computer Conferences (ICC)
3990 Westerly Place, Suite 100
Newport Beach, California 92660
United States
Phone: (714) 476-9117
Facsimile: (714) 476-9969

Dataquest Japan Limited
Shinkawa Sanko Building
1-3-17, Shinkawa, Chuo-ku
Tokyo 104
Japan
Phone: 81-3-5566-0411
Facsimile: 81-3-5566-0425

Dataquest Korea
Trade Tower, Suite 3806
159 Samsung-dong
Kangnam-gu, Seoul 135-729
Korea
Phone: 011-82-2-551-1331
Facsimile: 011-82-2-551-1330

European Headquarters
Dataquest Europe Limited
Roussel House, Broadwater Park
Denham, Uxbridge
Middlesex UB9 5HP
England
Phone: 44-895-835050
Facsimile: 44-895-835260/1

Dataquest GmbH
Kronstadter Strasse 9
8000 Munich 80
Germany
Phone: 011-49-89-930-9090
Facsimile: 011-49-89-930-3277

Dataquest Europe SA
Tour Gallieni 2
36, Avenue du General de Gaulle
93175 Bagnolet Cedex
France
Phone: 011-33-1-48-97-3100
Facsimile: 011-33-1-48-97-3400

Representative Agencies in
Bangkok, Hong Kong,
Kronberg, North Sydney,
Singapore, Taipei, and Tel Aviv

N01SEMIWW SCNDWW1X9303 BH: 1 N:
Mr. Clark Fuhs
Dataquest Incorporated
1-1100
****
SJ - INTERNAL DISTRIBUTION
****

Inquiry Summaries

Dataquest®

Q&A Dataquest Inquiry Summary

Semiconductors

Semiconductors

December 1993

Dataquest®
a company of The Dun & Bradstreet Corporation

Program: Semiconductors
Product Code: SCND-WW-IS-9312
Publication Date: December 27, 1993

Markets and Applications

Q1

What is the outlook for 4Mb and 16Mb DRAM pricing in North America for the first quarter of 1994?

A

The results of Dataquest's quarterly price survey show the power of suppliers over buyers. Table 1 presents survey results for key 4Mb and 16Mb devices in contract volumes.

Table 1
Estimated DRAM Price Trends—North American Bookings (Contract Volume; U.S. Dollars)

Product	Q4/93	Q1/94
4Mbx1 DRAM 70-80ns SOJ		
Survey Averages		
User	12.56	12.30
Supplier	12.69	12.46
Overall	12.63	12.41
1Mbx4 DRAM 60ns SOJ		
Survey Averages		
User	12.67	12.48
Supplier	12.86	12.67
Overall	12.80	12.62
256Kx16 DRAM 70-80ns SOJ		
Survey Averages		
User	15.02	14.10
Supplier	15.37	14.74
Overall	15.26	14.53
4Mbx4 DRAM 70ns SOJ 400 mil		
Survey Averages		
User	68.50	58.67
Supplier	72.25	64.00
Overall	71.00	62.00

Source: Dataquest (December 1993)

The 4Mx1 and 1Mx4 configurations average $12.55 to $12.85 for year-end 1993. The survey indicates a relatively flat price curve for the first quarter of 1994. Although the survey signals a slight tilt downward in pricing, some suppliers expect to increase 4Mb pricing again next quarter.

The x4 and x16 configurations appear prone to remaining on allocation. For example, buyers report that suppliers plan to de-emphasize the commodity x1 business. As a result, the x16 configuration typically commands a 20 percent premium over the 4Mbx1 device. The x4 part has sold for a slight premium over the x1 device—although that spread might increase during early 1994.

The 4Mbx4 DRAM continues to decline in an orderly fashion—about 10 to 15 percent per quarter—as the production ramp-up proceeds. The 4Mbx4 crossover from the 1Mbx4 part should occur during midyear 1994. By contrast, the 2Mbx8 crossover from the 512Kx8 device will likely occur toward year-end 1994 or early 1995.

By Ronald Bohn

Q2

We read in DQ Monday that the 4Mb DRAM production run rate is expected to be at 1 billion per year before year-end 1993. Are you changing your 1994 4Mb units forecast. If so, why?

A

Given the strong DRAM and PC market conditions today and the status of the 16Mb DRAM in design-ins, prices, and part types, our forecast of 865 million units of 4Mb DRAM for 1994 will almost certainly be increased, perhaps to more than 1 billion units, barring an unforeseen collapse of the market. Not only is the 4Mb run rate and demand high as we leave 1993, but the 16Mb has been slow to take off—still too distant from the (inflated) 4Mb price. It is increasingly seen as the wrong part (x1 or x4) for the early market, which would prefer more 1Mbx16 and 2Mbx8, preferably 3V, as well.

Also, the forecast of 51 percent bit growth for 1994 versus 1993 will be moving up to about 60 percent or more, adding some revenue to the DRAM market size, both for prices and units. Although we still expect steady price declines for DRAMs during 1994, those declines are expected to be modest for the first half. Prices will be higher than anticipated starting about year-end 1993 ($12.60 versus our earlier-expected $11.75) and will accelerate in the second half as the 16Mb volumes begin to build, and competition heats across the entire DRAM market.

By Lane Mason

Q3

What is the overall status of the microcomponents marketplace?

A

Dataquest will soon publish a MarketTrends document (*Setting the Pace in the Semiconductor Market*) that will provide a detailed look at the microcomponents market. This report will detail the trends in demand, industry competition, and product forecasts behind the development of this thriving business.

The following is excerpted from the MarketTrends document.

Microcomponent products are the key elements that make possible the intelligence, functionality, and user-friendliness of electronic equipment varying in complexity from tennis shoes and microwave ovens to workstations and supercomputers. With revenue of more than $14 billion in 1992 and estimated revenue that is expected to exceed $19 in 1993, microcomponents is the fastest growing segment of the semiconductor industry. Microcomponents represented 22 percent of total semiconductor sales in 1992, and we forecast it to be 34 percent in 1997.

Major findings of this report are as follows:

- The microprocessor segment continues to be the largest segment of the microcomponent category and continues to be dominated by the 80x86 family of microprocessors. Microprocessors represented 38 percent of microcomponents in 1992 and will grow to about 55 percent in 1997.
- Microprocessors designed for use in embedded applications are showing strong growth, with dramatic increases anticipated for sales into one of the most exciting new applications—hand-held electronic devices. This single application will have a pronounced effect on microprocessor technology, primarily driving the leading edge in higher levels of functional integration and power management.
- Microprocessor (and microperipherals) revenue is overwhelmingly dominated by North American companies; Dataquest believes that this will continue for the foreseeable future.
- The microperipherals segment represents a collection of functional areas that share a common demand factor, the growth of microprocessors, but have differing driving forces that shape their success and obsolescence. Dataquest believes that microperipherals in total will grow, but at a rate diminished by the integration of their functionality within the microprocessors they support. Math coprocessor microperipherals will be hardest hit by microprocessor integration, showing declining sales. On the other hand, graphics, communications, and mass storage controllers will flourish as system performance demand increases for these critical functions, which will remain outside the microprocessor.
- Microcontroller revenue has historically been dominated by Japanese companies selling the bulk of their products in Japan. But the sluggish Japanese market, when combined with the strength of the other regional markets, has propelled North American and European microcontrollers into positions of strength. Motorola, long the dominant supplier of 8-bit microcontrollers, should move into the No. 1 position for total microcontrollers in terms of both revenue and units in 1993.

By Jerry Banks

Technology

Q4 What are the advantages of digital signal processing (DSP) versus traditional analog signal processing?

A DSP is a technology that allows signals to be processed in the digital domain. It involves converting an analog signal into digital, performing some sort of process on this digital representation of the signal such as noise filtering or echo cancellation, and then converting the signal back into an analog form. DSP is rapidly displacing analog signal processing as the technique of choice for processing signals. This conversion from analog signal processing to DSP is being driven by several factors. The most critical of disadvantages of analog signal processing are as follows:

- Analog circuits have a tendency to drift over time because of component degradation.

- Analog circuits are sensitive to changes in voltage and temperature.
- Analog circuits are difficult to duplicate because component characteristic specifications are often imprecise.
- Analog circuits operate in "real time," making it difficult to stop a process for whatever reason and then continue.
- The output from an analog circuit is difficult to save for later analysis.

DSP can overcome many of the problems associated with analog signal processing. The following are the advantages of DSP, versus the disadvantages of analog signal processing previously mentioned:

- Digital circuit components do not degrade over time.
- Digital circuit components are precisely specified to operate over a wide range of temperature and voltage.
- Digital circuit components can be exactly duplicated.
- Digital circuits can be stopped and restarted virtually at any time.
- Results from a digital circuit can be easily stored for later analysis.

However, DSP is not without its disadvantages. The dawn of the era of DSP has uncovered a whole new set of problems that must be overcome by the designer. The most common DSP disadvantages are as follows:

- Quantization error—An analog signal is a continuous wave form. When it is converted to the digital domain, the result is an approximation that is dependent upon the resolution of the converter. If the resolution of the converter is not high enough, the resultant output may be a severely distorted representation of the input.
- Aliasing—If the analog input signal is not sampled often enough, the wave form may be incorrectly interpreted and processed by the signal processor. (This effect may also be noticed in some analog signal processing applications that use sample-and-hold circuits at the front end of the signal processor.)
- Clock feed through—Because digital signal processors require a clock for operation, the risk exists that the clock may feed through to the analog signal output.

By Jerry Banks

Company and Other Issues

Q5 Please provide an overview of Actebis and Escom, the two German PC assemblers, and an idea of their sourcing policies?

A Actebis Computerhandelsges GmbH is located at Lange Wende 42, 4770, Soest, Germany, telephone (+49) 29 21 99 00, and fax (+49) 29 21 99 33 99.

The directors are as follows:

- Geschäftsführer: Ulrich G. Puhrsch

- Chairman: Norbert F. Wrede
- Geschäftsführer: Martin Menzel
- General Manager: Joachim Kürten

There are 550 employees in the total staff; the assembly staff is 150.

Ulrich Puhrsch and Norbert F. Wrede founded Actebis as a distribution company in 1986, and each holds 50 percent interest. The company started assembling PCs in 1988 in Soest. The machines are configured with DOS and Windows. Actebis is the second largest Novell distributor in Germany. About half the production is badged and sold under other names.

Actebis assembles PCs under the two known brands called Targa and CPA, as well as for private label customers. Motherboards are purchased, and partial stuffing is carried out. Actebis and Schneider, also of Germany, announced in March 1993 that they had reached an agreement for Actebis to manufacture all of Schneider's PCs.

Escom AG is located at Tiergartenstrasse 9, 6148, Heppenheim, Germany, telephone (+49) 62 52 70 90, and fax (+49) 62 52 70 94 42.

The president is Manfred Schmitt. The total staff numbers 500; the number of employees in assembly is unknown.

Escom Computer was founded in 1972 as a manufacturer of synthesizers and electronic keyboards, moving into PCs in 1985. It is wholly owned by President Schmitt. PCs are produced in Heppenheim and are configured with DOS and Windows and, on 486s, Lotus 1-2-3 and Amipro. Escom makes its own 24-pin printers and also supplies Hewlett-Packard, Star, and Epson printers.

Escom announced during 1993 that it would set up an assembling and testing plant for PCs in Irvine, Scotland. The units will be manufactured in Germany. The monitors will come from an Escom joint-venture manufacturing company also based in Irvine. Escom is believed to be selling a large number of PCs into the eastern European countries.

Escom sources most of its components in the Far East and on the spot market; it has its motherboards specially made in Taiwan. The company is also the master distributor for Conner disk drives in Europe through its subsidiary, Peripherals Europe. Escom only produces 486-based PCs. The management of currencies (especially eastern European currencies) is important for Escom, because component suppliers do not compensate for exchange rate fluctuations by changing their prices.

By Andrew Norwood and Mike Williams (Europe)

Q6 What are the activities of the top worldwide monolithic analog players in the Japanese market?

A Table 2 shows 1992 worldwide and Japanese monolithic analog market share rankings. Toshiba ranks No. 4 among the top 10 makers worldwide; three other Japanese companies are also on the list. In the Japanese monolithic analog market, however, Matsushita, which ranks No. 9 in the

Table 2
1992 Worldwide and Japanese Monolithic Analog Market Share Rankings

Company	Worldwide Ranking	Worldwide Share (%)	Japan Ranking	Japan Share (%)
Worldwide Top 10 Makers				
National Semiconductor	1	6.9	15	2.2
SGS-Thomson	2	6.5	22	0.7
Philips	3	5.9	20	1.0
Toshiba	4	5.2	2	9.1
Motorola	4	5.2	10	3.4
Texas Instruments	6	4.8	9	3.9
Sanyo	7	4.6	3	8.8
Analog Devices	8	4.2	13	2.4
Matsushita	9	4.0	1	10.0
Sony	10	3.3	6	7.2
Other Major Japanese Makers				
NEC	11	3.3	5	7.8
Mitsubishi	12	3.1	4	8.3
Hitachi	14	2.4	7	6.2
Rohm	16	2.3	8	5.9
Fujitsu	25	1.1	11	3.3
New JRC	26	1.1	12	2.9
Sharp	34	0.6	16	2.0
Toko	55	0.2	23	0.6
Oki	62	0.2	24	0.6
Seiko Epson	67	0.1	30	0.3
Yamaha	67	0.1	39	0.1
Fuji Electric	75	0.1	31	0.3
Ricoh	79	0.1	37	0.2

Source: Dataquest (December 1993)

worldwide market, leads other makers with 10.0 percent share. Seven major vendors follow Matsushita. Non-Japanese vendors, including the top three worldwide makers, hold meager shares. To boost share in the Japanese monolithic analog market, foreign makers will have to put more emphasis on their specialties.

By Yoshihiro Shimada (Japan)

Q7 How does Dataquest differentiate between computer and embedded applications?

A Computer systems encompass two broad categories—personal computers in both desktop and portable form factors, and business computers, which include workstations, servers, the midrange, mainframes, and supercomputers. However, because microcomponent revenue is largely driven by the volume of systems shipped, not by its resultant revenue, we focus on the PC portion of the computer systems market.

Embedded system applications include all noncomputer types of electronic equipment that use intelligent control but are not reprogrammable by nature (they cannot compile their own code). Thus, embedded systems include printers, communications switching systems, and video games, as well as hand-held devices (personal digital assistants, organizers, and communicators). The central processing units for the vast majority of embedded applications are microcontrollers. However, with more intelligent features being added to all types of electronic equipment and with an increasing focus upon data processing in embedded applications, the use of embedded microprocessors is growing at a rapid clip.

By Jerry Banks

Q8 Many alliances between U.S. and Japanese companies involving RISC-type microprocessor development have been formed during the past several years. What is the current status of these partnerships?

A Table 3 lists the major RISC-related alliances since 1987.

Table 3
Major RISC-Related Alliances

Date	Japanese Company	Partner	Product
7/87	Fujitsu	Sun Microsystems	SPARC RISC
10/87	Kubota	MIPS Computer	MIPS RISC MPUs
9/88	Matsushita	Sun Microsystems	SPARC RISC for Solbourne workstations
10/88	Seiko Instruments	Sun Microsystems	SPARC chip for own workstations
2/98	NEC	MIPS Computer	MIPS RISC MPUs
3/89	Sony	MIPS Computer	MIPS RISC for NEWS workstations
7/89	Hitachi	Hewlett-Packard	PA-RISC chips for workstation
7/89	Toshiba	Sun Microsystems	SPARC RISC for workstation
2/90	Toshiba	MIPS Computer	MIPS RISC MPUs
9/91	Oki	Hewlett-Packard	PA-RISC chips
10/91	Toshiba	Siemens/IDT	MIPS-based RISC
2/92	Kubota	Digital Equipment	Alpha RISC for workstations
3/92	4 Japanese companies	Hewlett-Packard	PA-RISC promotion
4/92	Hitachi	Oki	HP PA-RISC
10/92	NEC/Toshiba	AT&T	Hobbit RISC MPU
3/93	Mitsubishi	Digital Equipment	Alpha RISC MPU
5/93	NEC/Toshiba	Silicon Graphics	Next-generation 64-bit RISC

Source: Dataquest (December 1993)

Sun Microsystems—SPARC

After acquiring Ross Technologies from Cypress Semiconductor, Fujitsu became the second largest supplier of SPARC microprocessors, trailing only Texas Instruments, to Sun-compatible workstation vendors. Although Sun remains the major consumer of all SPARC chips produced, Fujitsu also uses SPARC chips in its own workstation products and appears committed to advancing the architecture, with plans for the company to field a broad range of both merchant semiconductor products as well as computer systems based on SPARC. Although SPARC-based workstations accounted for 37 percent of the worldwide workstation market in 1992, many industry forecasts predict that SPARC will not maintain its market dominance through the end to the decade. In these scenarios, as RISC architectures become viable alternatives to Intel-based CPUs in traditional PC systems, the RISC architectures promoted by larger players with greater software resources will prevail.

Silicon Graphics (SGI)—MIPS

NEC, Toshiba, and Sony are the three primary Japanese companies that have licensed and championed the MIPS RISC design. Of these three, NEC is the only company that is a supplier of both microprocessors and systems that incorporate the MIPS design. Toshiba is a merchant supplier of MIPS CPUs but evidently does not employ them in its machines. Sony, in contrast, has licensed the MIPS architecture for use in its NEWS workstations but does not participate in the MIPS semiconductor markets.

NEC is the largest merchant supplier of MIPS chips. It is manufacturing both MIPS-compatible microprocessors and MIPS-based microcontrollers for embedded applications. It began manufacturing its own spin on the MIPS design with its VR3000 product. Design has progressed to its current top-of-the-line VR4400 generation, which runs at 75 MHz and is used in high-end graphics workstations. NEC supplies processors to Silicon Graphics, Tandem, Digital Equipment Corporation, and its own workstation subsidiary, NEC Technologies. NEC has also developed an embedded version of the architecture, the V800 series, which has design wins in laser printer controller/servers and other low-end applications such as game machines.

NEC last month released a new RISC-based PC that probably is Windows NT-compliant. Being both a vendor and end user of microprocessors often raises conflict-of-interest issues, as NEC must appease its system-maker customers that would probably rather avoid being dependent on a major competitor for their source of CPUs.

Toshiba trails NEC as a MIPS supplier, but this is likely to be by choice. It has elected to hedge its RISC ventures by being simultaneously involved with several RISC camps; it supplies MIPS parts while employing Fujitsu's SPARC and Intel X86 microprocessors in its desktop and portable machine products. Furthermore, there is growing speculation that Toshiba will also soon embrace PowerPC as a merchant supplier of semiconductors, computers, or both. Toshiba supplies MIPS chips to SGI and Acer. It has also allied itself with IDT and QED to codevelop IDT-originated designs of MIPS RISC chips.

Because Sony does not have a merchant MIPS-compatible chip license, it only develops captive use R3000-based chips using an in-house ASIC process. Sony plans to further use these chips in the game machines it will build together with General Magic.

Hewlett-Packard—PA-RISC

Hitachi and Oki have allied themselves with Hewlett-Packard's Precision Architecture design (PA-RISC). Hitachi is shipping at sample levels, and Oki has not yet begun shipping. HP manufactures its own chips. Oki will stake out the low end, Hitachi the middle performance levels, and HP the high-end PA-RISC chips. Also, Hitachi manufactures its own proprietary RISC design, the SH series, which it uses in its own workstation and hard disk controller products. Hitachi and Sega have teamed to use Hitachi's 32-bit RISC microprocessor in Sega's next-generation game machines.

Digital Equipment—Alpha

Although Mitsubishi agreed last March to manufacture Digital's Alpha RISC chips, products have not yet shipped, in part because of very low yields.

IBM/Motorola—Power PC

Toshiba is reportedly negotiating with IBM to license the PowerPC.

By Junko Matsubara

Q9

What is the current estimated use of contract manufacturing relative to in-house printed circuit board manufacturing, and what are your estimates for 1997?

A

Based on recent research of top contract manufacturing users, the 1992 use of contract manufacturing relative to the $96.3 billion total was 21.2 percent. This percentage is expected to grow to 30 percent of the estimated $130.4 billion 1997 market because of increased capital expenditure costs and reduced product life cycles, which make contract manufacturing an increasingly viable manufacturing option.

By Mark Giudici

Q10

Please provide a brief profile of Promex.

A

Promex PWS Enterprises Inc. is located at 3075 Oakmead Village Drive, Santa Clara, California 95051, telephone (408) 496-0222, and fax (408) 496-0117.

The president is Bill Stansbury. Products are multichip modules, hybrids, and SMT/mixed technology. The facility is 30,000 square feet. There are 85 employees. Revenue was less than $5 million in 1992.

Promex of PWS Enterprises Inc. was formed in 1977. It offers fully automated manufacturing expertise in the production of multichip modules, hybrid circuits, SMT, COB, and semiconductor assembly. Promex is a quick-turn contract assembly house, with 85 percent of company sales generated in the United States.

By Mary A. Olsson

NO1SEM1WW SCNDWW1S9312 BH: 1 N: 1
Mr. Clark Fuhs
Dataquest Incorporated
1-1100
****
SJ - INTERNAL DISTRIBUTION
****

For More Information...

Rick Spence, Industry Analyst .... (408) 437-8642
Via fax .... (408) 437-0292

Dataquest®
a company of The Dun & Bradstreet Corporation

Q&A Dataquest Inquiry Summary

Semiconductors

November 1993

Contents

Dataquest®
a company of The Dun & Bradstreet Corporation

Program: Semiconductors
Product Code: SCND-WW-IS-9311
Publication Date: December 6, 1993

Products

Q1

What strategic trends do you see as far as maintenance of 1Mb and 4Mb DRAM production rates as the market moves forward to increasing 16Mb production in 1994?

A There are several trends, and we believe that the industry is set to simultaneously serve all three generations more smoothly than ever before.

Most of the capacity originally intended for 16Mb is running 4Mb shrinks and will gradually be brought over to 16Mb production as the 16Mb market (which has been slow to advance) gathers momentum in 1994. We count 18 facilities in this group, with major opportunities for expansion, filling out vacant modules, and ramping into full utilization, among others. We expect a smooth transition from 4Mb to 16Mb because of this large reservoir of "dual-use" facilities.

With the strength of the 4Mb market in 1993, many producers reduced 1Mb production in favor of 4Mb, but perhaps not so much as in prior cycles. The 1Mb market remains profitable and is declining in demand only very slowly. There is, and will be in 1994, a vibrant aftermarket for SIMM upgrades that depend on 1Mb DRAMs. The still ubiquitous parity bit, although under some pressure, will probably be with us for a long time.

We are starting to see some discussions and activities in increasing cooperative production-sharing of either 1Mb or 4Mb DRAMs, either on a private label, foundry, or joint-venture-type operation. Hyundai's recently announced agreement with Fujitsu for DRAM production in Gresham, Oregon is just a single example, but Hitachi has been making broad use of Goldstar and Nittetsu SC for DRAM production for some time, and GoldStar also makes DRAMs for Siemens and Motorola. (Advanced Micron Devices and Intel in EPROMs, in particular, have used this strategy in the past.) Many DRAM makers seem intent on serving the residual 1Mb market longer than earlier generations and will surely persist in the 4Mb market as well. Clearly, the market does not turn over to the new generation as rapidly as it did in earlier periods, largely because each generation of DRAM chip capacity is outstripping system memory demand trends, and price parity between generations is coming more slowly.

As we move into 1994, look for more shared production deals in DRAMs as companies more freely cross corporate boundaries to efficiently use the overall available industry capacity.

By Lane Mason

Q2

What does the total DRAM capacity within the U.S. borders look like as we approach year-end 1993?

A Counting IBM, which is increasingly active in the merchant market with 4Mb and 16Mb products, we believe that December's monthly run rates are about 11 million of 1Mb, 16 million of 4Mb, and 700,000 of 16Mb DRAM from all sources (see Table 1). There are steady but small

Table 1
U.S. Fabs That Make DRAMs, Year-End 1993 Capacity and Production Rates

Company	Location	Fab Name	DRAMs	Other Products	Design Rule (µm)	Wafer Size (mm)	Capacity (Wafer/Mo.)	Estimated DRAM Production (Units per Month)
Fujitsu	Gresham, OR		1Mb, 4Mb		0.7-0.8	150	13,000	1Mb (2M)
Hitachi	Irving, TX		4Mb	SRAMs, MPUs	0.7-0.8	150	12,000	4Mb (2M)
	Irving, TX (expansion planned)		16Mb		0.5	200	Planned	Planned
IBM	Burlington, VT		4Mb, 16Mb	Many	0.5-0.6	200	40,000	4Mb (3.5M)
	Burlington, VT					200	20,000	16Mb (500K)
Matsushita	Puyallup, WA		1Mb		0.7-0.8	150	15,000	1Mb (2M) 4Mb (150K)
Micron SC	Boise, ID	Fab 1, 2	1Mb, 4Mb	SRAM, VRAM	0.6-0.8	150	70,000	1Mb (5M, Including VRAMs)
	Boise, ID	Fab 3	1Mb, 4Mb, 16Mb			150	(Total)	4Mb (5.5M)
Mitsubishi	Raleigh-Durham, NC		1Mb, 4Mb*	ASICs	0.7	150*	12,500	4Mb (1.5M)
NEC	Roseville, CA	K-Line	256K	ASIC, MPU	0.8	125	25,000	256K (1.5M)
NEC	Roseville, CA	M-Line	4Mb, 16Mb		0.5	150	20,000	4Mb (3.2M) 16Mb (100K)
Oki	Tualitin, OR		Back-end only at present			Planned	NA	No fab yet
SGS-Thomson Microelectronic	Carrollton, TX		256K	SRAM, Logic	0.6	150	20,000	About 0
Texas Instruments	Dallas, TX	DMOS 4.2	1Mb, 16Mb	MPUs, DSPs	0.55	150	6,000	1Mb (2M) 16Mb (100K)
Toshiba	(Planned in Oregon)		DRAMs	ASICs	0.5	200	Planned	Planned
Motorola	None							
MOSel-Vitelic	None							
Siemens	None							
Korea Inc.	None							
Sanyo, Sony, Sharp	None							

*Unconfirmed
NA = Not available
Source: Dataquest (November 1993)

increments of capacity coming online in 1994 from announced expansions at Micron, Hitachi (Irving, Texas), and probably from IBM. But the biggest DRAM producers, led by the Japanese, are still cautious in their expansion plans, and Texas Instruments' expansion, so far, has been mostly in the Far East. If market demand grows as we expect, North America will have to import more of its DRAM requirements in 1994.

By Lane Mason

Q3

What is the material cost for 1Mb and 4Mb DRAMs?

A

Table 2 shows the material cost of silicon wafer and photoresist used for a chip. The table assumes a 6-inch wafer size, die sizes of 50 sq. mm. for 1Mb DRAM and 90 sq. mm. for 4Mb DRAM, and a photoresist dispense volume of 1.7cc per wafer per mask.

Table 2
Material Costs for 1Mb and 4Mb DRAM

	1Mb DRAM	4Mb DRAM
Silicon Wafer Cost		
Wafer Price (¥)	4,500	4,600
Gross Die per 6-Inch Wafer	245	133
Wafer Cost per Chip (¥)	18.4	34.6
Device ASP (¥)	380	1,300
Wafer Cost/Device (%)	4.8	2.7
Photoresist Cost		
Mask Steps	16	20
Resist Consumption/Wafer (cc)	27.2	34.0
Resist Cost/Wafer (¥)	359	449
Gross Die per 6-Inch Wafer	245	133
Resist Cost/Chip (¥)	1.5	3.4
Device ASP (¥)	380	1,300
Resist Cost per Device (%)	0.39	0.26

Source: Dataquest (November 1993)

By Kunio Achiwa (Tokyo)

Markets and Applications

Q4

What is the current status of personal communications networks in Europe?

A

There are two PCN networks for the United Kingdom, one network called "One 2 One" run by Mercury and U S WEST, and a second network called "Microtel" run by Hutchinson Telecom (with some small share holding from Barclays Bank and British Aerospace).

The original handset suppliers to One 2 One are Motorola and Siemens. Nokia became a third supplier by the end of 1993. Handset pricing is $375 for Siemens, $450 for Motorola, and $450 for Nokia. These prices are heavily subsidized by Mercury. We estimate that the level of subsidy is 50 percent (that is, the cost to Mercury is twice the price the customer pays; the subsidized price is only available as part of an air time contract).

The Microtel network will use telephones provided by Nokia. The Microtel network is due for launch in spring 1994. The network is proposed to cover 90 percent of the population of the United Kingdom when launched, essentially covering all major towns and cities.

The "E" network in Germany, E-Plus, is expected to be operational by early 1994. The operators of E-Plus will be Thyssen and Veba. Initially the service will be based in major cities, but eventually will roll out to cover other parts of the country, especially in the eastern states of Germany. Nokia is the planned supplier of handsets to E-Plus.

France has agreed in principle to allow a DCS1800 PCN network to go ahead, but no network operator has been chosen and no launch date for a service has been decided.

The suppliers of PCN chipsets are very similar to GSM suppliers. The major differences between these standards that affect device selection are the frequency of transmission (1.8 GHz rather than 900 MHz for GSM), and that the transmitted power output for a PCN handset is significantly lower than for a GSM handset.

The major handset suppliers are putting severe price pressure on semiconductor suppliers to reduce component pricing. We expect the 1997 semiconductor content in a GSM phone to be less than the original Dataquest forecast of $80. The RF section for PCN telephone will be more expensive than GSM because of the higher operating frequency at 1.8 GHz, but the transmitted power output is less, so the price premium for 1.8 GHz over 900 MHz will not be too great.

There are also product trends to make phones dual standard, as follows:

- GSM- and PCN-compatible although these seem appropriate for non-European markets
- GSM and DECT
- PCN and DECT

GSM/PCN chipset suppliers are as follows:

- Cirrus (PCSI)
- Siemens
- Sony
- Philips

- AT&T
- Hitachi
- Fujitsu
- Texas Instruments
- Analog Devices
- VLSI Technology
- Motorola
- LSI Logic
- Toshiba
- SGS-Thomson
- AMS

By David Moorhouse (United Kingdom)

Q5 What impact will Intel's recent flash memory announcements have on pricing trends?

A On October 27 Intel announced its next-generation of 16Mb and 32Mb flash memory technology. Intel outlined its flash memory strategy and the supply-demand outlook for device densities of 1Mb through 8Mb. Intel's announcement—along with recent announcements from Advanced Micro Devices, Samsung, and Matsushita—generated a series of inquiries on flash memory price trends.

Prior to Intel's announcement, the results of Dataquest's Semiconductor Procurement service's (SPS) third-quarter 1993 survey of North American quarterly bookings pricing had signaled the start of a downward trend in flash pricing by fourth-quarter 1993 or early 1994. Dataquest conducted the survey during August, and SPS published the forecast in its *Pricing Trends* document entitled "North American Price Outlook: Fourth Quarter 1993," dated September 20, 1993 (SPSG-WW-PT-9302).

For example, SPS' September 1993 forecast called for a 40 percent decline in North American pricing for the 128Kx8 flash device from the fourth quarter of 1993 to the fourth quarter of 1994. This pricing applies to 10,000-unit volumes of 12V parts in the PDIP or PLCC package. The quarterly price curve for this 1Mb part should drop from more than $6 to less than $4 during this period.

(SPS will perform the fourth-quarter 1993 survey during November and publish the results in December.)

Intel's strategy calls for a lowering of the flash price curve but not a DRAM-type pricing war. With its flash fab network now ramping up, Intel's strategy over the short term should place the most direct pressure on 1Mb and 2Mb device pricing. For example, Intel's Fab 7 in Albuquerque, New Mexico has already started to achieve 1Mb and 2Mb cost reductions with supply ramping. Intel's flash memory competitors closely monitor the market's response.

Intel has forged a somewhat "multidimensional" flash memory pricing strategy. Intel will exert pricing pressure on its flash memory competitors. However, the flash pricing curve also depends on trends outside the flash market. Intel envisions that flash will "eat into" the DRAM, hard disk drive, and floppy drive markets. Intel's pricing strategy for flash will depend as much on these market trends as the competitive trends in the flash arena.

For example, Intel prices the 8Mb device (10,000-unit volume) at slightly less than $30—which is competitive to the volume price for the equivalent density of a DRAM-based SIMM. Intel will certainly monitor SIMM pricing but also watch hard disk drive pricing. Intel will price its flash-based products to be competitive against lower-density hard drives in addition to DRAM-based SIMMs. For example, Intel will price its newly announced 5MB flash drive next year at $60 per megabyte (1,000-unit volume). This pricing makes it a cost-competitive alternative to hard drives.

How would Intel respond if a DRAM price war occurred during the next year or so? Intel likely will remain competitive with DRAM pricing but not engage in that kind of pricing. Intel envisions that flash will take some total available market from DRAM, hard drives, and floppy drives. By contrast, Intel does not expect flash to totally usurp the DRAM or magnetic drive markets. Because flash does not face an either-or battle against DRAM, there will be no need to settle the technology war via a price war.

By Ronald Bohn

Company and Other Issues

Q6 Who purchased Philips Circuit Assemblies?

A Philips Circuit Assemblies of Tampa, Florida, with estimated sales of $90 million, was purchased from Philips Electronics North America by Group Technologies Corporation of Tampa, Florida. The purchase was finalized July 1993.

As of year-end 1993, Group Technologies is ranked as the fifth largest contract manufacturer in the world. Purchase of the Philips facility now boosts its manufacturing site profile to 560,000 square feet over three facilities. Group Technologies now has two locations in Tampa and another subsidiary from a 1992 acquisition, Metrum Inc., based in Denver. The Denver site has a 100,000-square-foot facility. The Metrum subsidiary supports the instrumentation, tape storage, and color imaging products for Group Technologies. The company now employs 2,200 people.

Founded in 1989, Group Technologies Corporation is a subsidiary of Group Financial Partners. Sales have grown from $80 million in 1989 to

$250 million for 1993. Its customer base is split at about 65 percent commercial and 35 percent military. Group Technologies Corporation was originally founded in 1965 as Honeywell Corporation's Defense Communications and Product Division.

The company's market structure is to focus on three core competencies: secure communications technologies, manufacturing capabilities, and ruggedized products. Its products include rugged hand-held computers, communications security equipment, data encryption/decryption devices, and secure telephone conferencing. Group Technologies is a full turnkey contract manufacturer. Its assembly capabilities include 10 surface-mount and 6 leaded through-hole production lines, box level assembly lines, as well as controlled areas with FAA, FDA, and mil-spec qualifications, and ISO 9001 certification. Test capabilities include component, printed circuit assembly, and environmental stress screening. Group Technologies also supports a complete CAD/CAM center.

The management team is as follows:

- Carl McCormick, president and chief executive officer
- Jack Calderon, vice president, Business Development
- Dr. Avi Margalith, vice president, Engineering
- Willie Little, Jr., vice president, Finance
- Jerry Hurley, vice president, Operations
- John Brennan, president, Metrum

By Mary A. Olsson

Q7

Who are the major rechargeable battery suppliers in the world?

A The following is a noninclusive worldwide listing of the major battery suppliers:

- Duracell
- Eveready
- Mallory
- Varta
- Tadiran
- Maxell
- Rayovac
- AER Energy
- Panasonic
- SAFT
- Sony

- Valence
- Gates
- VST Power Systems
- Portable Energy Products
- Toshiba
- General Electric
- Sanyo Energy
- Asahi Chemical
- Phoenix Energy

Most of the rechargeable developments in batteries are coming from Japan and, lately, the U.S. regions. Japanese suppliers are primarily focusing on lithium-based cells, while U.S. suppliers are developing Ni Hydride and other types of storage (that is, low-cost lead-acid cells, long-life zinc air batteries). European suppliers continue to focus on NiCad and the green Ni Hydride technologies.

By Mark Giudici

NO1SEMIWW SCNDWW1S9311 BH:

Mr. Clark Fuhs
Dataquest Incorporated
1-1100
****
SJ - INTERNAL DISTRIBUTION
****

For More Information...

Rick Spence, Industry Analyst .... (408) 437-8642
Via fax .... (408) 437-0292

Dataquest®
a company of
The Dun & Bradstreet Corporation

Q&A Dataquest Inquiry Summary

Semiconductors

October 1993

Contents

Products

Company and Other Issues

Dataquest®
a company of The Dun & Bradstreet Corporation

Program: Semiconductors
Product Code: SCND-WW-IS-9310
Publication Date: October 25, 1993

Products

Q1

What is the short- and long-term outlook for the standard logic product family?

A The overall supply-demand picture is that the supply of standard logic has plateaued while demand continues to grow because of the lack of an economical, quick-turn alternative solution. The overall supply has flattened as a result of the unprofitable nature of the commoditized logic market. For practical purposes, there are only six broad-based bipolar/CMOS standard logic suppliers: National, Motorola, Texas Instruments, Philips, SGS-Thomson, and Harris. We have not heard of any new suppliers or additional capacity being put in place to address the current allocation situation, so we expect the situation to worsen still before it improves. (This assumes that end demand for PCs continues at its steady pace.)

If demand for PCs softens toward the end of this year or in early 1994, allocations of standard logic will diminish, but the overriding supply-demand dynamic will remain. Alternatives for current standard logic are the "value-added" advanced BiCMOS products offered by most of the larger suppliers, TTL PLDs (both limited supplier bases), FPGAs (expensive), or full-scale gate arrays (long design-in). Prices for most logic devices have risen since our forecast and will continue to rise by 5 to 20 percent from 1993 to 1994 because of the supply situation described.

By Mark Giudici

Q2

What has happened to semiconductor inventories in the past month, and has this had any effect on the sales of ASICs?

A Semiconductor inventory levels (all OEMs) remained relatively stable between August and September, significantly below the value posted for July. The swing in inventory from July to August did not have a large impact on the industry, and the following stability in the August-to-September time frame helped some ASIC vendors post record third-quarter calendar year revenue. Diversification in many application markets has helped the MOS ASIC market continue its growth, which is expected to top 16 percent for 1993. In regard to programmable logic, where inventories are of greater concern, we have also seen strong growth. In response to a normal slowdown in the calendar third quarter, at least two suppliers have posted record revenue while others have posted gains. For more information on the ASIC forecast, see the 1993 fall edition of the *Worldwide ASIC Forecast*, dated September 27 (ASIC-WW-MS-9303).

By Duane Kuroda

Company and Other Issues

Q3 What is the market background and outlook for Aspec Technology, the ASIC start-up?

A Aspec Technology, a fabless ASIC start-up, recently briefed Dataquest on its strategy, technology, and objectives. The company offers ASIC design tools, products, and services. The 1992 start-up's headquarters are in Santa Clara, California.

Conrad Dell'Oca is president and chief executive officer. While serving as LSI Logic's R&D director during the 1980s, he led LSI's move into the "sea of gates" segment of the ASIC market.

Business Model

The start-up pursues a licensing-and-partnering strategy. Aspec's licensing strategy will include the following:

- Product line to OEMs—primarily of PC and peripherals
- Technology to IC manufacturers like Samsung and Sanyo

Aspec gears the business model to customers that seek independence from proprietary ASIC technology, software, and single-sourcing. Aspec either designs the ASIC for the OEM customer or licenses its software with the OEM designing the ASIC. The OEM customer goes to licensed foundry sources—Samsung and Sanyo to date—for final product manufacturing. Aspec expects more foundry sources to emerge.

Aspec calls the patented technology "high-density architecture" (HDA). The 0.8-micron CMOS process permits up to 500,000 available gates. Aspec's strategy focuses on these factors, among others: low cost, rapid time to market, and multiple sources.

The HDA product portfolio includes a full range of gates, masterslices, embedded arrays, custom masterslices, macrocells, I/O cells, macrofunctions (74xxx TTL), megafunctions, and compilers (cell, chip, function).

Applications thus far include PC devices, video games, graphics controllers, multimedia products, and Windows accelerators.

The Outlook

Does the brutally competitive gate array business need another player? Perhaps "no" regarding new players with huge 0.8-micron fabs. Aspec's fabless strategy, however, could parlay continuing ample capacity in the gate array segment into a win for buyers, foundry partners, and itself. For example, Aspec claims a smaller die size, for example, from 17 percent to 25 percent smaller than LSI's die. Aspec's foundry partner, Samsung of Korea, targets long-term growth in the global ASIC business and has already demonstrated an ability to deliver competitive IC technologies such as DRAMs in timely fashion at very competitive pricing. Buyers—especially those that work for PC and peripherals companies—will carefully evaluate an opportunity for lower costs and increasing profits. In a similar vein, another foundry partner, Sanyo of Japan, strives during the 1990s to be like Toshiba. Last decade Toshiba vaulted—via a technology alliance with LSI Logic—to worldwide market leadership in ASICs.

These three partners expect aggregate 1993 bookings to reach $100 million. Most design-ins today emanate from the Silicon Valley. If the partners successfully execute on manufacturing and design-in plans during 1994, Aspec might pave a new business strategy in the global ASIC market during this decade.

By Ronald Bohn

Q4

What are the Japanese semiconductor capital spending trends in 1993?

A

The year 1992 was difficult for the Japanese semiconductor industry, and semiconductor capital spending in Japanese market decreased 30.6 percent over 1991 on a yen basis (calendar year). Most Japanese semiconductor manufacturers attribute the drop to declines in their revenue and profits. However, Dataquest expects semiconductor capital spending in Japan to recover in 1993 and increase by 5.6 percent, compared with 1992. The main targets of the investment in 1993 will be expanding existing DRAM lines and advanced technologies such as flash memory, 64Mb, and 256Mb DRAM. Nevertheless, most Japanese companies are expected to invest smaller amounts in 1993. Table 1 shows worldwide capital spending estimates of the major Japanese companies.

Table 1
Worldwide Capital Spending Estimates for Major Japanese Semiconductor Manufacturers (Billions of Yen)

Company	1992	1993
Toshiba	85.0	80.0
Fujitsu	71.3	79.5
Hitachi	65.0	75.0
NEC	77.5	70.0
Mitsubishi	60.0	50.0

Source: Dataquest (October 1993)

By Kun Soo Lee

Q5

What is the average ASIC NRE charge per design in Japanese market?

A

ASIC NRE charges depend on design methodologies, by which the devices are manufactured. Table 2 shows the average NRE charge and development term for each methodology in Japan.

Table 2
Average NRE Charges in Japan

	Gate Array	Cell-Based IC	Full-Custom IC
Average NRE (¥M)	3	7.5	16
Average Development Term (Months)	0.5 to 1.0	2.5 to 3.0	5.0 to 6.0
Average Gate Count	8K	13K	25K

Source: Dataquest (October 1993)

By Satoru Oyama

Q6

What is the current status of Austria Mikro Systeme International?

A

Austria Mikro Systeme International (AMS), located in Unterpremstatten, Austria, was recently transferred out of the Austrian government-owned Austrian Industries group. The Austrian Industries group transferred its 26 percent share of AMS to the Austrian government's financial holding company OIAG in September. AMS produces mixed-signal ASIC devices, and ISDN components for fiber-optic and SONET applications. AMS recently purchased $1 million worth of Synchro Plus test systems from LTX Corporation. Nokia is AMS' largest customer, representing more than 25 percent of AMS' business revenue.

By Mary A. Olsson

Q7

What is the difference between software being run in emulation versus native mode?

A

When a software application can be run in native mode, it was written specifically for the instruction set of a certain microprocessor. For example, the MS-DOS operating system, the graphical user interface Windows, and the applications that run on DOS or Windows are all written for the x86 instruction set. These programs run on an x86 microprocessor in native mode. There is no need to emulate or interpret any of the instructions. In native mode, the entire power of the processor can be brought to bear on the application rather than have it spinning its wheels performing an emulation. Any microprocessor that has a different instruction set would be forced to "emulate" the x86 instruction set. Basically, this means that the non-x86 microprocessor would have to implement one or more of its own instructions to emulate each x86 instruction. As a best case, emulating the x86 instruction set on another microprocessor would result in a serious degradation in performance when compared to that same processor running in native mode. In a worst case scenario, it is possible that specific x86 instructions cannot be practically emulated.

"Architecture-independent" operating systems, such as Windows NT, are being developed to alleviate the emulation bottleneck. Although we are still a ways off from having a completely level playing field, it does seem inevitable that such a leveling will take place within the next few years, at which time we will see operating systems and applications that will run on a multitude of microprocessor architectures in native mode.

By Jerry Banks

Q8

Can you briefly sort out the different 486 manufacturers and explain which manufacturers offer SX versus DX versus clock doubling/tripling, and also which parts are pin-compatible?

A

There is a lot of confusion in the marketplace today about who offers what in terms of microprocessors. This is particularly true in the case of the x86 architecture. We will "briefly" attempt to address this issue in Table 3.

Table 3
486 Product Offerings by Company

	Intel	AMD	Texas Instruments	Cyrix	IBM
486 Instruction Set					
486SX (without Floating Point)	X	X	X	X	X
486DX (with Floating Point)	X	X		X	
Pinout					
i486SX	X	X			
i486DX	X	X		X	
386SX			X	X	X
386DX			X	X	
Proprietary			X		X
Clock Multiplication					
486SX2			X		X
486SX3					X
486DX2	X	X		X	

Source: Dataquest (October 1993)

By Jerry Banks

N01SEMIWW SCNDWW1S9310 BH: 1 N: 1
Mr. Clark Fuhs
Dataquest Incorporated
1-1100
****
SJ - INTERNAL DISTRIBUTION
****

For More Information...

Rick Spence, Industry Analyst .... (408) 437-8642
Via fax .... (408) 437-0292

Dataquest
a company of The Dun & Bradstreet Corporation

Q&A Dataquest Inquiry Summary

Semiconductors

September 1993

Contents

Products

Markets and Applications

Technology

Company and Other Issues

Dataquest®
a company of The Dun & Bradstreet Corporation

Program: Semiconductors
Product Code: SCND-WW-IS-9309
Publication Date: September 27, 1993

Products

Q1 How will the rapid appreciation of the yen against other currencies affect Japanese semiconductor manufacturers?

A In the third week of August, the Japanese yen nearly reached parity with the U.S. penny. While the yen has been continuing to appreciate for some time, which is a natural economic reaction to a trade imbalance, the particularly high level of appreciation has caused alarm in many circles, both in Japan and abroad. As a trade balancing mechanism, appreciation of the yen would normally be expected to cause an increase in imports to Japan, because of the increased purchasing power of the yen, which in turn would create a more desirable balance of payments for Japan and its trading partners. However, many individuals and companies will take a cautious approach to capital spending in a recessionary or postrecessionary state, even with an appreciating yen. Although most in Japan probably would like to stimulate the economy by consuming more, fear of not knowing how long the recovery will take has resulted in conservative spending, a behavior that tends to make recovery self-limiting. The yen's appreciation is a mixed blessing for Japanese industries. While many of their foreign purchases, including investment in offshore manufacturing sites, are becoming more affordable, Japanese exports are simultaneously rising in cost relative to their foreign customer's buying power.

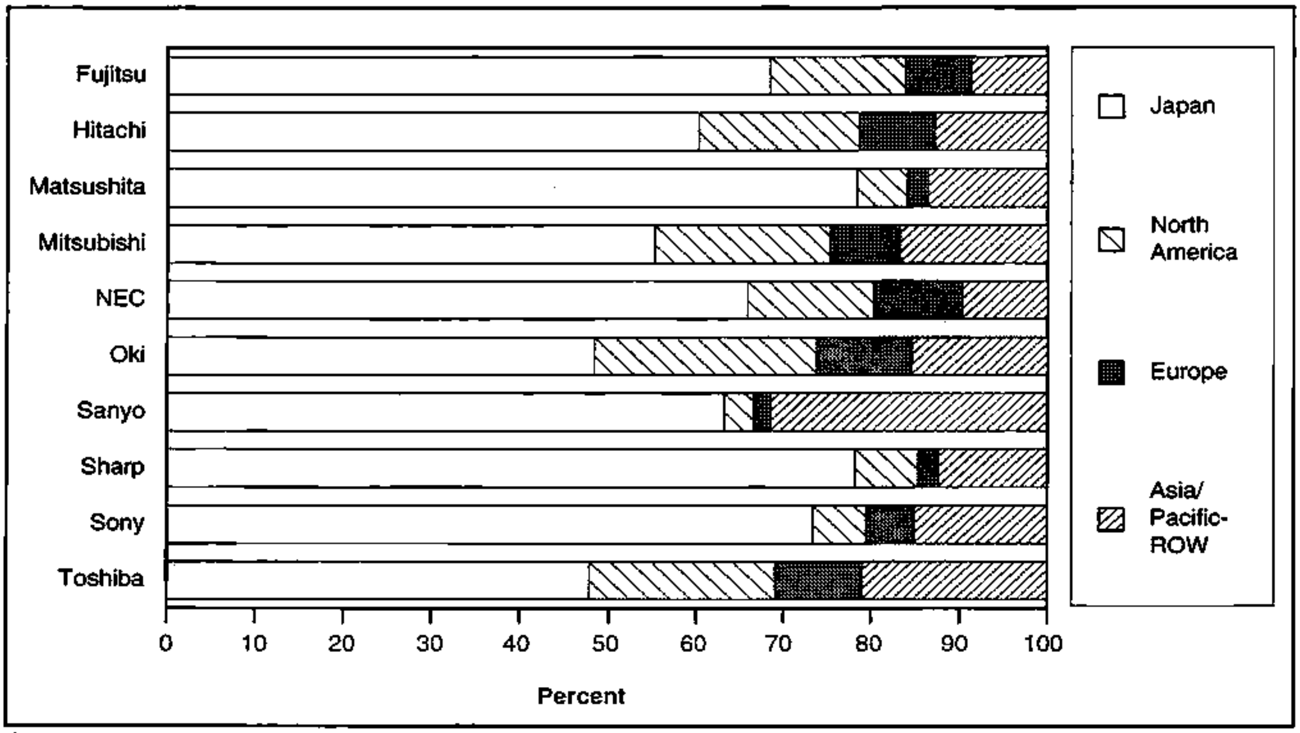
Hence, major Japanese industries such as the automobile, steel, and electronics industries are struggling with the dilemma of how best to continue selling products to trading partners whose buying power has been substantially diminished by appreciation of the yen. Furthermore, in the short term, the Japanese government is also concerned that the rise in the yen will magnify the current trade surplus as expressed in foreign currency. Trading practices are already a controversial issue of both the outgoing Miyazawa and incoming Hosokawa administrations, without the added pressures brought on by a rising yen.

Figure 1 shows the top 10 Japanese semiconductor manufacturers with their 1992 semiconductor sales by four regional areas. All of the top 10 companies listed have significant portions of their semiconductor revenue derived from overseas markets. Companies such as Oki and Toshiba sold more than half of their semiconductor chips in foreign markets during 1992.

The appreciation of the yen has already led to price increases on some Japanese chips, which has resulted in erosion of their market share. However, demand for DRAMs is generally greater than supply because the booming PC markets in the United States and parts of Europe are fueling demand for 4Mb and even 1Mb parts. There is also some apprehension that the recent explosion at the Sumitomo Chemical resin material facility will exacerbate the DRAM shortage in the near future. Nevertheless, Japanese DRAMs are found to be more expensive, and hence less cost competitive, than similar parts from Korean competitors.

Since the last peak in the value of the yen, which occurred during 1986, many Japanese semiconductor manufacturers have established manufacturing sites overseas, partly to insulate them from international economic conditions or fluctuations in currency markets. Many Japanese companies are upgrading or shifting offshore facilities from assembly and test-type operations to even more advanced front-end productions in order to

Figure 1
Top 10 Companies Sales by Region



Source: Dataquest (June 1993)

G3000705

further transfer capital-intensive operations offshore and thus reduce the yen cost of the final product. In fact, the trend to move semiconductor facilities offshore is so prevalent that there are those that now fear that a manufacturing
vacuum will soon exist in Japan

By Junko Matsubara

Q2

How is the market for 3V SRAMs shaping up?

A Most SRAM manufacturers have a wide range of 3V parts screened from their 5V standard SRAMs. Very few have 3V designs, and the only SRAMs shipping that have been designed for 3V are fast parts aimed at cache designs for 3V versions of the Advanced Micro Device 386 or Intel 386SL.

We have been told by other manufacturers that the market for 3V SRAMs is developing very slowly, despite a long sampling period. It appears that other issues are taking up the majority of the notebook PC designers' attention, including backlighting and hard disk drive power usage. As a result, the majority of today's 3V market appears to be in smaller battery-operated equipment such as pagers and inventory terminals. These applications use slow SRAMs.

SRAM manufacturers tell us that they do not plan to offer 5V versions of their 16Mb density parts. Before this, 5 percent to 7 percent of this year's SRAM revenue was expected to come from sales of 3V 256K and 1Mb slow SRAMs. This will ramp to 12 percent of the total market by 1995, with the majority of the difference between 1993 and the level for 1995 being made up of the 4Mb density.

By Jim Handy

Q3

Who are the manufacturers of static RAM, and what do they each do best?

A To say that the SRAM market is fragmented is an extreme understatement. The $3 billion market is shared among 52 vendors. Table 1 identifies each vendor, along with their estimated 1992 revenue and target market.

Table 1
Players in the 1992 SRAM Market

Company	1992 SRAM Revenue ($M)	Product Portfolio	Notes
Advanced Micro Devices	14	FIFO	
Alliance	12	64K/256K fast	
Atmel	2		
AT&T	33	64K/256K fast	Phasing out
Austin	NA	Mil Rel	Special test house specializing in military
Benchmarq	NA	Battery backup	

(Continued)

Table 1 (Continued)
Players in the 1992 SRAM Market

Company	1992 SRAM Revenue ($M)	Product Portfolio	Notes
Chip Supply	NA	Screened dice	Special test house specializing in die level
Cypress Semiconductor	119	1K/4K/16K/64K/ 256K fast	
Dallas	NA	Battery backup, FIFO	
Electronic Designs Inc.	20	256K/1Mb fast	Repackage other companies' products
Elmo	NA	Modules only	
Fujitsu	245	Broad	
Goldstar	37	64K/256K slow	
Harris	16	Military	
Hitachi	494	Broad	
Hualon	6		
Hyundai	99	64K/256K slow	
IBM	NA	Broad	Captive use only
IC Works	NA	64K/256K fast	
Integrated Device Technology Inc.	61	16K/64K/256K fast	
Intel	12		
ISSI	NA	64K/256K fast	
Logic Devices	4	16K/64K/256K fast	
Matra MHS	37	16K/64K/256K fast	
Matsushita/Panasonic	21		
Micron Technology	111	64K/256K/1Mb fast	Reducing production to favor DRAMs
Mitsubishi	162	Broad	
MOSel/Vitelic	52	Broad	
Motorola	222	256K/1Mb fast	
National Semiconductor	13	64K/256K fast	Resell product from other manufacturers
NCR	2		
NEC	264	Broad	
NKK	0	256K fast	New fab alliance with Paradigm
Oki	17		
Paradigm	25	256K/1Mb fast	
Performance	16	4K/16K/64K/256K fast	
Quality	8	16K/64K/256K fast	
R-Ohm	10		
Samsung	170	Broad	Aiming at No. 1 position in 1997
Sanyo	48		

(Continued)

Table 1 (Continued)
Players in the 1992 SRAM Market

Company	1992 SRAM Revenue ($M)	Product Portfolio	Notes
SGS-Thomson	18	16K/64K/256K fast	
Sharp	123	256K/1Mb fast	Focus on high speed and density
Seiko-Epson (S-MOS)	35	256K/1Mb slow	
Silicon Integrated Systems	3		
Sony	179	256K/1Mb	Focus on high speed and density
Synergy	NA	ECL I/O	
Texas Instruments	4	Cache-tags, FIFO	
Thunderbird	NA	Experimental	Have patent on innovative fast SRAM technology
Toshiba	261	Broad	
United Microelectronics Corporation	32	64K/256K fast	Focus on Asia/Pacific market
UTMC	NA	Rad-hard	
Vitesse	NA	GaAs 4K	No silicon components
White	NA	Military only	Repackage others' dice
Winbond	35	64K/256K fast	Focus on Asia/Pacific market

NA = Not available
Source: Dataquest (September 1993)

By Jim Handy

Q4

Who makes pseudostatic RAMs (PSRAMs)? What kind of applications use these parts?

A

There are two users of PSRAMs in North America, and two suppliers. The two suppliers are Hitachi and Toshiba. NEC dropped out of the market last year, and two other vendors, Samsung and Sharp, appear not to have successfully penetrated the market. The two users are Apple Computer and Hewlett-Packard.

PSRAMs are simply self-refreshing DRAMs in a pinout convention matching that of the next-density SRAM. These devices offer bit densities equivalent to those of DRAMs with the ease of design of SRAMs. It is hard to imagine that such a device, which has been available since the mid-1970s, has never gained widespread popularity.

Applications that use PSRAMs not only take advantage of their density, but also of the devices' low price per bit and low power consumption. PSRAMs are designed for low power consumption more than are DRAMs, partly because the refresh circuitry is inside the chip, putting the power consumption wholly under the control of the chip designer. As a result, PSRAMs find their widest use in laptop computers, where the computers use hard disks for mass storage and operate from batteries. This configuration is important to note because execution of disk-resident programs lends itself to PSRAMs and DRAMs, while the execute-in-place approach used by systems without disk storage, such as PCMCIA and PDAs, lends itself more to the use of nonvolatile memories and standard SRAMs.

Most PSRAM manufacturers expect interest in this part to wane in the near future in deference to self-refreshing DRAMs, which use an equivalent technology with a DRAM-like pinout and will put low-power and low-price-per-bit parts into a lower-pin-count package, thus easing space consumption.

By Jim Handy

Q5

Recent SRAM pricing is very peculiar. 4Mb DRAMs are selling at higher prices than are 1Mb SRAMs (even though the manufacture of each of these is about equivalent in complexity and cost), and 256K SRAMs have undergone phenomenal price fluctuations. What does Dataquest make of this?

A

The SRAM market is not behaving completely rationally, so certain prices are going to see dramatic adjustments at the end of this year and the beginning of next year. Expect slow 1Mb SRAMs to move up to $12, and slow 256Ks to return to the $4.25 level, where they were until May 1993. Allocation is already in effect for these parts, and all suppliers outside of Korea that produce both DRAMs and SRAMs are shifting their capacity away from SRAMs. If Japan comes out of its recession by the middle of next year and starts to consume 1Mb SRAMs in consumer electronics at the pace that would be expected in a healthy economy, and if supplies of 1Mb SRAMs remain less than those necessary to support the rest of the world, there should be a tremendous shortage of these devices in 1994.

Dataquest believes that the Japanese consumer electronics market has delayed the introduction of new designs using 1Mb SRAMs until the country's economy improves, and once that happens, all the new designs based upon the 1Mb density will suddenly ramp quickly. Naturally, Japanese suppliers can be expected to support their domestic market first, causing the most severe shortages to occur in the United States. This could be a very good opportunity for Korean manufacturers.

By Jim Handy

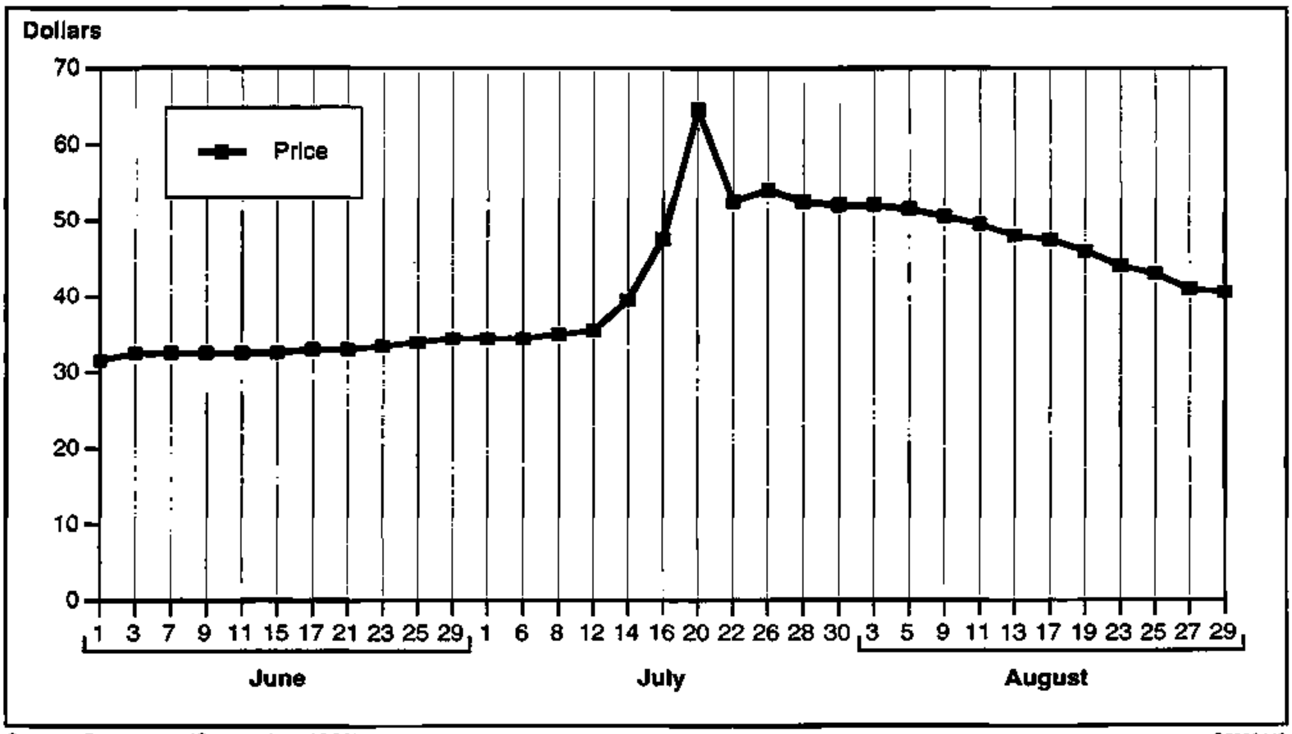
Q6

What was the effect of the Sumitomo resin fire on the 1Mbx9 (three-chip) U.S. spot market SIMM price?

A

Figure 2 shows the volatility of the spot market. The spot market price for the standard 1Mb SIMM rose more than 100 percent from mid-June to mid-July. This price increase was based primarily on speculation and uncertainty of the market. Actual supply demand patterns that would warrant such price activity have not changed since the Sumitomo accident. Dataquest expects prices to stabilize during the next 3 months as the true effect of the Sumitomo fire is felt.

Figure 2
Daily Prices for Standard 1Mbx9 (Three-Chip) SIMM in the U.S. Spot Market



Source: Dataquest (September 1993)
G3005445

By Mark Giudici

Markets and Applications

Q7 What was 1992 Japanese MOS memory consumption by application and product?

A Table 2 shows the 1992 Japanese MOS memory consumption by application and product.

Japanese MOS memory consumption amounted to $4.04 billion in 1992. DRAM share was $1.80 billion, SRAM $1.03 billion, EPROM $314 million, EEPROM $779 million, and mask ROM $793 million.

Among DRAM applications, PCs drove the market in 1992. This trend will become stronger this year because Windows 3.1J was introduced in May 1993. Japanese PCs now require a larger capacity of main memory—4MB compared with 2MB last year. Hard disk drives and TV video games have consumed many 256Kb SRAMs, and users are requesting 512Kb products instead of 1Mb products. Fast SRAM will be used in PCs for cache, with RISC processors and Pentiums.

TV video game software and kanji ROM for word processors dominate the mask ROM market. This trend will continue for a while.

Table 2
1992 Japanese MOS Memory Consumption by Application/Product (Percentage)

	Data Processing	Consumer	Communi-cations	Industrial	Trans-portation	Military/ Aerospace	Total
MOS Memory	60.9	25.8	6.4	4.4	1.8	0.5	100.0
DRAM	81.1	10.1	5.9	1.9	1.0	0	100.0
SRAM	60.3	19.2	8.8	7.3	2.7	1.8	100.0
Fast SRAM	62.7	1.0	18.2	15.0	2.0	1.0	100.0
Slow SRAM	59.6	24.9	5.8	4.9	2.9	2.0	100.0
EPROM	64.6	9.9	10.2	10.2	5.1	0	100.0
EEPROM	24.2	22.9	25.4	20.4	6.4	0.8	100.0
Mask ROM	18.5	77.6	0.9	2.0	1.0	0	100.0
Flash Memory	58.3	8.3	16.7	16.7	0	0	100.0
Other MOS Memory	NA	NA	NA	NA	NA	NA	NA

NA = Not available
Note: Data may not add to totals shown because of rounding.
Source: Dataquest (September 1993)

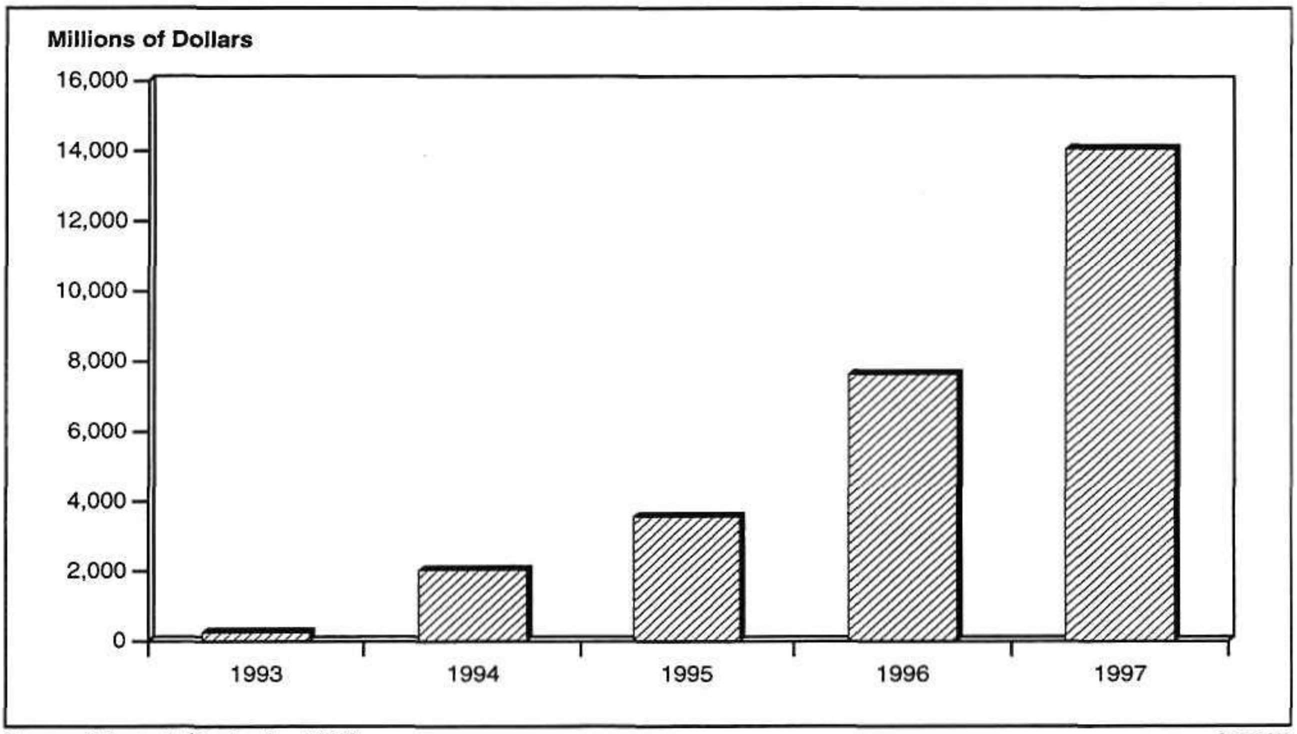
As a whole, the share of data processing will increase gradually because computers require more memory capacity to improve their capabilities, and i486-based PCs, which are becoming popular in Japan, stimulate memory demand.

By Akira Minamikawa

Q8 What impact will Pentium-based PCs have on overall PC chip demand?

A Figure 3 is extracted from the upcoming *Focus Report* entitled "PC and Workstation Opportunities: PDAs through Advanced Desktops." Dataquest predicts that these systems will be a $14 billion opportunity by 1997, representing 41 percent of the PC chip market.

Figure 3
Pentium Chip Demand (Millions of Dollars)



Source: Dataquest (September 1993)

G3005446

By Greg Sheppard

Q9

What is the competitive outlook in the interactive CD-ROM player marketplace on the eve of the critical 1993 holiday sales season?

A

The market remains wide open. For example, during this year's normally quiet summer season, Atari and Nintendo made announcements that could take some gleam from the performance of Sega and 3DO, the erstwhile market leaders. Regardless, Sega appears well poised for an impressive fourth quarter with its competitive $339 price for performance strategy. Matsushita's Panasonic division could win the short-term market war with its 3DO-based system; however, the estimated $700 price tag creates a more risky outlook.

Atari announced plans to introduce its 64-bit interactive multimedia player in time for the holiday season for New York City and San Francisco customers only. The CD-ROM peripheral for the player will be available the first half of next year. Nintendo made an exciting 64-bit RISC MPU vaporware announcement based on its alliance with Silicon Graphics. Nintendo's "project reality" system will appear in arcades next year but not in the home until 1995—unless the alliance partners can accelerate their schedule. Philips continues to demonstrate grudging market staying power with the CD-I player, including a series of technical upgrades such as full-motion video capability and video CD. Commodore Business

Machines was introducing a 32-bit CDTV system at press time. Tandy relies on the VIS system for year-end holiday sales.

The 1993 holiday sales result likely will not determine the ultimate winners in this arena. Table 3 shows the complex set of issues—the market catalysts, core issues, and enabling factors—that will shape long-term trends in this marketplace.

The "catalyst" column in Table 3 includes a "technology threat" that now ominously looms over the strategic plans of all competitors in the market. The threat is a recent U.S. court decision—now being appealed—that grants telephone companies the right to enter the cable TV marketplace. If so, telephone companies could undercut long-term demand for interactive CD-ROM players. The trend toward video-on-demand could become "interactive games-on-demand" from the telephone company to the TV set—obviating the need for interactive players.

By Ronald Bohn

Table 3
Factors Shaping the Interactive CD-ROM Player Marketplace

Catalysts	Core Issues	Enabling Factors
Economics: In-home demand for players Arcade and theme park demand Exchange rates (yen-dollar)	Standards: Hardware—Similar to the VHS/Beta war Software titles development	Hardware Technology: Semiconductors—fast 32-, 64-bit MPUs Compression ICs Encoding ICs
Business: Mergers, acquisitions, and alliances among broadcast TV, cable TV, computer, film production, game players, telecommunications, and theme park companies	Price/Performance Tradeoff: Sub-$300 consumer price point versus $700 leading-edge technology Manufacturing Semiconductor cost curve Worldwide player production	Display Resolution: TV screens versus computer monitors
Law and Regulation: Cable TV Telecommunications	Manufacturing: Semiconductor cost curve Worldwide player production	Software Technology: Interactive games and titles 3-D graphics Modular Windows
Technology Threat: Home delivery of interactive games and movies by cable TV and telephone companies		Software Medium: Cartridges CD-ROM Video CD

Source: Dataquest (September 1993)

Technology

Q10 For memory products, how much of the industry is swinging from Alloy 42 to copper leadframes?

A Leadframes, referred to as the backbone of a molded plastic package, are made from Alloy 42, clad materials, and copper. Mechanically, Alloy 42 leadframes are stronger than copper, are easily electroplated or solder-dipped, and have an expansion coefficient near that of silicon. The drawback is its low-thermal conductivity. Some memory manufacturers are finding that Alloy 42 leadframes used in Type I packages on FR4 boards are prone to wear out early after prolonged device operation during thermal cycling tests. Although the tensile strength of copper leadframes is lower than that of Alloy 42 leadframes, the trade-offs are that thermal coefficiency and thermal dissipation are better with copper. The majority of memory suppliers have indicated that the use of Alloy 42 versus copper leadframes is becoming application-dependent. Although almost all suppliers prefer PLCC packaged devices in Alloy 42 leadframes, the leadframe choice varies for DRAM, SRAM, VRAM, and flash.

Regionally, Japan is staying with Alloy 42 leadframes in the low-end applications. The Type I for flash and VRAM are almost all Alloy 42. Type II for DRAMs and high-density SRAMs are predominantly copper. U.S. manufacturers have always used more copper leadframes than have Japanese suppliers. Most U.S. memory suppliers have always used Alloy 42 in PLCC packages. Most have planned to continue using Alloy 42 in PLCC packages. However, all are seeing a swing to copper leadframes for the thin molded packages. The copper leads bend in the more flexible board applications. Although the U.S. memory manufacturers are using a mixture of both copper and Alloy 42 in the TSOP designs, they believe that most of the industry usage of memory will switch to copper leadframes.

By Mary Olsson

Company and Other Issues

Q11 How can I estimate a company's historical dollar sales of a certain density of SRAM?

A As a matter of policy, Dataquest does not report individual companies' DRAM, SRAM, or any other memory dollar sales by density. To estimate this data for yourself, the suggested method is to derive "dollarized units" (our name for unit shipments times ASP) by compiling the company unit shipment and density average selling price data from the Semiconductor Memory service's *Quarterly Unit Shipments* books in the Memory binders for 1991 and 1992. The 1991 binder has a compilation of all historical shipment information dating, in the case of SRAMs, back as far as 1975.

By Jim Handy

Q12 How many worldwide gate array design starts were there in 1992?

A According to a recent worldwide gate array supplier survey that will be used as the basis for a regional gate array *Focus Report*, Dataquest estimates there were 8,733 MOS gate array design starts in 1992. Furthermore, Dataquest estimates the regional distribution of these 1992 gate array designs as follows: 34.9 percent in North America, 46.5 percent in Japan, 13.1 percent in Europe, and 5.5 percent in Rest of World countries. Other information provided in this gate array design start *Focus Report* includes: regional design starts by process geometry, regional design starts by utilized gate count, regional design starts by functional block (RAM, ROM, and MPU/MCU, among others), regional design starts by package type, and regional design starts by pin count. Additional information regarding the contents of this gate array *Focus Report* can be obtained by contacting your sales representative or an analyst in the ASIC service.

By Bryan Lewis

Q13 What has been the recent history of International Rectifier?

A International Rectifier (IR) has become a leading supplier of power MOSFETs after a period of difficulty.

In the 1985 to 1986 time frame, IR invested heavily ($90 million) in a new power MOSFET facility, just as the market was softening. The result was a three-year struggle in which the company lost money while the new "HEXFET America" facility was underutilized. In late 1987, IR had to borrow $60 million from Chrysler Corporation to keep afloat. The strengthening of the market in 1989 and the legal victories in regard to its patent position on power MOSFETs brought the company back to life (and put Siliconix into Chapter 11 bankruptcy).

IR has a very strong position in the market because it holds the fundamental patents on power DMOS structures. Virtually all manufacturers of power MOSFETs pay royalties to IR, including NEC, Siliconix, Hitachi, and Toshiba. Patent litigation over IGBTs was settled with Harris Semiconductor last year. Royalties will be paid by Harris to IR for using MOSFET technology, while IR will license Harris' IGBT patents.

The big problem for IR in 1992 was an inability to deliver power MOSFETs in the popular TO-220 package. This severely impacted its business and profitability in the fourth quarter of 1992 (its second fiscal quarter). The expansion of manufacturing capacity in 1992 also depressed its profitability, and it showed a loss in its second fiscal quarter.

Table 4 shows our estimates for International Rectifier's product portfolio.

Because of the difficulties in supplying MOSFET products in 1992, IR's market share dropped from 20.4 percent of the total market in 1991 to 18.6 percent in 1992. Table 5 shows the ranking of power MOSFET suppliers in 1992.

Table 4
International Rectifier's Product Portfolio

	Revenue ($M)	1991 Growth (%)	1992 Revenue ($M)	Growth (%)
Power MOS Transistors	149.0	11.2	183.0	21.4
MOSFETs	142.0	10.1	178.0	25.3
IGBTs	7.0	40.0	5.0	-28.6
Thyristors	27.0	-12.9	30.0	11.1
Power Rectifiers	47.0	-13.0	49.0	4.3
Other Discretes	5.0	0	8.0	60.0
Total	228.0	1.8	270.0	18.4

Source: Dataquest (September 1993)

Table 5
Estimated 1992 Market Share for Top 10 Suppliers of Power MOSFETs (Includes IGBTs)

Rank	Company	Share (%)	Revenue ($M)
1	International Rectifier	18.6	183.0
2	Toshiba Corporation	9.5	93.0
3	Motorola Semiconductor	9.1	89.0
4	Harris Semiconductor	6.8	67.0
5	Hitachi	6.3	62.0
6	Siliconix	5.7	56.0
7	Siemens AG	5.6	55.0
8	NEC Corporation	4.9	48.0
9	Samsung Electronics	4.5	41.0
10	SGS-Thomson Microelectronics	4.5	41.0
	Others	24.5	248.0
Total Market		100.0	983.0

Source: Dataquest (September 1993)

By Gary Grandbois

Q14 What is Quality Semiconductor, and what are its major strengths?

A Quality Semiconductor is a small manufacturer of logic and SRAM-based digital semiconductors based in Santa Clara, California. Founded in 1989 by some original founders of IDT, it produces state-of-the-art speed devices using processes it codevelops using other fabs' foundry services. The company attains capacity in part out of these relationships.

We estimate Quality's 1992 sales to be $18 million, half of which consisted of fast SRAMs (exclusively 64Kb and 256Kb densities). These are both extremely competitive markets, and the company has been de-emphasizing its presence in these markets. The other half of its business is high-speed logic, which performs very well for the company. We expect the mix to shift significantly in favor of logic in 1993.

The company's logic products are not widely sourced. Quality manufactures the highest-speed devices available—per its claims—and focuses on the solution of user problems through the use of highly innovative and unique packaging. Through its innovative packaging it is a sole source to several commercial system manufacturers, and it is working to put itself into the same position with the military. Some of its packages are most appealing to manufacturers of small runs of products—those that cannot afford to manufacture using surface-mount technology. Margins on the logic products are extremely high because they are capable of yielding thousands of good dice per wafer.

Threats to the company are not imminent. Quality plays into ignored niches and seems focused on orienting itself away from products that are multiply sourced and competitively priced. We doubt that other manufacturers, big or small, will follow Quality into this business. There is the possibility that its current product line will be competed against by the descending price per pin of ASICs, but that will take a long enough time for management to adjust the product mix to compensate for this threat.

Despite current rampant shortages of logic products, the market for Quality's specialty products is limited. The company is not headed in the direction of becoming the next Intel, Texas Instruments or Motorola, but it should be expected to remain a niche player as long as its current strategy remains in place.

By Jim Handy

Q15 What should be looked at when evaluating the marketability of fabs in the United States? Why was Western Digital's fab worth buying?

A There are two main reasons why a company would purchase a fab rather than build a new one. Today's state-of-the-art IC manufacturing facilities are being built at price tags of $600 million to $1 billion. A small company may not be able to afford either the time or the investment required for a new fab. Even though existing fabs may require some upgrade investment, the total of the fab plus upgrade can be 30 to 70 percent cheaper than for a new fab, depending on various factors.

Also, some IC manufacturers may not create sufficient volume to utilize a fab at full capacity. In this case, part of the fab could be allocated for foundry work, whereby an IC design house would purchase time or, in effect, "rent" the fab to make chips it has designed. Companies overseas, particularly in Taiwan, have made a lucrative business operating as foundries. Some "fabless" companies in the United States, after factoring the foundry as part of their business plan, could reach the conclusion to add a fab.

There are several factors to consider when evaluating fab marketability in the United States. Three main categories are: location, facilities, and installed equipment. Location relative to labor expenses, infrastructure of supporting industries, and employee well-being are issues for operational efficiencies of the plant. The facilities and installed equipment, however, are the key factors in the basic desirability of a fab. Numbers that will give a close initial estimate of these factors are size of wafers running, line width technology (expressed in "microns"), and the cleanroom particle specification.

Line width technology gives a snapshot of the type and capability of equipment installed. A 0.8-micron fab has lithography equipment capable of and optimized for performance at that line width, and other processing equipment with particle performance capable of producing high yields at that technology level. Further, a 0.8-micron fab trying to manufacture the more advanced 0.5-micron technology chips would do so at significantly lower, if any, yield. Most new advanced fabs in the United States being announced today, with production beginning in the next 2 to 3 years, have the minimum capability of 0.35 to 0.4 microns.

How does this translate to fab value and comparison to the mainstream? Semiconductors have a technology cycle (time between production peaks) of about 3 to 4 years per generation. Each successive generation decreases line width by 25 to 40 percent as expressed in microns (2.0, 1.5, 1.2, 1.0, 0.8, 0.5, 0.35, and 0.25 microns are the broad categories). When a new plant is built, its initial products are leading-edge technology. For example, the new Intel plant in New Mexico is expected to produce Pentium microprocessors. As a plant matures, gradual transitions toward production of "lower" technology products occurs. Several 5- to 10-micron fabs today produce discrete semiconductors and power MOSFETs. Depending on transition and product strategies, fabs can be productive for several decades. Mainstream production in the United States today is generally at 0.7 to 0.8 microns, on par with Japan and Korea. Taiwan, a key foundry country, is generally at 0.8 to 1.2 microns.

Another key number is the particle specification of the fab. Small particles floating in the air can land on chips, destroying them and decreasing the yield of the fab. The cleanroom air particle specification, represented by the term "Class," gives a snapshot of the fab facilities. Class 100 was typical of 1.5-micron fabs, Class 10 at 0.8 to 1.0 microns, and Class 1 at or less than 0.5 microns. Running at larger wafer sizes also adds to the operational efficiency of the plant because more chips can be placed on these larger substrates. Wafers of 150mm in diameter are the mainstream, but a transition to 200mm wafers is expected to occur at 0.5 microns, based on the economics of cost per chip.

The equipment and facilities of an existing fab can be upgraded, of course, but this incurs an added capital expenditure. The specific amount varies widely, and is dependent on matching the type of product being produced with an audit of the equipment in the fab.

The Western Digital fab recently purchased was a 0.9-micron, Class 1 facility running 150mm wafers. At first glance, this appears to be on the leading-edge of foundry capability with the ability to be upgraded into U.S. production mainstream with minimal capital investment.

By Clark J. Fuhs

Q16 What are the primary microprocessors being used for the upcoming hand-held devices, and who will manufacture them?

A The new genre of hand-held devices promise to combine the processing power of a PC, the communications abilities of a wireless phone, and the direct utility of a personal organizer. Furthermore, most of the products being introduced stem from one of these three bases, starting out as downscaled PCs, intelligent communicators, or upscaled organizers. Microprocessors being developed to power these products have the most challenging set of trade-offs of all designs—they must provide the optimal balance of processing performance, power dissipation, functional integration, and unit cost. To date, four major microprocessor product families have announced products for this market. During the next year additional entries can be expected from the PowerPC, Alpha, and MIPS processor families. The four families with announced products are as follows:

- ARM: A series of devices architected by Advanced Risc Machines Ltd. and manufactured by GEC-Plessey, VLSI Technology, Sharp, and TI (use as a core only).
- Hobbit: A family of products architected by AT&T and manufactured by AT&T.
- x86: A combination of integrated 8086, 386, and 486 products being architected and manufactured primarily by Intel and AMD.
- 68K: A subset of the 683xx series, based on a 68030 core with integrated functionality, architected and manufactured by Motorola.

By Ken Lowe

Q17 Some statements were made in the August 30 *Inquiry Summary* (SCND-WW-IS-9308) about Texas Instrument's newer facilities. Was the information about timeliness of construction accurate?

A The following sets the record straight regarding TI's successful latest fabs.

TECH Semiconductor actually is ahead of the schedule set forth 18 months ago, has finished the qualification of its fab late in the summer, will have its official opening ceremonies on September 30, and will be in the first stages of production in the fourth quarter of 1993 for 200mm wafers and a 0.5-µm process.

TECH's sister facility, KTI in Japan, will ship about 1 million units of the "Supershrink" 4Mb DRAM this month, also higher than we stated last month. With a very quick ramp-up, KTI is also running 16Mb DRAMs, and is starting to add logic products. There are nearly 500 gross die per wafer on the 200mm wafers KTI and TECH are now running for TI's 4Mb DRAM (not the 275 we had reported earlier, which was for a 150mm wafer), and nearly 200 gross die of the 16Mb DRAM. Each facility has a capacity of about 6,000 wafers per month at present.

Acer and Avezzano, Italy are each running 150mm wafers (up to about 16,000 starts per month), and each has room in its existing building for a totally separate module that can be used to expand capacity by an additional 9,000 to 10,000 200mm wafers each (no decision has been made yet as to timing). TECH and KTI will need to add another building to grow beyond their present modules.

By Lane Mason

NU1SEM1WW SCNDWW1S9309 BH: 1 N: 1
Mr. Clark Fuhs
Dataquest Incorporated

****
SJ - INTERNAL DISTRIBUTION
****

For More Information...

Rick Spence, Industry Analyst .... (408) 437-8642
Via fax .... (408) 437-0292

Dataquest®
a company of The Dun & Bradstreet Corporation

Q&A Dataquest Inquiry Summary

Semiconductors

Semiconductors Worldwide

August 1993

Dataquest®
a company of The Dun & Bradstreet Corporation

Program: Semiconductors Worldwide
Product Code: SCND-WW-IS-9308
Publication Date: August 30, 1993

Products

Q1 What kind of memory is used in the new Apple Newton PDA?

A Apple's Newton uses 640KB of SRAM, and 4KB of mask ROM. The mask ROM is used to store the operating system and some applications programs, while the SRAM is used both as operating space for the programs and for data storage of user data. Programs are executed "in place": They are not moved into RAM before execution, as happens in a disk-based desktop or laptop system. As a result, the SRAM in the Newton does not need to be all that big. Also, because large amounts of RAM are unnecessary, the device does not need to resort to the use of pseudo SRAMs to store programs pulled into main memory from the hard disk, as opposed to the Apple PowerBook computers. Pseudo SRAMs were the PowerBook's means of achieving a cost-per-byte about equivalent to that of a DRAM, while getting power requirements nearer to that offered by SRAM.

Still, 640KB is an unusual number. How did it get that way? Because the limit of the main memory space of the original IBM PC was 640KB, we originally wondered whether that had something to do with it, but it was just coincidence. The real reason stems from a combination of size, cost, and power consumption constraints. The Newton does not use pseudo SRAMs—they consume too much power. It instead uses two standard SRAMs: one 128Kx8 (1Mb) and one 512Kx8 (4Mb) device. Two 128Kx8s would have only provided 256KB, which would not have been enough. Two 512Kx8s would have provided an even megabyte of SRAM, but cost about $150 each (as opposed to the $9 price of a 128Kx8). Newton's targeted list price is less than $700. Any intermediate size would have required the use of more chips, which would have increased the power and size of the system. Power consumption is more closely related to the number of chips used than to the number of bits in the system.

Next year, as the price of the 4Mb SRAM tumbles to the $30 range, we expect to see all Newtons ship with a full 1MB of SRAM. In another 3 years, as 16Mb SRAMs become available, the device will be able to offer 2MB using only one SRAM package. By then, ROM densities will have also shifted upward, as will have user sophistication, and a 2MB SRAM will be a reasonable size for this sort of device.

By Jim Handy

Q2 What are the midyear trends in 486DX pricing?

A Dataquest has received a flurry of inquiries about 486DX pricing. Dataquest estimates a third-quarter price of $283 for the 486DX-33 device (1,000 to 5,000 units), which is slightly less than Intel's list price of $294 for 1,000-piece orders. For the 486DX(2)-50 device (1,000 to 5,000 units), Dataquest estimates a third-quarter price of $395, the same as Intel's list price for 1,000-piece orders. For larger volumes in excess of 10,000 to

20,000 units, Dataquest expects some major buyers to receive discounts in the range of 20 to 30 percent.

Dataquest has received differing reports during the summer months about 486DX spot market pricing. No genuine spot market trend, however, has yet emerged. For example, late July 1993 reports of soft 486DX pricing in the spot market were soon followed by reports of firm spot market pricing.

Intel outlined its 1993 strategy for the 486 and Pentium markets at an analyst meeting held in the Silicon Valley during the first quarter. The company continues to adhere to that core strategy, with some modification. Table 1 highlights key elements of Intel's strategy.

The Competitive Environment. Unless Advanced Micro Devices (AMD) forms a major submicron foundry alliance in the near term, AMD will have muted 486 market impact this year. The company fully utilizes its submicron capacity for a host of advanced product and R&D efforts.

IBM's Blue Lightning family of 486SX-compatible products moves the company into the public forefront of the 486 marketplace. Although IBM may not sell 486 standalone devices, IBM may sell 486 motherboards. To date, IBM ships boards that in effect combine competitively priced 486s with value-added service and software.

Even so, IBM must convince the market that desktop applications do not require the floating point unit (FPU). The 486DX contains an FPU. IBM's market impact has just started and should not achieve full force—like AMD—until the post-1993 period.

What Could Drive Down 486 Pricing by Year-End 1993? The answer to this question is a slowdown in worldwide PC shipments. For example, the European market has slowed considerably during the past several months. A second-half-1993 rebound in that region looks unlikely.

Table 1
The Direction for Intel in the 486-Pentium Markets

Direction	Dataquest Analyst's Notes
486s Everywhere	Intel will introduce 35 new 486 devices in 1993. 30 million 486 systems will ship in 1993. The 486DX(2) will be a key product. 486SL-type power management capabilities in desktops PCs will be another key 1993 strategy.
Pentium Reshapes the Market	Pentium launched in second quarter. Intel expects to ship hundreds of thousands of Pentiums in 1993.
Move to 0.6-Micron Process	Moving the Pentium from the 0.8-micron process to the 0.6-micron process should result in about a 40 percent die shrink.

Source: Dataquest (August 1993)

In North America, 486 demand remains robust as of the middle of the third quarter. U.S. Department of Commerce data on unit shipments by computer OEMs, however, indicates that the U.S. market has now peaked. PCs represent an important share of these shipments. The traditional fourth-quarter surge in U.S. computer shipments—as occurred last year—now looks more unlikely than likely.

Although demand for 486 devices should hold momentum for the next several months, by the October-November period U.S. businesses will formulate preliminary 1994 capital budgeting plans. Economic pessimism would hinder fourth-quarter 1993 corporate expenditure on PCs. If so, the "quiet" 486 pricing trends of today could become quite noisy by year-end—if not sooner.

By Ronald Bohn

Q3 Please provide an update on the major U.S. DRAM makers.

A Three to five "U.S. DRAM makers" are present in the market today, participating in widely different fashions. Only Micron Technology is a purebred, fully integrated, self-funded entity that lives and dies by plying the merchant trade, in the model of the Europeans (that is, Siemens), the Koreans, or the Japanese. Each of the others has novel twist in its business model.

DRAMs from IBM have been in the market for about three quarters, but only in the past few months has the company been shipping standard product, in SIMM and chip form, to OEM and aftermarket channels. And though it has been using its 16Mb internally for 1.5 years, we have seen no evidence of it shipping this product outside. Just 4Mbs are being shipped outside, so far.

Internally, IBM probably is producing enough DRAM to be among the top five or six worldwide suppliers, but its internal demand continues to be great, limiting its rate of entry into the merchant market.

Micron Technology announced a capacity expansion in the spring that would increase wafer starts by about 20 percent by year-end 1993. It has since announced another expansion, involving the construction of a new building, that will add yet another 25 percent capacity by the second quarter of 1994. All its expansions are still sticking with the 150mm wafers that it first brought up in 1989, though the newest expansions are "200mm-upgradable" when Micron believes that the timing is right. (Micron has access to IBM's 200mm technology through their cross-licensing agreement of November 1989.)

Present production die size is about 56 sq. mm. (240 die per wafer), with about 20 percent of starts at year-end 1993 to be 330 d/w).

Texas Instruments continues to forge ahead with all of the facilities it had begun to build during or shortly after the last tight market in 1988-1989.

KTI, its joint venture with Kobe Steel in Japan, is now running TI's 4Mb supershrink (275 d/w, and 250,000 per month units out), with some 16Mb. TECH Semiconductor, its joint venture with Canon, Hewlett-Packard, and SEDC, has slipped somewhat, and now expects to go into production in the first quarter of 1994, about a quarter later than expected 9 months ago.

TI's major 4Mb DRAM volumes continue to come out of its joint venture with Acer, TI-Acer, and from Avezzano, Italy, each of which is running 2 million-plus per month and is transitioning to the supershrink version. There are smaller contributions from Miho (about half the wafer starts—1.2 million per month—and slowly ramping down) and KTI. TI still produces 16Mb DRAMs in Dallas 4.2. (TI's announced fab to be built in Dallas, Dallas 5, is intended to be used for custom and microprocessor products, not memory. It will come online in late 1995.)

Since the merger, MOSel-Vitelic arguably is not even a U.S. company, with only U.S. equity investors and a U.S. sales and marketing outlet. It too has eschewed the mainstream, and is making fine progress in the high-speed end of the DRAM market. With the tight market, high-speed premiums have also improved, and for the most part, MOSel-Vitelic owns the market at sub-50ns. Its April 3, 1993 agreement with Oki affords it some capacity upside, until it can finish its Hsin Chu fab, which Vitelic began building more than four years ago. Sales are expected to rise more than 50 percent in 1993.

Motorola is the ultimate dis-integrated DRAM producer, and will phase out of wholly produced DRAMs this quarter from its East Kilbride facility in Scotland. It will depend entirely on its joint venture facilities in Tohoku (more than 50 percent of Motorola's DRAM revenue), and its OEM agreements with Mitsubishi, Goldstar, and Toshiba. Motorola will be hard pressed to gain access to increased product until capacity loosens up. DRAM sales will increase in 1993, but Motorola will likely lose market share for the first time since its re-entry into DRAMs in 1986.

By Lane Mason

Q4

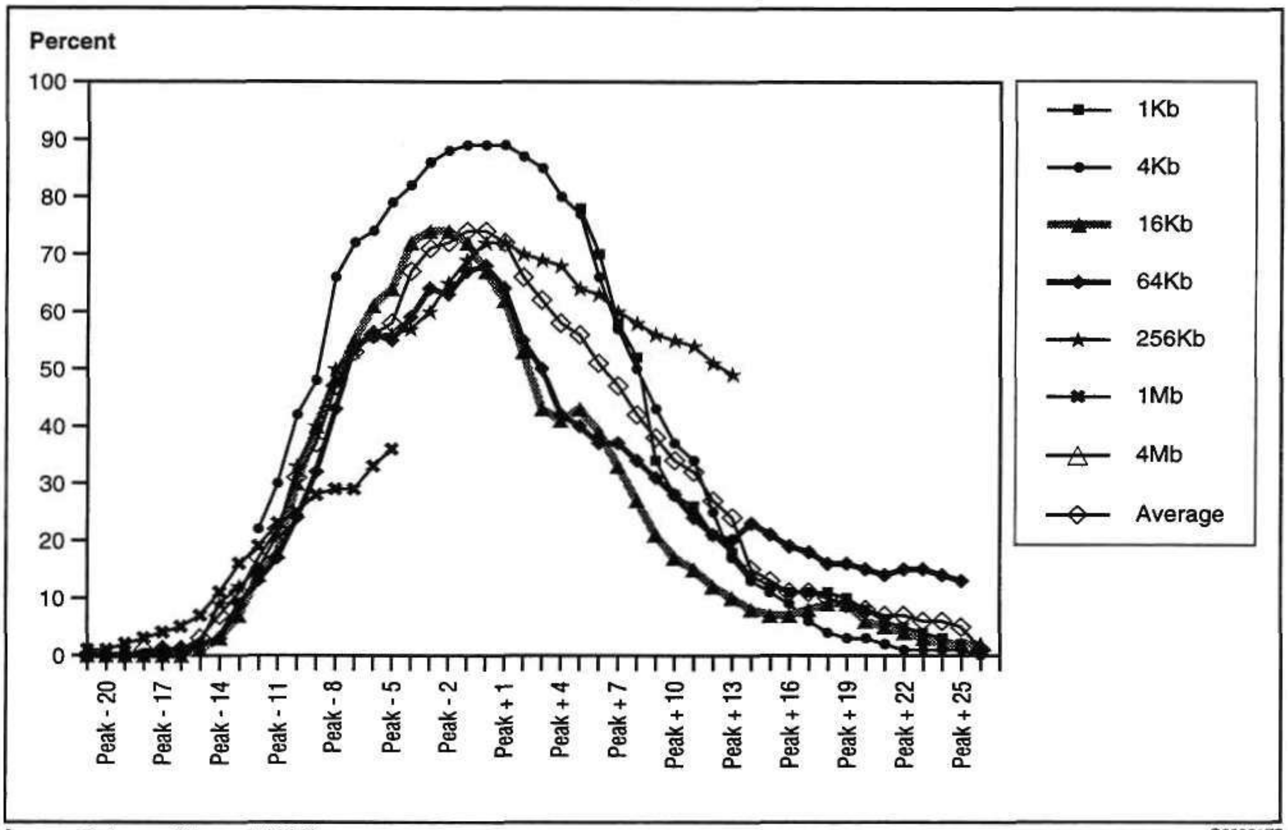
Why does the 1Mb SRAM not seem to be growing in use at anywhere near the rate of any of its predecessor densities?

A

Life cycles in percentage of bits for all SRAMs from the 1K density to the 1Mb density are time-normalized and overlaid in Figure 1. It is very obvious that the 1Mb is not receiving the acceptance of any previous density, and is not replacing the 256K and 64K densities as fast as should be expected, causing those two densities' life cycle curves not to decline as rapidly as would be expected.

We believe that the 1Mb SRAM's lack of acceptance in 1991 was because of bad financial times in the United States, where more advanced densities are usually employed earlier than they are in the rest of the world. In 1992,

Figure 1
Slow SRAM Quarterly Bit Market Share, by Density, Time Normalized



Source: Dataquest (August 1993) G3002178

the United States caught up, but the poor Japanese economy caused the 1Mb density not to be used in consumer applications as widely as would have normally occurred. This state of affairs is still in effect, and should continue until Japan comes out of its financial doldrums.

By Jim Handy

Q5 What sort of applications use fast SRAMs?

A SRAMs in the 10- to 19ns and 20- to 44ns speed categories are almost exclusively used in cache memories. The next speed grade, 45ns to 70ns, plays a relatively minor role in overall SRAM shipments, and the largest group, slow SRAMs, fit into an incredible diversity of applications.

Naturally, the biggest cache markets are PCs and workstations, and these consume mainly 4-bit- and 8-bit-wide standard SRAMs. Wider devices are about to make a dent in this market, with 16/18-bit versions already in limited use, and 32/36-bit devices on the horizon. The other markets for SRAMs in this speed range are diverse and are small enough that they do not readily factor into our forecasting efforts.

By Jim Handy

Q6

What is the status and projected growth for video CODECs?

A

Video compression and decompression chips (collectively referred to as CODECs) represented less than $20 million in revenue in 1992 but are projected to grow to nearly $400 million by 1997, an 81 percent compound annual growth rate. Demand for these devices comes from a variety of end-use applications, including multimedia computers, consumer entertainment systems, video communications, and other commercial applications. The CODEC chip sets can be divided into decoders (which perform decompression only) and encoders (which perform compression and commonly are sold in configurations to also support decompression). There also is a variety of standard and proprietary compression formats competing for dominance, which is further complicated by the diversity of applications involved. The MPEG standard (a mixture of MPEG 1 and MPEG 2) will rise to dominance during the next five years, representing a combined total of more than 65 percent of the total units by 1997.

Unit demand for video CODEC ICs will be driven by decoder products (decompression only) used in consumer entertainment systems. The conversion of consumer entertainment products (TVs and games) from analog to digital format will drive CODEC IC sales during the next five years. Multimedia computers will not command the large unit sales anticipated in the past because of both the lack of compelling applications and the increase in central CPU power adequate to perform decoding. Video communications products will grow slowly during the next five years because their two-way nature requires critical mass before rapid growth will occur. However, they will continue to dominate the unit volumes of combined encoder/decoder components during this time frame.

By Ken Lowe

Markets and Applications

Q7

Please provide the percentage breakout by application in Japan for MOS gate arrays.

A

Table 2 shows MOS gate array consumption in Japan during 1992.

Table 2
1992 MOS Gate Array Consumption in Japan

Segment	Percentage
Data Processing	43.1
Communications	17.5
Industrial	13.5
Consumer	22.8
Military	0
Transportation	3.1
Total	100
Total Market	$1.1 billion

Source: Dataquest (August 1993)

By Bryan Lewis

Q8 The five-year forecast shows the discrete category only growing by a 7.4 percent compound annual growth rate. What is the outlook for discrete transistors?

A The discrete transistor category shows a higher overall growth rate than do discrete devices in general (see Table 3). Power transistors represent the growth component for transistors because discrete small-signal transistors are expected to show little growth in the coming five years.

Table 3
Worldwide Transistor Consumption Forecast (Millions of Dollars)

	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
Transistors	4,462	4,835	5,300	5,770	6,287	6,840	8.9
Small-Signal	1,801	1,835	1,870	1,900	1,937	1,980	1.9
Power	2,661	3,000	3,430	3,870	4,350	4,860	12.8

Source: Dataquest (August 1993)

By Gary Grandbois

Q9 What is the North American market share for 8-bit microcontrollers?

A Although Motorola grew strongly in 1992 and continues to dominate the 8-bit MCU market, several smaller companies exhibited stronger growth rates (see Table 4). National Semiconductor moved past Intel into second place, based on a 51 percent growth rate. Microchip gained the No. 1 position in growth, rocketing into the No. 9 position past Zilog and moving into a position to challenge Hitachi and NEC. Of the major Japanese companies participating in the North American market, Mitsubishi showed the strongest growth and is well positioned to continue this growth pattern in 1993.

Table 4
8-Bit MCU Preliminary North American Market Share (Millions of Units)

Rank	Company	1991 Units	1992 Units	Growth (%)
1	Motorola	86,603	104,877	21.1
2	NSC	18,200	27,500	51.1
3	Intel	20,281	21,165	4.4
4	Philips	9,974	13,520	35.6
5	Texas Instruments	9,900	11,700	18.2
6	Mitsubishi	4,864	6,027	23.9
7	NEC	6,888	6,093	-11.5
8	Hitachi	5,314	5,426	2.1
9	Microchip	3,042	4,715	55.0
10	Zilog	2,975	4,000	34.5
11	SGS-Thomson	3,030	3,563	17.6
12	Matra MHS	1,448	2,073	43.2
13	AMD	1,320	940	-28.8
	Others	15,115	20,053	32.7
	Total	188,952	231,651	22.6

Source: Dataquest (August 1993)

By Jerry J. Banks

Q10 What is Dataquest's view of 1993 Japanese electronic equipment production?

A Dataquest Japan estimates that the total 1993 Japanese electronic equipment production growth rate will be negative 4.3 percent on a yen basis, compared with 1992 (see Table 5).

Table 5
1993 Japanese Electronic Equipment Production Growth Rate, on a Yen Basis (Percentage)

	Q1	Q2	Q3	Q4	Growth (%) 1992-1993
Data Processing	-11.7	-7.2	-4.7	3.1	-5.2
Communications	-4.7	-9.8	-3.2	6.5	-3.0
Industrial	-11.7	-3.6	1.6	4.5	-3.0
Consumer	-15.2	-10.9	-3.3	8.0	-5.5
Military/Aerospace	NA	NA	NA	NA	2.3
Transportation	-1.1	-1.1	0.4	1.5	-0.1
Total	-11.0	-7.9	-2.7	5.3	-4.3

NA = Not applicable
Source: Dataquest (August 1993)

Japanese electronic equipment production will turn to positive growth in the third quarter of 1993. Each segment market will grow 3 to 8 percent in the fourth quarter. Rapid regeneration of industry is not expected in the fourth quarter of 1993. The most significant decline came in the fourth quarter of 1992, when growth was negative 18.4 percent. Positive growth in 1993 is expected from the following segments: mobile and radio, instruments, medical equipment, and personal electronics. The electronic equipment production market's shrinkage in the first and second quarters was so serious that Dataquest Japan does not expect the growth of the third and fourth quarters to compensate for 1993. Japanese electronic equipment production will have negative growth for two consecutive years.

By Naotoshi Yasuhara

Q11 Who are the top five players in the modem market?

A Table 6 shows the market share of the top five suppliers of modems in the United States.

Table 6
1992 Market Share: Suppliers of Modems to the United States

Supplier	Percentage
Codex (Motorola)	12
USD (Motorola)	11
Hayes	10
U.S. Robotics	8
Racal-Datacom	8
All Others	51
Total	100

Source: Dataquest (August 1993)

By Nicolas Samaras

Q12 How does Dataquest define the specialty SRAM market, and what is your current outlook?

A Specialty SRAMs are limited in use. Their markets are small and tightly controlled by very few suppliers. Dataquest divides this market into synchronous SRAMs, latched SRAMs, cache-tag SRAMs, dual-port SRAMs, FIFOs, and CAMs.

We estimate that synchronous SRAM sales were less than $20 million worldwide in 1992, and that less than $10 million worth of cache-tag SRAMs were sold. This year, synchronous SRAM sales will probably almost double. The only latched SRAMs to ever sell in volume were special parts used to manufacture caches for the 386 and older SPARC CPUs. Neither still sells today.

Other kinds of specialty SRAMs are shown in Table 7, with their applications and their worldwide sales. These are all small markets, and all are dominated by one or two manufacturers.

Table 7
Specialty SRAMs' 1992 Sales and Applications

Device	1992 Sales ($M)	Applications
FIFOs	150	DSP, telecom switches, laser printers
Dual-Port SRAMs	<50	Telecom switches, LAN nodes
CAM	<10	LAN bridges/routers

Source: Dataquest (August 1993)

By Jim Handy

Company and Other Issues

Q13 What are the historical semiconductor inventory levels from January 1992 to the present?

A Table 8 shows the historical inventory levels from January 1992 to June 1993.

Table 8
Historical Inventory Levels, January 1992 to June 1993 (Inventory Level in Days)

Date	All Target	Actual	Computer Target	Actual
1/92	19.4	19.6	18.4	18.0
2/92	20.6	20.7	19.0	18.7
3/92	18.4	20.1	18.1	18.6
4/92	20.2	26.5	25.5	26.7
5/92	20.7	27.1	22.2	28.7
6/92	17.0	22.9	18.8	21.6
7/92	18.0	25.1	21.0	23.0
8/92	15.4	23.0	15.8	21.0
9/92	16.1	22.2	18.0	20.6
10/92	16.3	20.8	18.4	21.2
11/92	15.8	22.1	19.4	22.6
12/92	13.0	22.1	13.7	19.2
1/93	16.0	29.6	11.3	21.3
2/93	12.4	19.1	7.6	15.2
3/93	10.3	18.5	7.5	12.3
4/93	16.4	21.1	15.0	19.3
5/93	21.3	25.9	8.0	13.75
6/93	15.0	16.71	16.25	21.25

Source: Dataquest (August 1993)

By Mark Giudici

Q14 How does Dataquest forecast the market for devices for which there is no current end application (in this instance, the 16Mb SRAM)?

A When we forecast sales of SRAMs in the more distant future, Dataquest analysts use several criteria other than end applications, as follows:

- The demand for cost-driven parts, such as slow SRAM, is highly dependent upon fluctuations in the economy. We drive the forecast for cost-driven parts from The Dun & Bradstreet Corporation's financial forecasts.
- Applications for new densities are primarily driven by cost per bit. We project this from our forecasts of the semiconductor capital equipment market, from our Semiconductor Equipment, Materials, and Manufacturing service group.

- Applications for older densities disappear as the SRAM for these applications gets pulled into a microcontroller or ASIC, or as the application itself becomes obsolete. It is relatively simple to predict when an ASIC or microcontroller will be able to contain a certain density of SRAM and yet be cost-effective.
- Speed requirements of slow SRAMs follow speed availability. We can estimate from process advances what will be the slowest available speed for any given density. We can also estimate speed trends for the fastest speeds from our understanding of the microprocessor market.
- The proportion of the entire semiconductor market that comes from discrete SRAMs follows a simple growing trend. By understanding that trend, and the expected proportions of the market contributed by each density, we can derive worldwide SRAM use from the overall semiconductor market, which ties into the worldwide economy.

Much of this trend analysis has been thoroughly discussed in the May 31, 1993 "Trends in the SRAM Market" *MarketTrends* document (MMRY-WW-MT-9301) sent to our Memories Worldwide service clients in May. The document can be purchased separately through Dataquest's sales organization. Readers of this document will come away with a much better understanding of the way the market moves.

By Jim Handy

Q15 What were the top 10 U.S. semiconductor manufacturers from 1988 through 1992, and how many were headquartered with fabs in Silicon Valley?

A Table 9 shows the top 10 semiconductor manufacturers from 1988 through 1992.

Table 9
Top 10 U.S. Semiconductor Manufacturers

1992	1991	1990	1989	1988
Intel*	Intel*	Intel*	Motorola	Motorola
Motorola	Motorola	Motorola	TI	TI
TI	TI	TI	Intel*	Intel*
National*	National*	National*	National*	National*
AMD*	AMD*	AMD*	AMD*	AMD*
AT&T	AT&T	AT&T	AT&T	AT&T
LSI Logic*	LSI Logic*	LSI Logic*	Harris	GE
Harris	Harris	Harris	LSI Logic*	LSI Logic*
Micron Technology	Micron Technology	Analog Devices	Micron Technology	Analog Devices
Analog Devices	Analog Devices	Micron Technology	ITT	ITT

*Designates headquarters and a fab located in Silicon Valley.
Source: Dataquest (August 1993)

By Mary Olsson

Q16 What are the major suppliers of ICs to sound card manufacturers, and what are some of the current trends?

A Semiconductor manufacturers include Analog Devices, Crystal Semiconductor, IBM, Integrated Circuit Systems, Media Vision, Motorola, and Yamaha. Creative Labs, which owns a large portion of the sound card market, internally consumes its sound ICs. Companies outside the United States include Dream in France and Worsey, a German keyboard manufacturer.

PC sound cards have historically been 8-bit boards that rely on FM synthesis for sound generation. Hence, Yamaha and the ubiquitous OPL3 come to mind when talking about sound cards. We expect the consumption of sound boards to flip-flop from about 75 percent 8-bit in 1992 to 75 percent 16-bit in 1994. Further, FM synthesis will be complemented by sample-based synthesis, and by the mid-1990s a new technique called waveguide may be implemented.

Causing the shift is the move toward more realistic synthesis methods and the demand for CD-quality sound reproduction. As a result, traditional electronic musical instrument (MI) manufacturers are now key suppliers to this industry as well. These include E-Mu, Ensoniq, Korg, and Kurzweil. Roland, a major player in both the MI industry and desktop music synthesizers, manufactures for internal consumption.

Recent developments are as follows:

- Creative Labs acquired E-Mu systems and offered a daughterboard using E-Mu technology with a General MIDI sample set.
- Media Vision introduced the PA 16 XL, a sound card with FM (OPL3)- and KORG-based sample set, and started developing algorithms for waveguide synthesis.
- Analog Devices, IBM, Sierra, and TI pushed for DSP-based solutions offering FM emulation (eliminates OPL3 cost), voice recognition, and upgradability with effects such as QSound.
- Integrated Circuit Systems acquired Turtle Beach, the leading supplier of high-end multimedia sound cards. (Turtle Beach is still using E-mu's G-chip in its board.)
- Kurzweil developed a sample-based chip set with an effects processor. Zoltrix (Fremont, California) and AVM (Sandy, Utah) started marketing daughterboards soon to be released for less than $300.
- Crystal Semiconductor introduced two new sample-based synthesizers with 4MB worth of sounds.
- Yamaha introduced the OPL4, which combines FM and wavetable synthesis on a single chip for $29, and optional effects processor for $19.

Sound cards are still used mainly for games and music, with the majority of cards (about 80 percent) sold to the home. Wave-table and addition of capabilities for reverberation, chorus, and other effects such as QSound continue to be popular. Although many manufacturers are touting new applications such as voice recognition (VR) and business audio (that is, annotating spreadsheets), the corporate use of shared audio will remain in the multimedia presentation and training domain until audio applications on the desktop such as VR and annotation become seamless and ultra-reliable. The use of business audio, although heavily marketed, now appears redundant and pales in comparison to already installed voice mail and e-mail systems for efficiency and ease of use in everyday business communications.

By Rick Spence

Q17 How did the leading suppliers of consumer-specific and automotive-specific ICs do in the 1992 market?

A The 1992 market for consumer electronics was down, especially in the Japanese domestic market. There was a worldwide drop of 7.8 percent in the value of consumer electronic equipment and 18.6 percent growth in automotive electronics. Combining the consumer and automotive electronic equipment markets gives an aggregate decline of 4.3 percent in 1992 from 1991. This decline in equipment value led to a 3 percent decline in semiconductor consumption in 1992 (see Table 10). The companies that show large declines are Japanese consumer-specific IC suppliers. They contrast significantly with Motorola and SGS, which showed strong growth in automotive-specific ICs in 1992.

Table 10
1992 Market Share for the Combined Revenue of Consumer and Automotive-Specific ICs

1992 Rank	Company	1992 Revenue ($M)	1991 Revenue ($M)	1992/1991 Percentage Change
1	Philips Electronics	457	444	2.9
2	Toshiba Corporation	414	461	-10.2
3	Sanyo	382	389	-1.8
4	Matsushita Electronics Company	313	348	-10.1
5	SGS-Thomson Microelectronics	304	243	25.1
6	Sony Corporation	252	299	-15.7
7	Rohm	189	200	-5.5
8	Motorola Semiconductor	183	137	33.6
9	Mitsubishi Electric	174	181	-3.9
10	NEC Corporation	144	156	-7.7
	Others	721	783	-7.9
	Total	3,533	3,641	-3.0

Source: Dataquest (August 1993)

By Gary Grandbois

NO1SEM1WW SCNDWWIS9308 BH: 1 N: 1
Mr. Clark Fuhs
Dataquest Incorporated

****
SJ - INTERNAL DISTRIBUTION
****

For More Information...

Rick Spence, Industry Analyst .... (408) 437-8642
Via fax .... (408) 437-0292

Dataquest Inquiry Summary

Semiconductors

July 1993

Dataquest®
a company of The Dun & Bradstreet Corporation

Program: Semiconductors
Product Code: SCND-WW-IS-9307
Publication Date: July 26, 1993

Products

Q1

What is Dataquest's opinion about using ball grid array (BGA) packages for ASIC devices?

A

Dataquest's ASIC service recently published a *Dataquest Perspective* on ASIC packaging, which examined today's MOS gate array and cell-based IC packaging trends, explored future application drivers, provided a five-year packaging forecast by package type and pin count, and concluded with our view on the emerging BGA package.

The following BGA information is abstracted from that *Dataquest Perspective.*

Dataquest finds it interesting that there has been a sharp increase in requests for BGA information over the last nine months, considering the wide range of ASIC packaging options. ASIC suppliers and ASIC users are wrestling with the decision of which package option will be the best long-term solution for their high-density/high-pin-count ASICs. Large ASIC users including Apple, Compaq Computer Corporation, IBM, and Sun Microsystems have stated that BGAs may be just the ASIC package for which they are looking.

There are many considerations when choosing a high-end ASIC package. Without going into detail on all the packaging issues, some highlights of the BGA package, compared to the plastic quad flat package (PQFP), are as follows:

- Reduced size
  - Smaller footprint
  - Low profile and low weight
  - PC-board savings
- Improved manufacturability
  - Relaxed lead pitch
  - Eliminates concerns over lead coplanarity and skew
  - Vastly improved board manufacturing yields
  - Lower manufacturing cost leveraged by high assembly yields
  - Reparable using hot airflow for removal and resoldering
- Improved electrical and thermal performance
  - Improved electrical performance with lower inductance
  - Comparable or better thermal performance

While the advantages are many, the primary disadvantages are the limited number of suppliers and the increased package cost. In terms of the limited number of suppliers issue, Dataquest is aware of four third-party

BGA packaging suppliers: Amkor/Anam, Citizen, Hestia, and Motorola. IBM also has entered the BGA market with an outstanding product offering. IBM is offering traditional BGAs with lead counts ranging from 256 leads to 625 leads, along with tape-automated bonding BGAs ranging from 240 leads to 936 leads. On the pricing issue, although Dataquest believes the price per BGA package will not reach the same level as the PQFP because of the increased cost associated with the extra steps required to add the solder balls, we expect the cost to come down substantially as volume production increases. Furthermore, additional cost savings can be achieved through better yields and reduced printed-circuit-board costs. Dataquest believes that the advantages of BGAs far outweigh the disadvantages.

In conclusion, Dataquest believes that BGA packages show great promise and may become the first great package since the PQFP.

By Bryan Lewis

Q2

Why are flash memories fabricated with epitaxial wafers?

A The primary reason that flash memories are fabricated with epitaxial wafers is to improve the maximum number of write-erase operations. There are two basic types of flash memory architecture: NOR-type and NAND-type. NOR technology utilizes hot electron injection to program the floating gate, whereas NAND technology employs tunnel current for programming.

During erase operations, electrons are discharged from the gate to the source at one edge of the gate in NOR technology, which can lead to gate oxide degradation near the gate edge, shortening the lifetime of the device and limiting the number of write-erase cycles. Epitaxial wafers are used to fabricate NOR-type flash memories to alleviate the oxide wear-out problem.

When using NAND technology, on the other hand, electrons stored in the floating gate are discharged to the body of the transistor, which creates far less stress in the gate oxide. Therefore, NAND-type flash memories can be fabricated using bulk wafers.

By Kunio Achiwa (Japan)

Q3

What are the applications driving the 8-bit microcontroller market?

A The ubiquitous 8-bit microcontroller is used in innumerable applications. Some higher-volume applications are as follows:

- Data processing
  - Pointing devices
- Mouse

- Trackball
- Pen
- Joystick
  - Hard disk drive controllers
- Telecommunications
  - Pagers
  - Cellular telephone handsets
  - Wireless telephones
  - Wired full-featured phones
- Automotive (particularly strong growth expected in Europe)
  - Engine/powertrain control (emission control, among others)
  - Body control (windows, sun roofs, and suspension, among others)
  - Entertainment (noise filtering, among others)
  - Safety (air bags and antilock brakes, among others)
- Consumer
  - Games
  - Camcorders
  - 35mm cameras

By Jerry Banks

Q4

Do cache designers prefer wider or narrower fast SRAMs?

A Fast SRAMs are used almost exclusively in cache memories. Wide parts are popular in cache designs, because the wider the SRAM, the lower the capacitive loading on the address output pins of the CPU chip. This helps the CPU to operate at its rated speed. Unfortunately, wider SRAMs tend to have slower address access times than do narrower parts, so there is a trade-off limiting the use of wider parts.

The width of the part a designer uses is usually determined by the speed of the cache, the size of cache the designer is looking for, and the densest part available at the time. If a cache designer wants a 256KB cache (64Kx32 bits), and the 64Kx16 (1Mb) SRAM does not operate fast enough, then 64Kx4 SRAMs must be used. Because of address loading, though, a 10ns 64Kx16 might be fast enough, but 8ns or faster 64Kx4s will have to be used instead. This is because there are eight SRAMs loading down the CPU bus, instead of two, and the increased capacitive loading slows the address bus enough that it must be compensated for in the address access time of the SRAMs.

By Jim Handy

Q5

What kind of synchronous SRAMs sell, and who uses them?

A

Of the synchronous parts now available, only one part is both popular and independent of any specific application. This is Motorola/Micron/Sharp's 16Kx16, which sells almost exclusively with the R3000 and R4000 processors. Other parts that sell well are the bursting 32Kx9 from Motorola and IDT (in different pinouts) for the Intel i486 and Pentium, a 128Kx9 for the superSPARC sold by Sony, and another 128Kx9 for Silicon Graphics. Unit sales for each of these is in the 100,000-to-1-million-units-per-year volume. It looks as though Pentium users will use the 64Kx18 bursting device, which Motorola is sampling. Motorola is actively seeking alternate sources for this organization. Also, Sun, Silicon Graphics, Compaq, and other system companies as well as some IC manufacturers are rumored to be trying to standardize on a family of 36-bit synchronous parts, so that there will not be the SPARC part, the R5000 part, the Intel x86 part, and so forth.

By Jim Handy

Q6

What are the average nonrecurring engineering (NRE) charges for ASICs in Japanese market?

A

ASIC NRE charges depend on gate size and design method. Table 1 shows the average NRE charge for major products in 1992.

Table 1
Average ASIC NRE Charges in Japan

	Gate Array	Cell-Based IC	Full-Custom IC
Typical Gate Size	5-10K	10-20K	20-50K
Average NRE (Thousands of Yen)	2,500	7,000	16,000

Source: Dataquest (July 1993)

As far as gate array, the average gate size grows 20 to 25 percent a year. However, the average NRE does not increase as much as does the gate size, which is one of the problems impacting the profitability of design centers.

By Satoru Oyama (Japan)

Markets and Applications

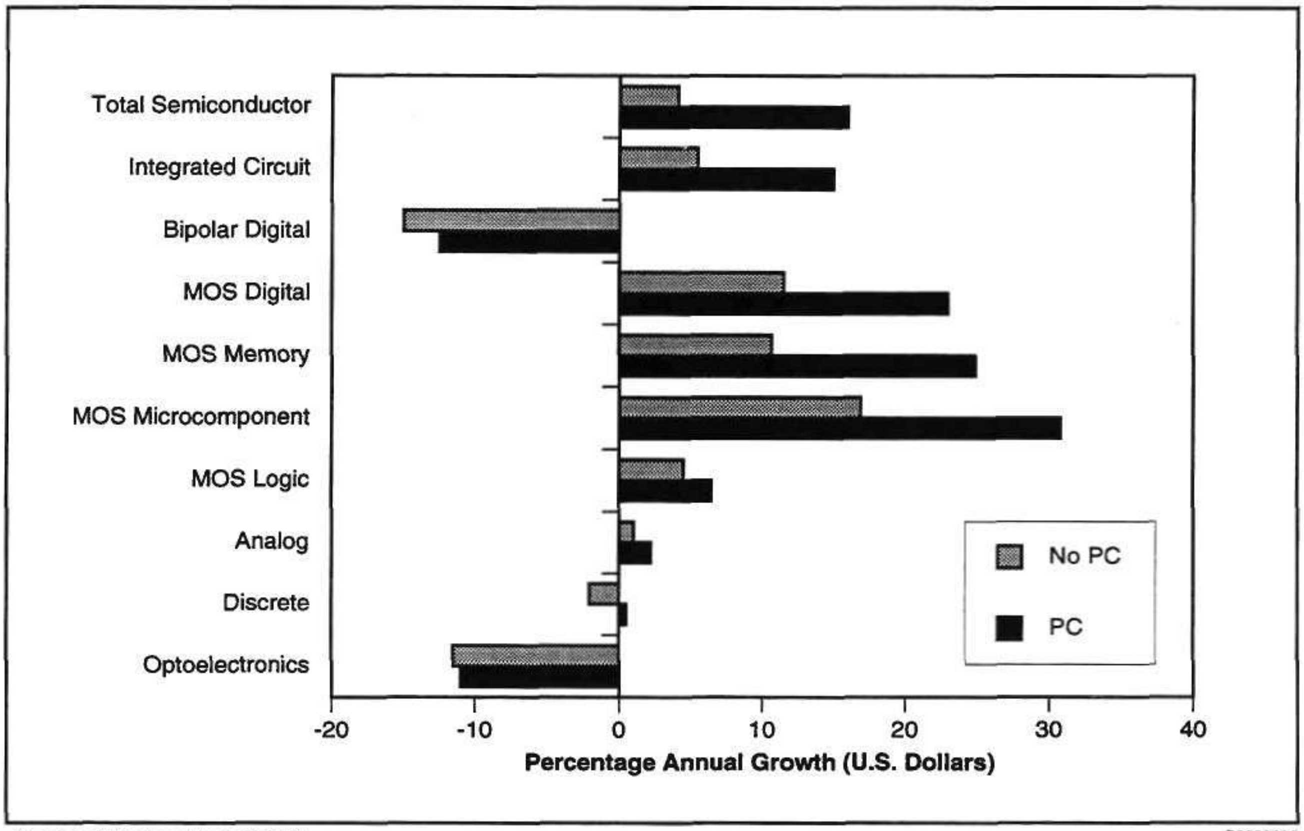
Q7

How much of Europe's semiconductor market growth did the PC account for in 1992?

A

Dataquest estimates that the European semiconductor market grew by 10.9 percent last year (in U.S. dollars). Most of the growth occurred in the last four or five months of the year as demand from PC manufacturers exploded. If it were not for the PC, the European semiconductor market would only have grown by 4.1 percent. Figure 1 shows the semiconductor market growth rate for each of the major product categories. The PC had most effect on microcomponent and memory sales. Without the PC, the microcomponent market would have grown by 16.9 percent, compared with 30.8 percent when the PC is included. The memory market grew by 24.9 percent with the PC and 10.7 percent without it. Overall, the PC accounted for 16.0 percent of the total European semiconductor market in 1992.

Figure 1
European Semiconductor Market Product Growth Rates, 1992 to 1991 (No PCs)



Source: Dataquest (July 1993)

G3003696

By Andrew Norwood (United Kingdom)

Q8 There are many opinions about the outlook for the DRAM market as we move into the summer and fall quarters. What does Dataquest expect of the DRAM supply-demand situation for the next several months?

A Despite the tight market and escalating prices we see at midyear, there are several reasons that we believe that supply will close the gap throughout the summer, and that 4Mb prices should fall around year-end.

The following paragraphs provide the basis for our supply analysis.

We believe that production of 4Mb DRAMs has been increased more than is generally recognized, with more upside coming in the second half of 1993. This increase has come from equipping and moving previously built shells into production, from die shrinks and yield improvements, and from a general focus on 4Mb DRAM production, reducing SRAM, 1Mb DRAM, and 1Mb VRAM wafer starts, and allocating about 60 to 70 percent of 16Mb-capable capacity to shrink 4Mb DRAMs.

We now estimate that 4Mb production for 1993 will exceed 800 million units, including a small contribution from IBM's TPG, up from 450 million in 1992.

The shortfall appears to not be nearly as severe as that of 1988-1989, if one looks at the fraction of desired DRAMs being delivered to original equipment manufacturing (OEMs) from DRAM suppliers. We estimate that the market in midyear is about 15 percent short of demand. Third-party single in-line memory module (SIMM) makers and smaller users are getting less, and paying more, per unit. Large OEMs generally are getting more, and will be paying about $11.25 per unit in the summer quarter. Prior to the Sumitomo explosion, secondary market prices had risen only about 30 percent, compared with the 60 percent rise in 1988-1989. We believe that the Sumitomo event's impact on the DRAM market will be short-lived, and that prices will revert to near their former levels within a few weeks.

The following paragraphs provide the basis for our demand analysis.

The PC market is still, almost, the sole driver of DRAM demand, and it is set against an increasingly weak economic environment. The euphoria of November to February, which was built on two good quarters of U.S. gross national product (GNP) growth, remarkable financial results and a positive outlook from Intel, a resumption of Japanese growth, the hope of a new U.S. administration, and a tolerable European economy, has faded.

Japan's GNP growth slowed from the first quarter to the second quarter in 1993, and there is political turmoil at the top. The U.S. slowed in the first quarter to less than 1 percent growth, and fared little better in the second quarter. There are concerns about the tax increases in the Clinton economic proposal, which will likely become law this summer. Europe looks worse at each review, and will shrink about 0.5 percent in 1993, with Germany, the ersatz locomotive of European recovery, declining about 1.5 percent. Overall, the world's economies do not look good, and eventually that shows up in the form of sagging order rates.

The U.S. book-to-billing ratio has declined for five straight months, and was most recently 1.10 at the June Flash reading. Europe, for which the Flash data is more suspect, has bounced down from 1.24 in April to 1.11 in May, to 1.08 in June. The WSTS MOS memory book-to-billing ratio (not the Flash) for May in Europe also showed a like decline in the May data, while the rest of the world improved marginally.

The PC market is very competitive, with thin margins getting thinner and no end in sight. It is likely that a summer lull will weed out some of the weaker players, freeing their DRAM orders to be shipped to the survivors. We expect this to become apparent, first in Europe, within the next few months.

So, as supplies increase and demand stagnates, we expect the market to become far more balanced at the end of the summer. Prices are likely to still rise in the fourth quarter, based on a certain inertia in the market, and on previously booked business. But we believe that resumption of price erosion is almost a certainty, beginning in the fourth quarter or certainly by the first quarter of 1994. How rapid it becomes in the first half of 1994 depends to a great degree on the timing of resumption of economic growth, and the potential for the demand side to broaden significantly from PCs, both of which may be more long-term remedies than short-term fixes.

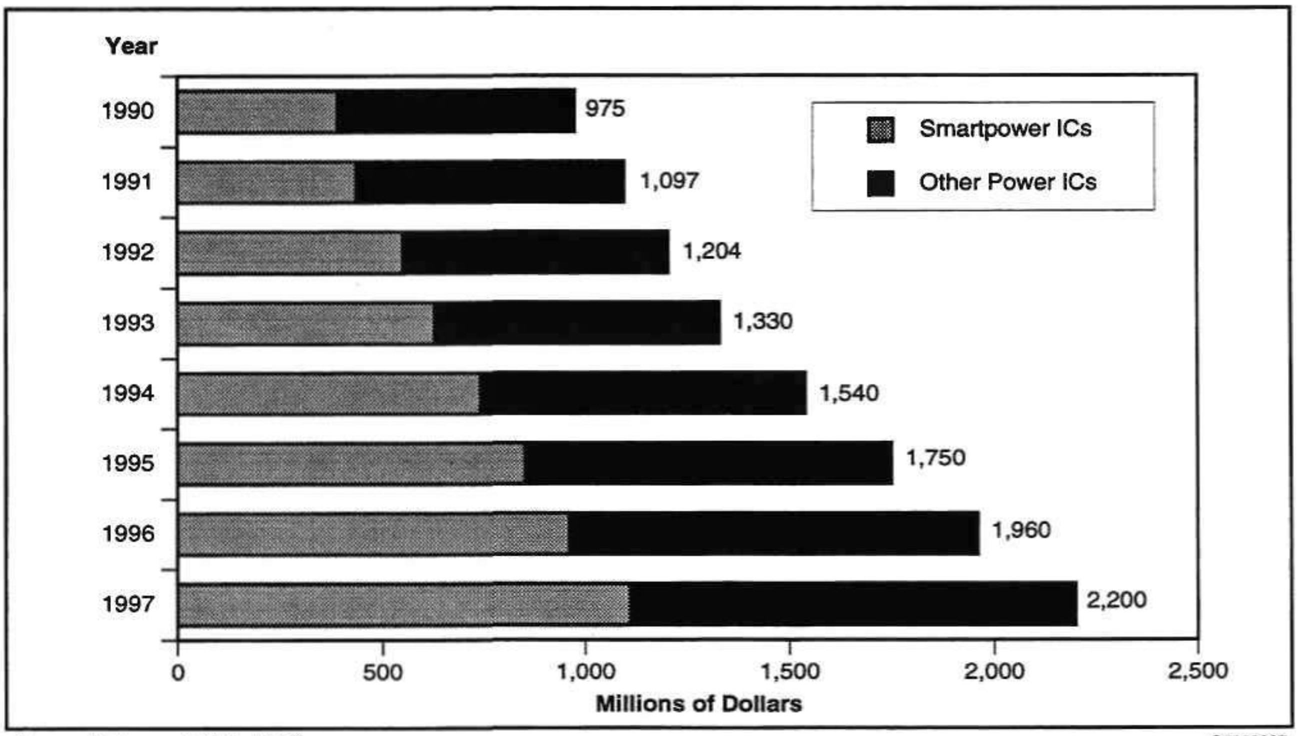
By Lane Mason

Q9

What is the five-year outlook for the power IC market?

A See Figure 2, which details our five-year power IC forecast.

Figure 2
Five-Year Power IC Forecast (Millions of Dollars)



Source: Dataquest (July 1993)

G3003697

By Gary Grandbois

Q10

What are the prices in the Japanese market for 1Mb and 4Mb DRAMs as reported by DQ Monday back to January 1991?

A See Table 2, which lists historical DQ Monday prices for 1Mb and 4Mb DRAMs.

Table 2
Historical DQ Monday 1Mb and 4Mb (80ns) DRAM Prices, Volume: 100,000 Units

	Japan ($)		Japan (¥)	
Date	1Mb	4Mb	1Mb	4Mb
1/91	5.01	26.50	675	3,700
2/91	5.01	27.50	675	3,650
3/91	5.10	25.80	675	3,400
4/91	5.05	23.41	675	3,250
5/91	4.46	20.85	640	2,900
6/91	4.35	18.15	605	2,550
7/91	4.16	17.50	615	2,550
8/91	4.15	17.50	580	2,400
9/91	4.25	17.10	565	2,250
10/91	4.10	15.85	550	2,150
11/91	4.10	15.25	540	2,000
12/91	4.05	14.65	528	1,925
1/92	3.95	14.75	500	1,850
2/92	3.95	14.51	490	1,675
3/92	3.28	11.25	455	1,550
4/92	3.28	11.25	440	1,500
5/92	3.25	11.25	435	1,500
6/92	3.20	11.25	415	1,430
7/92	3.22	11.05	395	1,365
8/92	2.90	10.05	390	1,360
9/92	3.12	10.53	385	1,300
10/92	3.11	10.50	385	1,250
11/92	3.00	11.00	380	1,200
12/92	3.45	11.50	370	1,200
1/93	2.98	9.65	370	1,200
2/93	2.98	9.66	370	1,200
3/93	3.15	10.30	370	1,200
4/93	3.27	10.55	370	1,200
5/93	3.44	11.53	370	1,240

Source: Dataquest (July 1993)

By Mark Giudici

Technology

Q11 What will be the trend for pitch on surface-mount packages? Are any suppliers using surface-mount packages with a pitch smaller than 0.5mm?

A The shrink quad flat package (SQFP) and very small QFP (VQFP) are extensions of the EIAJ package that is available in 1.0mm, 0.8mm, and 0.65mm. The new SQFPs and VQFPs have a reduced pitch of 0.5mm, 0.4mm, and 0.3mm. They are also available in pin-count ranges from 32 to 520 leads. A new subset of the VQFP is the thin QFP (TQFP) with the same pitch, but the package thickness has been reduced to 50 mils or 1.27mm. Products are being shipped in all available pitch levels. Most of the very fine or reduced pitch level packages are for ASIC products. These include cell-based ICs, FPGAs, interphase logic, and gate arrays. The 0.3mm VQFP is being used in Japan for consumer applications. Hitachi, IBM, Motorola, NEC, Texas Instruments, and Toshiba are all shipping gate arrays in 0.5mm and 0.4mm. They have all advertised high-pin-count (400 to 600 pins) package availability in 0.4mm- and 0.3mm-pitch levels.

The 0.3mm pitch is expected to be in small volumes until 1994. Although the suppliers have achieved significant reduction in pitch levels to 0.3mm, PCB assembly of less than 0.5mm is still a challenge for the majority of the industry.

By Mary A. Olsson

Company and Other Issues

Q12 What is the status of the various General Signal semiconductor equipment companies since the announced divestiture plans earlier this year?

A On January 14, 1993, General Signal announced its plans to divest its semiconductor equipment companies, which include Assembly Technologies, Drytek, Electroglas, GCA, Kayex, and Ultratech Stepper. Table 3 presents the current status for each of these companies (as of June 30, 1993).

Table 3
Current Status* of General Signal Semiconductor Equipment Companies

Company	Products	Status
Assembly Technologies	Die attach systems and dicing saws	May 3: General Signal signs letter of intent to sell Assembly Technologies to Semicon Tools, a manufacturer and distributor of scribing tools for wafer dicing.
Drytek	Dry etch systems	June 23: General Signal signs definitive agreement to sell Drytek to Lam Research, a major manufacturer of advanced etch systems.
Electroglas	Automatic wafer probers	June 24: General Signal announces an initial public offering for its Electroglas subsidiary.
GCA	Steppers	May: GCA's stepper operations are closed down after no serious suitor is forthcoming.
GCA Tropel	Optics and lenses	June 29: General Signal signs letter of intent to sell GCA Tropel to the management of the company.

(Continued)

Table 3 (Continued)
Current Status* of General Signal Semiconductor Equipment Companies

Company	Products	Status
GCA Integrated Solutions	Service and spares organization	June 29: General Signal signs letter of intent to sell GCA Integrated Solutions to the management of the company.
Kayex	Crystal growing furnaces	Kayex moved into General Signal's process control equipment division pending more favorable offers for the company.
Ultratech Stepper	1x steppers	January 18: General Signal signs letter of intent for management buyout, which is completed on March 18.

*As of June 30, 1993
Source: Dataquest (July 1993)

By Peggy Marie Wood

Q13 What is the latest specification from the Multimedia Marketing Council for a multimedia PC, and what is its impact on the semiconductor market?

A According to the recently released Level 2 specification, as a minimum a so-called "multimedia" PC (MPC) should have a 25-MHz 486SX processor, 4MB of main memory, a CD-ROM drive capable of 300 MB/sec transfers and multisession recording, and 16-bit sound input/output at up 44.1 kilo samples per second (CD quality). The sound specification further calls for music synthesis capable of six simultaneous melody notes and two simultaneous percussive notes.

The specification fell short of requiring the CD-ROM/XA standard, which interleaves audio with data. It also did not specify an audio compression standard nor any digital video capability beyond BitBLT for window acceleration.

The potential impact on the chip business includes further rollover to the 486 machines for home use, where most of the MPC PCs are going so far. Other factors include larger memory configurations, and increased demand for upgraded CD-ROM data/servo electronics, and 16-bit audio processing. These and future changes should create plenty of opportunities for adding value and differentiation.

By Gregory Sheppard

NO1SEM1WW SCNDWW1S9307 BH: 0 N: 1
Mr. Richard Spence
Dataquest Incorporated
300-1264
****
SJ - INTERNAL DISTRIBUTION
****

For More Information...

Rick Spence, Industry Analyst .... (408) 437-8642
Via fax .... (408) 437-0292

Dataquest®
a company of The Dun & Bradstreet Corporation

Q&A Dataquest Inquiry Summary

Semiconductors

Semiconductors Worldwide

June 1993

Products

Markets and Applications

Company and Other Issues

Dataquest®
a company of The Dun & Bradstreet Corporation

Program: Semiconductors Worldwide
Product Code: SCND-WW-IS-9306
Publication Date: June 28, 1993

Products

Q1 What are the historical unit shipments for MOS memory for the past decade or so? What do the trends foretell about "peaking of unit shipments" in the near future?

A Table 1 shows that DRAMs are clearly the biggest single force driving MOS memory unit shipments (and therefore packages, and probably testers and test time). But SRAMs have gained share since the mid-1980s, and each memory type has shown periods of growth and pauses as the

Table 1
MOS Memory Shipments, 1977-1992 (Millions of Units)

Year	DRAM	SRAM	EPROM	ROM	EEPROM	Flash	OMN	Total
1977	67	37	7	31	5	0	3	150
1978	104	54	15	37	6	0	4	220
1979	147	79	35	63	8	0	5	337
1980	229	107	50	92	9	0	8	495
1981	258	132	71	154	11	0	9	635
1982	357	174	107	256	14	0	11	919
1983	623	220	145	220	25	0	12	1,245
1984	1,012	291	221	132	43	0	10	1,709
1985	782	298	245	137	45	0	9	1,516
1986	1,038	304	267	154	49	0	11	1,823
1987	968	377	309	156	55	0	15	1,880
1988	1,298	549	395	305	122	0.2	23	2,692
1989	1,254	630	402	299	118	0.7	25	2,729
1990	1,336	620	424	315	127	3.0	27	2,852
1991	1,286	704	476	383	213	12.0	32	3,106
1992	1,488	928	423	366	300	27.0	33	3,565

Source: Dataquest (June 1993)

competitive price, applications, and technologies change. The rise of ROM units in the early 1980s will be remembered as Video Games I, the rise and fall of Atari. EEPROM units for the past several years have been driven by the low-density, 90-cent part types.

Much of the talk of a peaking of DRAMs has been tempered, for the time being, by the 1992 (continuing into 1993) resurgence of unit growth.

By Lane Mason

Q2

Is the TSOP well accepted for SRAMs?

A The TSOP (thin small-outline package) is enjoying rapid acceptance in the world of slow SRAMs. Suppliers shipping 32Kx8 and 128Kx8 slow SRAMs in TSOP are enjoying the better part of the business right now, because average selling prices are 5 percent to 10 percent higher for this package, and supplies are tightening. Fast SRAMs still ship predominantly in DIPs and the SOJ package, with a few unusual parts shipping in the PLCC. It looks as if this will not change in the near future, because there is limited capacity for the TSOP package, and the most pressing need for such a small package device is in the hand-held device market, which is dominated by slow devices.

By Jim Handy

Q3

What was the growth of the product segments within the analog category in 1992?

A Table 2 shows the 1992 growth for the major product types considered to be part of the analog IC category, and contrasts the latest annual growth with the five-year compound annual growth rate (CAGR).

Table 2
Growth by Product Category

Product	1992 Revenue ($M)	Growth (%) 1991-1992	CAGR (%) 1987-1992
Amplifiers	874	-4.4	1.3
Comparators	133	-4.4	-1.8
Voltage Regulators	744	10.9	11.4
Data Converters	995	2.7	6.7
Interface	644	3.9	0
Special Functions/ASIC	1,845	43.0	21.1
Telecom-Specific	1,366	7.2	NA
Consumer-Specific	3,533	-3.0	6.4
Monolithic Subtotal	10,134	6.5	9.5
Hybrid ICs	1,381	-1.0	2.8
Total Analog ICs	11,515	5.5	8.5

NA = Not available
Source: Dataquest (June 1993)

By Gary Grandbois

Markets and Applications

Q4 The 68K family of microprocessors from Motorola has historically dominated the laser printer controller market. Intel and Advanced Micro Devices seem to have captured a large number of new design-wins in this area, with the i960 and AM29000, respectively. Who is leading in terms of market share and what does the future hold?

A The recently released "Embedded Microprocessor Market" *Focus Report* from Dataquest's Microcomponents service addresses this and several other applications issues. Despite the recent onslaught by Intel, AMD, and others, the 68K family still maintained nearly a 78 percent market share in 1992. Some high-profile design-wins have occurred for both Intel and AMD, however, and Motorola still wins a fair share of these design-win battles. Motorola continues to introduce higher-performance, lower-power, and higher-integration versions of its 68K family. Once an embedded processor is designed-in, it is difficult to "steal" its socket. The incumbent architecture typically has a lot of inertia in its favor when competing with competitors' products. This inertia is made up of existing application software, custom-developed ASIC support chips, familiarity with the incumbent architecture, and development hardware and software. As a result, it is not an easy task to switch from one microprocessor architecture to another. We believe that Motorola's focus on the embedded marketplace will keep in it in good stead, and that it will remain a leading supplier of embedded processors to the laser printer market and other high-volume markets.

By Jerry Banks and Ken Lowe

Q5 What is Dataquest's view on the penetration of multimedia into the Japanese market?

A Dataquest Japan believes that the strongest growth in multimedia will be seen in the video game industry. This industry is regarded as the closest thing to multimedia, and, because the video game market has been extremely explosive, it has become the unexpected foundation of home multimedia. In terms of other equipment (nongames), it is still uncertain when the expansion of the market will take place into the home and for business use. However, Dataquest believes that home units will drive the multimedia market. In terms of price, the level of TV video game performance at its current price will be the benchmark for evaluating future multimedia players. Video game manufacturers are focusing their attention on the home market, while traditional consumer electronics companies such as Matsushita and Sony are eager to break in. Recent Japanese alliances in the multimedia area are as follows:

- Sony with Apple, Philips, IBM, and Kaleida
- Matsushita with 3DO, Philips, Electronic Arts, Gain Technology, and Kaleida

- Nintendo with Philips and Electronic Arts
- Sega with Electronic Arts and General Electric

By Kun Soo Lee (Japan)

Company and Other Issues

Q6 When will IBM enter the merchant ASIC market, as rumored? What will be the product offering? What is Dataquest's view on its products and potential market success?

A On May 10, 1993, IBM officially entered the ASIC market during the Custom Integrated Circuit Conference (CICC). On the same day, Dataquest's ASIC service distributed a six-page *Dataquest Alert* on the announcement and the product offering, entitled "IBM Enters Merchant ASIC Market at CICC." The following comments are from this *Dataquest Alert*.

IBM did not hold back with its ASIC product introduction: It is offering the same state-of-the-art ASIC products to the merchant market that it sells to its internal system divisions.

IBM introduced two types of ASICs at CICC: a 0.8-micron ASIC family (CMOS 4LP) and a 0.5-micron family (CMOS 5L). Each family comprises three types of devices: gate arrays, cell-based ICs, and embedded arrays (gate arrays with megacells diffused in the gate array base wafer). The company also is being very flexible and is willing to sell any part of the device, ranging from bare die to just the package.

Highlights from the CMOS 5L family are as follows:

- CMOS 5L family
  - 0.5µm drawn high-performance CMOS technology
  - Up to 1,300K usable logic gates
  - Five levels of wiring metallization (2.4µm pitch)
  - Wiring pitches:
    - M1: 1.4µm
    - M2: 1.8µm
    - M3: 1.8µm
    - M4: 1.8µm
    - M5: 3.6µm
  - 220PS typical gate delays (2 NAND, FO=2, 3.6V)
  - Low power (1.0 to 1.5 µW/MHz)
  - Up to 508 bidirectional I/Os
  - 0.49µm nominal effective channel length

- 1.4µm transistor pitch
- Salicided polysilicon and diffusions
- Single 2.3V to 3.8V power supply
- Solder ball (C4) package interconnect
- Two libraries to allow performance/power trade-off
  - Gate array library optimized for low power
  - Cell-based library optimized for high performance

IBM is offering a wide variety of packages with a wide range of pin configurations. Its package offering ranges from standard plastic quad flat packs with 100 to 296 pins to multichip modules with up to 3,500 pins. Other packages include: C4 plastic quad flat packs with up to 504 pins (0.3mm pitch), multilayer ceramic (MLC) packages with up to 545 pins, pin grid arrays with up to 1,073 pins, ball grid arrays (BGAs) with up to 625 pins, and tab BGAs with up to 940 pins.

Dataquest believes that IBM has set the density record and metal interconnect record with the introduction of its 0.5-micron gate array with up to 1.3 million usable gates and five-layer metal interconnect. The maximum usable gates for a 0.5-micron gate array before IBM's introduction was about 650,000 with three-layer metal interconnect. Clearly, IBM has industry-leading ASIC technology and packaging.

Dataquest believes that the remaining overriding question is whether IBM will be able to effectively market its ASIC products to the merchant market. AT&T and Hewlett-Packard were in a similar situation and they found it difficult to execute a solid merchant strategy in a timely manner. IBM will face a number of challenges in the near future. First, it must capture some high-density ASIC designs from key electronic equipment suppliers to prove its new design environment and technology. Second, the company is now using distributors and outside representatives to get sales leads and support. Dataquest believes that IBM will need a strong direct sales force and product support group to develop its merchant potential because its product offering is a highly technical sell that requires in-depth knowledge of the products. Third, IBM must continue to invest in advanced library megacells. At this point, the cell offering can be considered above average but not outstanding. However, the company is believed to be working on some important core cells including a PowerPC RISC microprocessor core. Fourth, the company must prove that it can deliver five-layer metal interconnect products with the extremely high densities the company boasts on a consistent basis. Finally, IBM must prove that it can supply cost-effective electronic solutions. Having industry-leading technology means little to the merchant market if it is not cost-effective.

Dataquest believes that IBM is serious about being a leading merchant ASIC supplier and that it has taken a solid first step toward achieving its goal. If its first ASIC product introduction is any indication of things to come, IBM will be one tough supplier to reckon with.

(Further analysis of this IBM announcement is available from Dataquest's ASIC service.)

By Bryan Lewis

Q7

What is the implication of the sudden investment activity by the regional Bell telephone companies in cable companies?

A

The big picture perspective shows that service revenue for the telephone and cable services has flattened out during the past few years. Therefore, both the telcos, cable, and direct broadcast satellite companies are looking at interactive, multimedia communications to the home as a revenue energizer through the latter part of the 1990s and the next century. The potential new service revenue is commonly estimated at $50 to $100 per household per month ($60 billion to $120 billion per year in the United States and Canada alone). The services envisioned include pay-per-view movies (a choice from 500 at any one time), electronic directories, video games delivery, home shopping, and home banking. These services will require new decoder boxes capable of two-way audio/video digital transmission and Motion Pictures Electronics Group (MPEG) II decompression.

The other part of the story is that, according to the cable television bill passed late last year, the Federal Communications Commission now has regulatory authority over cable operations. The FCC is only allowing telcos to take a maximum 5 percent position in colocated cable operations and an unlimited position in remote cable operations. Therefore, in an effort to hedge their bets, telcos such as US WEST are investing in big cable operations such as Time Warner. The investment is prompted by the fact that cable companies already serve more than 50 million U.S. homes with high bandwidth services, and companies such as TCI have announced plans to invest $1 billion per year to upgrade for interactivity using fiber-optic technology.

In the meantime, Bell Atlantic, for example, is turning to a conditioning technology called asymmetrical digital subscriber line (ADSL) with MPEG compression to turn home phones lines into 1.5-Mbps-capable pipelines ready to deliver many of the previously mentioned services.

Dataquest will track this battle and report on the big "W"—when—which will be more evident when this current euphoric frenzy of investment settles and the reality of the economics sets in.

By Greg Sheppard

Q8

When will 16Mb DRAM become mainstream in the market?

A

One important factor that will help 16Mb DRAMs prevail is the price-per-bit (ppb) comparison between current 4Mb DRAMs and 16Mb DRAMs. Dataquest expects the ppb of 16Mb DRAMs to match that of 4Mb DRAMs in the latter half of 1994.

Factors that will account for the delay in the crossover include the following:

- Many Japanese DRAM suppliers reduced their capital spending on 16Mb and are having a difficult time getting financing.
- Korean memory suppliers are having an effect on the ppb. Dataquest estimates that Korean suppliers owned about 25 percent of the DRAM market in 1992, a percentage that has helped them control the ppb. Although the Koreans sacrificed margins for market share in the past, they appear to be changing course and are now putting more emphasis toward profits.
- From an application point of view, workstations consume the majority of 16Mb DRAMs, and supply has not reached demand yet. However, PCs will be one of the memory-eaters in the market in 1994. If chip-makers supply 16Mb products of lower ppb in that time frame, PC manufacturers could use them in compact PCs.

Based on current trends, it looks as though the latter half of 1994 will be the next boom of 16Mb DRAM. If that happens, look for the ppb of 16Mb products to drop off in 1995.

By Akira Minamikawa (Japan)

Q9

Why are microprocessor clock rates set at odd frequencies?

A

It often appears strange that microprocessor clock rates would be set at odd frequencies such as 33 MHz or 66 MHz. To start with, the primary clock rate determines the timing relationship for the data, address, and control signals. These timing relationships involve detailed values for data validity and setup/hold time, among others, which are all calculated in the time domain (or 1/frequency), so primary consideration is given to making these time values turn out to be even numbers. If the clock period for each popular microprocessor frequency is examined, it becomes apparent that successive clock rates have been created by decreasing the clock period by multiples of 5ns at each increment (see Table 3).

Table 3
Microprocessor Frequency versus Clock Period

Frequency (MHz)	Clock Period (ns)
20	50
25	40
33	30
40	25
50	20
66	15

Source: Dataquest (June 1993)

By Ken Lowe

Q10 Please provide an update on Micron Technology's DRAM program. What can we expect for the remainder of 1993?

A Now running more than 85 percent DRAMs, Micron is clearly riding the buoyant DRAM market. It increased its revenue from about $131 million in the final quarter of 1992 to $176 million in this year's first quarter, and probably to more than $205 million in the quarter ending May 31, 1993. Profits have risen in line with industry profits: Micron had profits of less than $2 million in 1988, $9 million in 1989, and about $20 million in the present quarter.

Micron's Ministack 4Mb DRAM is now running more than 3 million units per month, as the company shifts wafer allocations from 1Mb DRAMs and VRAMs, and SRAMs, to 4Mb DRAMs and 2Mb VRAMs.

The ministack version, its third die revision for the 4Mb, has about 240 candidate die per 6-inch wafer. It also has seen silicon on its next revision, which has 330 candidate die. It expects about 20 percent of 4Mb DRAM wafer starts to be the shrunk die by year-end. Yet another "hyper-shrunk" 4Mb is in the wings, which uses the 16Mb technology, but its introductory timing depends on the market. That die would add 100 candidate die per wafer, and further reduce the mask count by 1 mask to 11 masks.

Micron has produced samples of its Revision 2 16Mb die, which is 129 sq. mm. and uses a 13-mask process. It expects to have its production 16Mb proven by year-end 1993, which will be sized to fit in a 300-mil package.

Clearly, Micron is riding the wave. Unfortunately, it remains strapped for cash, and its present facility expansion plans are modest (plus 20 percent wafer starts in the next 9 months). On the other hand, it has temporarily fended off the dreaded Texas Instruments "Intellectual Property Monster," while building its own portfolio to more than 230 patents. It has taken the patent offensive both to TI itself and to Goldstar and Hyundai, and appears to have slowed, if not reversed, the intellectual propety tide altogether.

By Lane Mason

Q11 In light of the ongoing trend toward surface mount IC packaging and the current allocation of most surface mount technology (SMT) products, when would be a less risky time to begin converting to SMT?

A The ongoing trend toward surface mount will continue. The current market allocation situation for SMT logic, linear, and selected memory and MPU devices highlights how fast demand has shifted to these packages, relative to the level of supply. The current situation is primarily because of the heavy demand for low-cost, high-powered PCs that are large users of semiconductors and in particular SMT semiconductors. The question as to when to switch to SMT should be looked at on a system-by-system basis. For those systems phasing out over the next five years, there is little need for conversion to SMT, while new designs and systems with more than five years of service left should be considered serious candidates for SMT packaging. Obviously, SMT packaging is mandatory for systems with less than two to five years of a life cycle.

SMT standard logic is expected to remain a tight commodity because of historical low profits, which do not encourage additional capital spending. Although many SMT parts are on allocation, the majority of memory products are now shipped in some form of SMT package and the surface mount percentage will continue to increase. The shift in technology from EPROM to flash memory has been rapid and has constrained both wafer and SMT supplies. This situation is expected to improve as more suppliers enter this market over the next six months.

By Mark Giudici

Q12 What is Dataquest's definition of MQFP?

A Dataquest does not define package types used for IC encapsulation, Dataquest reports on the package types being used for active ICs. When Dataquest surveys users of package types by components, a generic package reference such as QFP for QUAD flat package is made so as not to promote or prejudice any one company's package development. However, because of the significant package proliferation, Dataquest does track the acronyms and the specific definition of those acronyms as given by the developing company or standards committee that has made the definition of or specification for that package acronym. Table 4 shows some of the many choices from the QFP family of packages.

Table 4
QFP Family of Packages

Package	Description
QUAD-PAK	GTE trademarked premolded plastic package
Cerquad	Digital Equipment Corporation development; alloy 42-lead frame between two ceramic layers
C-QUAD	Northern Telecom's ceramic QUAD flat package
PQFP	EIAJ Japan specification, plastic QUAD flat package

(Continued)

Table 4 (Continued)
QFP Family of Packages

Package	Description
PQFP	JEDEC plastic QUAD flat package with bumpers developed by AT&T; sometimes referred to as BQFP
CQFP	JEDEC ceramic QUAD flat package
TQFP	Tape QUAD flat package developed by LSI Logic Corporation
TQFP	Thin QUAD flat package, EIAJ specification
MQUAD	Patented by Olin Corporation; stamped, anodized, aluminum cap and base available in Metric QFP, JEDEC bumpered QFP, and Metric QFP TapePak outlines (TapePak is a registered trademark of National Semiconductor)
Metric QFP	New JEDEC QUAD flat package
SQFP	Shrink QUAD flat package, EIAJ specification
PowerQUAD:	Amkor Electronics proprietary package
VQFP	Very small QUAD flat package, EIAJ specification
GQFP	Guard Ring QUAD flat package, EIAJ specification

Source: Dataquest (June 1993)

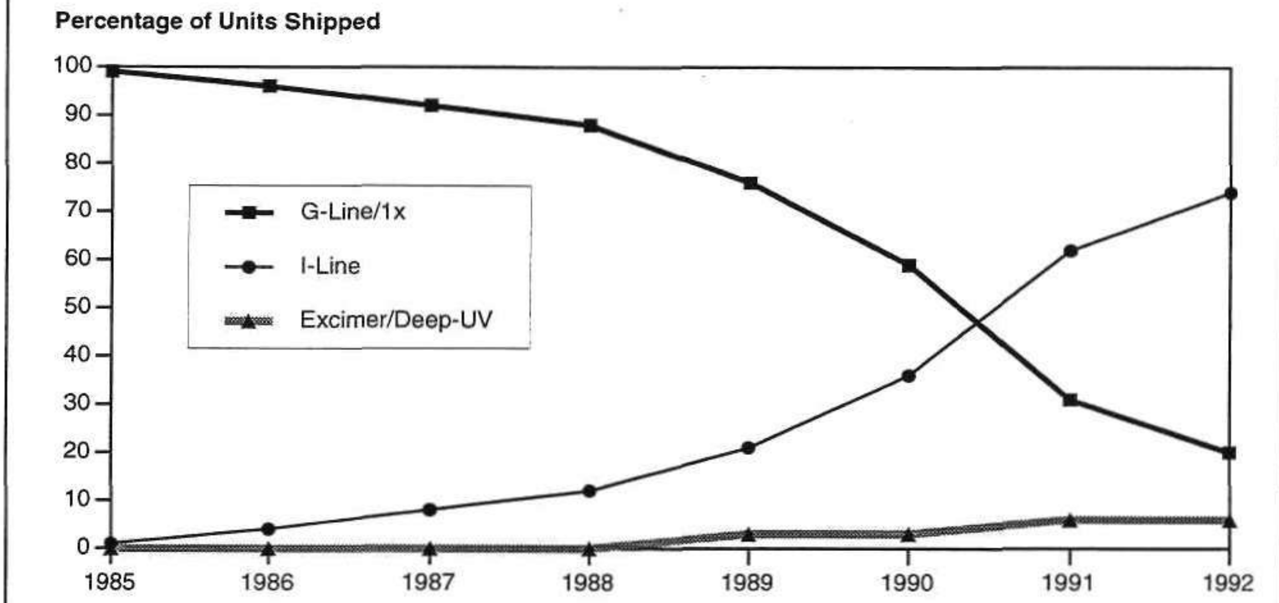
By Mary A. Olsson

Q13 On a unit basis, how has the worldwide stepper technology product mix changed during the past several years?

A Figure 1 presents Dataquest's estimate of the worldwide stepper technology product mix for g-line and 1x (combined), i-line, and excimer/deep-UV steppers. According to our estimates, the first i-line tools shipped in 1985. Their portion of the worldwide product mix has grown most rapidly over the past several years from a mere 21 percent in 1989 to 74 percent of all stepper shipments in 1992. The improved technical performance and wide-field capability of i-line tools, coupled with phase shift mask technology and off-axis illumination techniques, have contributed to make i-line the dominant stepper technology well through the 64Mb DRAM generation. Dataquest believes that i-line tools will continue to maintain about three-fourths of the total product mix of new stepper shipments through the 1995 time frame.

Excimer/deep-UV tools accounted for only 6 percent of all steppers shipped in 1992. Their portion of the total mix is expected to grow moderately during the next several years at the expense of the continuing decline in g-line stepper demand. Today, the push to excimer/deep-UV lithography is still perceived to be limited by the lack of a broad offering of production-worthy resists from photoresist manufacturers. For that reason, we believe that excimer/deep-UV tools will not see widespread usage until the 256Mb DRAM generation at the end of the decade.

Figure 1
Worldwide Stepper Unit Shipments by Technology Split



Source: Dataquest (June 1993) G3003000

By Peggy Marie Wood

Q14 What are the current trends in the interactive CD ROM player marketplace?

A Multimedia captures the market spotlight. Multimedia strategists believe that near-term demand for CD ROMs for use "in the home" should set the stage for long-term demand for business multimedia products such as real-time remote videoconferencing. In effect, home or school use of interactive CD ROM players for entertainment or educational purposes will pave the way for comfortable use of multimedia systems in the office. Some multimedia market players fervently wish for a hit CD ROM player during the 1993 Christmas season as a way of accelerating this process.

Although the interactive CD ROM player marketplace continues to grow and attract Hollywood-style press coverage, midyear 1993 market trends do not assure a year-end boom in sales. For example, 3DO commands investor attention, yet it was not ready for summer the Consumer Electronics Show, as promised earlier, and may not meet its most recent pledge of a just-in-time Christmas introduction. With the strong presence of game suppliers, Sega may emerge at year-end as an early leader in the long-term battle to make its CD-ROM system the de facto standard akin to VHS's victory last decade over Beta in the VCR arena.

During April and May 1993, Tandy tested price elasticity for its VIS player, a 286-based system. A big question for Tandy remains when, if ever, the company will introduce a next-generation Windows-compatible interactive system that offers full motion video, and at what price. The likely answer is, not by Christmas 1993.

Tandy's recent sale of its manufacturing operations to AST muddles the issue. At press time, details on the impact of this transaction on Tandy's computer operations were not publicly known. Perhaps the question should be when, if ever, AST will introduce a 386-based Windows-based system that offers full-motion video.

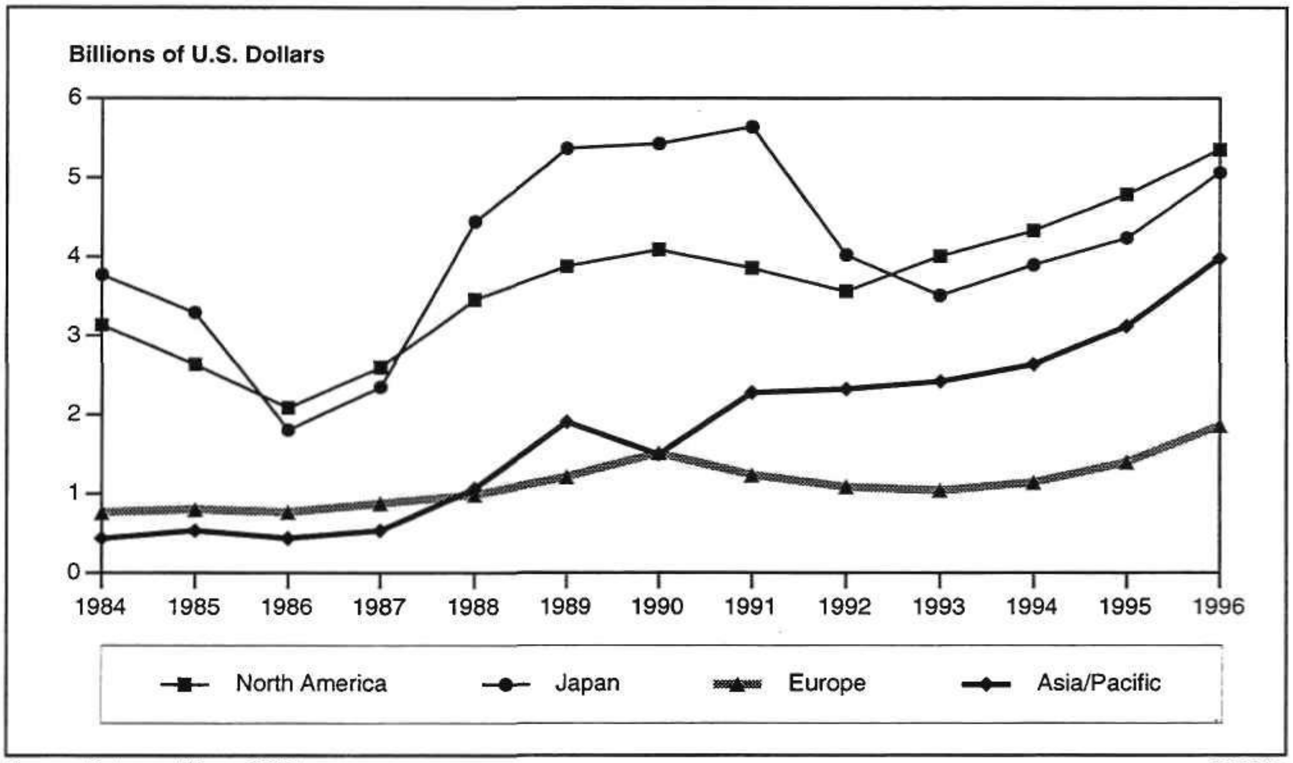
The 386 technology offers a key advantage over other technologies; 386 systems can tap into the huge base of low-cost DOS software—and Windows-compatible players can tap into the large base of multimedia PC (MPC) titles. For ultimate end users, the number of titles that a system can play—especially at a low price—might outweigh some sacrifice in system performance. AMD certainly thinks so. AMD now searches for a CD-ROM player home for a "full-motion player 386 chip set" that can not only provide full-motion playback of MPC titles, but also be rather readily converted to a full-blown home computer. Systems based on the Am386 chip set would be geared for 1994—not this Christmas—at an attractive sub-$500 price point that could spell multimedia market boom by Christmas 1994.

By Ronald Bohn

Q15 How does semiconductor capital investment in Europe compare to the rest of the world?

A Figure 2 shows capital investment by world region since 1984, and incorporates our latest capital expenditure forecast from 1993 to 1996. Since 1988, Europe has attracted less semiconductor dollar investment than the other major regional markets. This trend continued to a point where Asia/Pacific received twice as much investment as Europe did last year. This picture destroys any misconception that Europe will become self-sufficient in semiconductors. Europe will continue to be a substantial net importer for the foreseeable future. In fact, its trade gap is set to widen.

Figure 2
Semiconductor Capital Investment by Region



Source: Dataquest (June 1993) G3003001

By Jim Eastlake (United Kingdom)

Q16 Where are Europe's major printer manufacturing locations, and which types are manufactured there?

A Table 5 shows the locations and the products manufactured in Europe.

Table 5
Major European Printing Manufacturing Locations, and Types Manufactured

Company	Town	Country	Laser	Dot Matrix	Others
Agfa-Gevaert	Antwerp	Belgium	•		
Brother Industries UK Ltd.	Wrexham	United Kingdom		•	
Bull	Milan	Italy	•	•	
Canon Bretagne S.A.	Liffre	France	•		
Citizen Manufacturing (UK) Ltd.	Scunthorpe	United Kingdom		•	
Dataproducts	Dublin	Ireland	•		•
Epson	Boneuil-Sur-Mame	France		•	
Epson Telford Ltd.	Telford	United Kingdom		•	
Facit	Atvidaberg	Sweden	•	•	•

(Continued)

Table 5 (Continued)
Major European Printing Manufacturing Locations, and Types Manufactured

Company	Town	Country	Laser	Dot Matrix	Others
Facit	Svangsta	Sweden	•	•	•
Ferrotec	Stillorgan	Ireland			•
Fujitsu	Malaga	Spain		•	
Hewlett-Packard	Coslada	Spain			•
IBM	Jarfalla	Sweden	•	•	•
Kyocera Manufacturing	LeGrand Quevilly	France	•		
Lexmark	Boigy	France	•		•
Mannesmann Tally	Elchingen	Germany		•	•
NEC Technologies (UK) Ltd.	Telford	United Kingdom		•	
Newbury Data	Winsford	United Kingdom		•	
Nipson Printing Systems	Belfort	France	•		•
Océ	Venlo	Netherlands	•		
Oki Electric (UK) Ltd.	Cumbernauld	United Kingdom		•	
Olivetti	Crema	Italy		•	•
Olivetti	Aglie	Italy		•	
Olivetti	Saint Bernardo	Italy	•	•	
Olivetti	Barcelona	Spain		•	
Panasonic	Duffryn	United Kingdom		•	
Printer Systems International	Siegan	Germany		•	
Rank Xerox	Venray	Netherlands	•		
Rank Xerox	Gloucester	United Kingdom		•	
Rank Xerox Espanola	Madrid	Spain	•		
Seikosha	Neumunster	Germany		•	
Siemens-Nixdorf	Poing	Germany	•		
Star Micronics (UK) Ltd.	Tregagara	United Kingdom		•	
Triumph-Adler	Nuremberg	Germany	•		•
Walther	Gerstetten	Germany		•	
Wenger	Therwil	Switzerland	•	•	

Source: Dataquest (June 1993)

By Andrew Norwood (United Kingdom)

Q17 What percentage of worldwide semiconductor revenue has historically been spent on wafer fab equipment?

A The historical average for equipment spending as a percentage of semiconductor revenue was 9.6 percent from 1980 to 1992. The percentage of total semiconductor revenue has exhibited a cyclic behavior in the past, and has been decreasing for the last three years, displaying a particularly sharp drop in 1992 (see Table 6). This decrease is because of nearly flat equipment sales in 1990 and 1991, with a sharp drop in 1992, at the same

Table 6
Total Wafer Fab Equipment and Total Semiconductor Revenue (Millions of Dollars)

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Total Semiconductor	14,098	14,801	15,231	19,537	28,825	24,341	30,834	38,250	50,859	54,339	54,545	59,739	65,264
Total Wafer Fab Equipment	335.1	736.2	1,414.1	2,121.4	3,523.3	3,357.2	2,713.4	3,136.9	4,984.0	6,022.5	5,872.2	6,024.4	5,091.4
Percentage of Total Semiconductor	2.4	5.0	9.3	10.9	12.2	13.8	8.8	8.2	9.8	11.1	10.8	10.1	7.8

Source: Dataquest (June 1993)

time that the semiconductor market was increasing. Ultimately, this pattern will give rise to a capacity shortfall, which is occurring now, and should bode well for equipment sales in the next few years.

By Charles Boucher

Q18 Please provide a quick review of recent activities at Hyundai.

A The most recent developments at Hyundai are as follows:

- Hyundai had its dumping margin increased twice in the course of the Micron Technology antidumping crusade. Hyundai came out the best in the preliminary round, with 5.99 percent duty. This was raised to more than 7 percent at the final stage, but even this was raised to more than 11 percent, about a month later, as the U.S. Department of Commerce found a "clerical error" in the cost calculation. Hyundai was happy at the beginning with the 5.99 percent rate, and even thought that was too high. It is far less happy now.
- It is shipping product to IBM Canada. Whether this has to do with avoiding the duties is uncertain, but it is probably still smart.
- Its present facilities are running at capacity, although it is introducing a shrink 4Mb die into production that will increase gross die/wafer from less than 200 to more than 280.
- It has a 16Mb DRAM of its own design that is in its introductory sampling stages. We have not seen them in the United States, but there may be some.
- It is now equipping its 10,000-starts 200mm line (its 16Mb line), and reportedly is paying premiums to equipment suppliers to deliver early.
- It is having to make the same allocation choices as are other DRAM makers, from finding customers for its DRAMs a year ago, to finding DRAMs for its customers today. It is a major supplier to the aftermarket and Asia, and some of the low-end parts of the market will be tight, as is now reflected in spot prices in the $15 range.
- Like all Korean companies, Hyundai is seeking ways to broaden its product line, from DRAMs to SRAMs, to other products yet to be revealed.

By Lane Mason

N01SEM1WW SCNDWW1S9306 BH: 0 N: 1
Mr. Richard Spence
Dataquest Incorporated
300-1264
****
SJ - INTERNAL DISTRIBUTION
****

For More Information...

Rick Spence, Industry Analyst .... (408) 437-8642
Via fax .... (408) 437-0292

Dataquest®
a company of The Dun & Bradstreet Corporation

Dataquest Perspective

Semiconductors

In This Issue

Strategic Alliances—First and Second Quarters 1993

This article provides an overview of worldwide alliances between companies in the electronics industry during the first half of 1993. It will characterize those alliances by company and region, and by alliance type as well as by product type.

Strategic alliances between companies can provide significant opportunities in the growth and direction of products, technologies, companies, and regions. Opportunities or benefits of strategic alliances include the following:

- Access to new markets
- Access to foreign markets
- Increased financial leverage
- Access to innovative technology
- Access to manufacturing processes
- Access to technology commercialization
- Strong regional ties during economic downturns

The strategic alliance data in Table 1 and Figures 1 through 3 is incomplete in that it covers only those alliances announced or released into the public domain. A significant amount of alliances made between companies are not disclosed for purposes of confidentiality, protection of technology, and other proprietary reasons. Dataquest classifies strategic alliances into the following major categories used in Table 1 and Figure 1:

- LA: Licensing agreement
- SS: Second source agreement

Dataquest®
a company of The Dun & Bradstreet Corporation

Program: Semiconductors Worldwide
Product Code: SEMI-WW-DP-9305
Publication Date: August 30, 1993

- SA: Sales agency agreement
- FA: Fab agreement
- AT: Assembly and testing agreement
- TE: Technology exchange
- JV: Joint venture
- JD: Joint development
- IV: Investment
- CO: Coordination of standard
- PC: Procurement agreement
- OT: Other types

The following paragraphs provide details on the categories.

LA: License agreements are defined as legal permission to use a company's patents or proprietary technology for a fee or royalty payment. This could also include a cross-licensing agreement where the companies involved have legal permission to another company's patents or proprietary technology.

SS: Second source agreements allow companies the ability to manufacture a product designed and developed by another company as a second source of supply for customers.

SA: Sales agency agreements provide companies with exclusive or nonexclusive rights to sell the partner's original products to which value is added, in specified markets.

FA: Fab agreements involve the use of another company's fabrication facilities to manufacture a product.

AT: Assembly and test agreements involve a company's manufactured components and parts shipped to another company for assembly and test.

TE: Technology exchange involves an exchange of proprietary technologies that may or may not involve a transfer of money.

JV: Joint ventures involve two or more companies that jointly form a company to develop, manufacture, or market new products.

JD: Joint development agreements are between two or more companies that decide to combine forces and capabilities to develop new products or technology.

IV: Investment alliances are made between regional companies or foreign companies in other companies for the purposes of gaining access to technology or acquisition of small start-ups or innovative companies.

CO: Coordination of standards are agreements on common or compatible technical standards that would link devices and systems and users of different components, systems, or tools.

PC: Procurement agreements are commitments by companies to purchase certain quantities of specific goods or services over a contracted time.

OT: Other types of agreements could include visitation and research participation where researchers visit, observe, and participate in the R&D activities of the allied company. An original equipment manufacturing agreement might involve the manufacturing of a product for another company that will label it with its name or logo and will also handle all of the business aspects of that product, such as marketing and service of the product. Service agreements are those provisions of follow-up service of the product in foreign markets.

Figure 2 shows the total number of alliances between regional companies, while Figure 3 categorizes all of the alliances for 1993 by type. Multiproduct alliances are combinations of one or more product areas. Other devices include video, disk drives, decoder chips, analog, discrete, and optoelectronic. Other product types include multichip modules, motherboards, SIMMs, multimedia technology, fabrication and foundry services, and other process technology agreements.

Dataquest Perspective

Highlights of the first half of the year agreements include the following:

- License and joint development agreements were the fastest-growing areas. Of the accountable 17 JD agreements, most were made between companies in the United States across all product areas. Of the 31 LA agreements, most were made by companies in the United States, with focus predominantly in the areas of video compression and telecommunications applications.
- Joint venture activity led by the U.S. companies in the area of telecommunications has already surpassed the total worldwide 1992 JV activity.
- In the area of semiconductor components, the most notable change is that agreements involving microcomponents have surpassed those of memory products.
- Systems and equipment agreements have surpassed 1992 totals, and those types of agreements are growing at a faster pace than are component agreements. During the first half of 1993, the most active companies in numbers of agreements for systems and equipment were Apple Computer, AT&T, The Bull Group, Motorola, and NCR.

Table 1
1993 Strategic Alliances

Company A	Region	Product	Company B	Region	Product	Type	Month	Year
Hewlett-Packard	United States	System service/support	Wyse Technology	United States	PCs/UNIX/Wyse kits	OT	January	1993
Motorola	United States	Trunked radio infrastructure	Racotek Inc.	United States	Wireless mobile data communications	IV	January	1993
Hewlett-Packard	United States	0.35µm CMOS process	AMD	United States	0.35µm CMOS process	TE	January	1993
VLSI Technology Inc.	United States	Logic design	Hitachi	Japan	Fab and manufacturing	FA, LA, JD	January	1993
Toshiba	Japan	5V NAND Flash	Samsung	Korea	Cross license and manufacturing	LA, SS	January	1993
Crosspoint Solutions	United States	FPGA architecture	Hitachi	Japan	Musashi FAB/foundry	FA, SA	January	1993
National Semiconductor	United States	6-inch fab 19.9 percent share	Defense Software & Systems Inc.	Israel	80.1 percent share of fab	JV	January	1993
Texas Instruments	United States	Programmable video DSPs	C-Cube Microsystems	United States	Decoder chips	JD	February	1993
AMD	United States	Flash technology	Siemens	Europe	Microcontroller and foundry	FA, TE	February	1993
General DataComm Inc.	United States	Public network switch equipment	NetComm Ltd.	Europe	ATM technology	JD	February	1993
Hoechst AG	Europe	Joint manufacture marketing	American Superconductor Corporation	United States	Superconductor wires	JD, IV	February	1993
Pyramid Tech	United States	MIPS-based server	ICL plc	Europe	SPARC/super SPARC processors	LA	February	1993
ARM	United States	ARM RISC CPU	Sharp	Japan		SS	February	1993
Thomson	Europe	Consumer	Compression Labs Inc.	United States	Video	JD, IV	February	1993
Texas Instruments	United States	3V logic CMOS/ BICMOS	Philips	Europe	3V logic	JD, SS	February	1993
LTX Corporation	United States	Test equipment hardware/software	Ando Electronic Co. Ltd.	Japan	Royalty and distribution agreement	JD	February	1993
LSI Logic Corporation	United States	Layout and delay calculation capabilities	Synapsys Inc.	United States	Synthesis, test, and simulation tools	JD	February	1993
AT&T	United States	Fast SRAMs/logic	NEC	Japan	Fast SRAMs/logic	TE	February	1993

(Continued)

Table 1 (Continued)
1993 Strategic Alliances

Company A	Region	Product	Company B	Region	Product	Type	Month	Year
Intel	United States	486 chip set	VLSI Technology Inc.	United States	Development and manufacturing	JD	February	1993
IBM	United States	Computers, services, software	Tata Information Systems LTD	India	Products and services	JV	February	1993
Texas Instruments	United States	16Mb DRAM facility	Acer	Taiwan	PCs	JD, IV	February	1993
Macronix	Taiwan	16Mb flash/FAB/patent	NKK	Japan	Fab, investment, distribution	JD, IV, SA	February	1993
Texas Instruments	United States	FIFO clock architecture	IDT	United States	FIFOs	JD, SS	February	1993
Motorola Semiconductor	United States	Small-signal transistors/diodes	Philips Semiconductor International	Europe	Assembly and test	JD	February	1993
Northern Telecom	Canada	DMS SuperNode switch system	Tandem Computers Inc.	United States	Service control/service creation environment	JD	February	1993
Apple	United States	Newton	Cirrus Logic Inc.	United States	Chipsets and silicon for Newton	LA	March	1993
Apple	United States	Newton	Motorola	United States	Hand-held wireless communications	LA	March	1993
Apple	United States	Newton	Kyushu Matsushita Electric	Japan	Newton operating system	LA	March	1993
Apple	United States	Newton	LSI Logic Corporation	United States	1.0µm interface ASIC/ARM CPU	LA	March	1993
Digital Equipment Corporation	United States	Alpha AXP chips	Mitsubishi Electric Corporation	Japan	0.5µm Saijo factory	LA, SS	March	1993
Intel	United States	X86 PC architecture in China	China Electronics Corporation	China	Assembly/test and distribution	AT	March	1993
GEC Plessey	Europe	Custom ICs for read channel	Conner Peripherals	United States	2.5/3.5 hard disk drives	OT	March	1993
Unitrode IC Corporation	United States	Power control ICs	Toko Inc.	Japan	Cross-license agreement	SS	March	1993
EO Inc.	United States	Hand-held communications	Olivetti	Europe	Distribution and development	JD, IV	March	1993
Hitachi	Japan	1Mb SRAM	Asahi Chemical Industries	Japan	Facility	FA, OT	March	1993

(Continued)

Table 1 (Continued)
1993 Strategic Alliances

Company A	Region	Product	Company B	Region	Product	Type	Month	Year
Graphics Comm. Labs	Japan	HDTV joint venture	ASCII Corporation	Japan	Digital compression technology	JV	March	1993
Graphics Comm. Labs	Japan	HDTV joint venture	Hitachi	Japan	Digital compression technology	JV	March	1993
Graphics Comm. Labs	Japan	HDTV joint venture	Victor Company of Japan	Japan	Digital compression technology	JV	March	1993
Graphics Comm. Labs	Japan	HDTV joint venture	NTT Electronics Corporation	Japan	Digital compression technology	JV	March	1993
National Semiconductor	United States	Codevelop Toshiba ACMOS	Toshiba	Japan	Second source for NSC logic	JD	March	1993
Advanced RISC Machines	Europe	ARM processors	Sharp	Japan	License and manufacture	LA	March	1993
Bull Group	Europe	IC card reader patents	Toshiba	Japan	Patent fees	LA	March	1993
Bull Group	Europe	IC card reader patents	Hitachi	Japan	Patent fees	LA	March	1993
Bull Group	Europe	IC card reader patents	Oki	Japan	Patent fees	LA	March	1993
Bull Group	Europe	IC card reader patents	Toppan Printing	Japan	Patent fees	LA	March	1993
Bull Group	Europe	IC card reader patents	Kyodo Printing Company	Japan	Patent fees	LA	March	1993
Apple Computer	United States	Apple Newton	Siemens/Rolm	Europe	NotePhone telephony and fax	LA	March	1993
Schlumberger	Europe	Metering products	Motorola	United States	Manufacturing	JV	March	1993
Toshiba	Japan	LCD technology	Orion	Korea	Display manufacturer	LA	March	1993
Silikon	Russia	Design house	MIPS	United States	MIPS processor	LA	March	1993
Samsung	Korea	Synchronous DRAMs	OKI	Japan	Royalty and SS	SS	March	1993
Harris Corporation	United States	Digital microwave radios	Shenzhen Telecom Equipment Company (TEC)	China	Designs, services telecom networks	JV	March	1993
Teradyne Inc.	United States	Test equipment	E&M Engineering	Israel	Sells, supports, services board test equipment	JV	April	1993
Zeos International	United States	PC systems and workstations	Intel Corporation	United States	Motherboard manufacturing	AT	April	1993

(Continued)

Table 1 (Continued)
1993 Strategic Alliances

Company A	Region	Product	Company B	Region	Product	Type	Month	Year
Seagate Technology	United States	Disk drive ICs	SGS-Thomson	Europe	1.2µm BiCMOS tech	TE	April	1993
Motorola	United States	88110 MCM	IBM	United States	C-4 manufacturing and MCM technology	JD	April	1993
Motorola	United States	88110 MCM	CHPC	United States	Lynx massively parallel processor	JD	April	1993
Parlex Corporation	United States	Flex circuitry	Motorola	United States	Automotive electronic products	JD	April	1993
Silicon Graphics Inc.	United States	Servers	Siemens Nixdorf	Europe	Marketing rights to servers	LA	May	1993
VLSI Technology Inc.	United States	PC chipsets	Future Domain Corporation	United States	SCSI technology	LA	May	1993
Sierra Semiconductor	United States	DSP Aria chipsets	Archer Communications Inc.	United States	QSound Virtual Audio	LA	May	1993
Sun Microsystems CC	United States	SPARC II design rights	Fujitsu	Japan	MicroSPARC II manufacturing	FA	May	1993
Advanced RISC Machines	Europe	ARM architecture	Texas Instruments	United States	Develop ARM core in DSP devices	LA	May	1993
Motorola	United States	Paging products	Simplex	United States	Security systems	LA	May	1993
Motorola	United States	Microcontrollers	Aptronix Inc.	United States	Fuzzy logic software application tools	OT	May	1993
Hitachi	Japan	DRAMs	Nippon Steel Semiconductor Corporation	Japan	Foundry for 4Mb DRAMs	FA	May	1993
Sandia National Labs	United States	PZT semi thin film	Radiant Technologies	United States	Design/manufacture NDRO NV semiconductor memory	OT	May	1993
Tektronix	United States	Analog/digital ICs	TV/COM International	United States	Communications systems	JD	May	1993
AT&T	United States	Voice and data services	KDD	Japan	Voice and data services	CO	May	1993
AT&T	United States	Voice and data services	Singapore Telecom	Singapore	Voice and data services	CO	May	1993
IBM	United States	Operating system	NEC	Japan	OS for NEC machines	JD	May	1993

(Continued)

Table 1 (Continued)
1993 Strategic Alliances

Company A	Region	Product	Company B	Region	Product	Type	Month	Year
AMD	United States	Flash facility	Fujitsu	Japan	Flash facility in Japan	JV	May	1993
Sega	Japan	video games	Time Warner Entertainment	United States	Cable TV channels	JV	May	1993
AT&T	United States	Fiber optics	Yazaki Electric Wire	Japan	Cable	JV	May	1993
SuperMac Technology	United States	Video compression technology	Microsoft Corporation	United States	Integrate Cinepak into video for Windows	LA	May	1993
SuperMac Technology	United States	Video compression technology	Cirrus Logic	United States	Cinepak decompressor	LA	May	1993
Wang	United States	SIMMs patent	NMB Technologies Inc.	Japan	License SIMMs	LA	May	1993
VTC Inc.	United States	Supply unpackaged read/write preamps	HEI Inc.	United States	Mount/interconnect on flex circuitry	JD	May	1993
IBM	United States	RS/6000 and PowerPC	Harris	United States	UNIX System V	LA	May	1993
NeXT Inc.	United States	NeXTSTEP software	Hewlett-Packard	United States	PA-RISC architecture, servers, VectraPC	JD	May	1993
Kaleida Labs	United States	ScriptX Multimedia Language	Creative Technology	Singapore	Engineering support and alliance	OT	May	1993
Kaleida Labs	United States	ScriptX Multimedia Language	Mitsubishi	Japan	Engineering support and alliance	OT	May	1993
Kaleida Labs	United States	ScriptX Multimedia Language	Hitachi	Japan	Engineering support and alliance	OT	May	1993
Kaleida Labs	United States	ScriptX Multimedia Language	Toshiba	Japan	CD-ROM-based system support	OT	May	1993
AT&T	United States	Wireless transmission equipment	Spectrum Information Technology	United States	Cellular protocol patents	IV, LA	May	1993
Hughes	United States	Molecular beam epitaxy (MBE)	Texas Instruments	United States	MBE	OT	May	1993
Mitsubishi	Japan	16Mb flash 0.5µm CMOS	SGS-Thomson	Europe	16Mb flash 0.5µm CMOS	SS, JD	May	1993

(Continued)

Table 1 (Continued)
1993 Strategic Alliances

Company A	Region	Product	Company B	Region	Product	Type	Month	Year
Sanyo	Japan	MPEG-based audio decoders	SGS-Thomson	Europe	MPEG decoders	OT	May	1993
Applied Materials	United States	License technology	Komatsu Ltd.	Japan	Equity investment in ADT/AM subsystem	JV, LA, IV	June	1993
NCR	United States	Radio LAN systems	Ricoh	Japan	NCR radio LAN systems sales	LA	June	1993
NCR	United States	Radio LAN systems	Otsuka Shokai	Japan	NCR radio LAN systems sales	LA	June	1993
NCR	United States	Radio LAN systems	Ungermann-Bass KK	United States	NCR radio LAN systems sales	LA	June	1993
NCR	United States	Radio LAN systems	Macnica	Japan	NCR radio LAN systems sales	LA	June	1993
NCR	United States	Radio LAN systems	Net World	Japan	NCR radio LAN systems sales	LA	June	1993
AT&T	United States	SONET cable and transmis. equipment	GTE	United States	SONET fiber-optic rings	JD	June	1993
Bel Fuse Inc.	United States	Fuse products	Gould Inc.	United States	Electrical power fuses	TE	June	1993
Viewlogic Systems Inc.	United States	EDA tools	Texas Instruments	United States	FPGAs	OT	June	1993
NTT	Japan	Multimedia/ communications	ATT	United States	Multimedia and communications	JD	June	1993
Advantest	Japan	Measuring equipment	Tektronix Inc.	United States	North American rights to market measuring equipment	SA	June	1993
Austin Semiconductor	United States	Micron military products	Micron Semiconductor	United States	Military products	OT	June	1993
Electronic Data Systems	United States	InCASE CASE tool and 20 percent ownership	Amdahl	United States	Huron tools and 80 percent ownership	JV	June	1993
NEC	Japan	One-way pager protocol	Motorola	United States	FLEX TM paging protocol	LA	June	1993

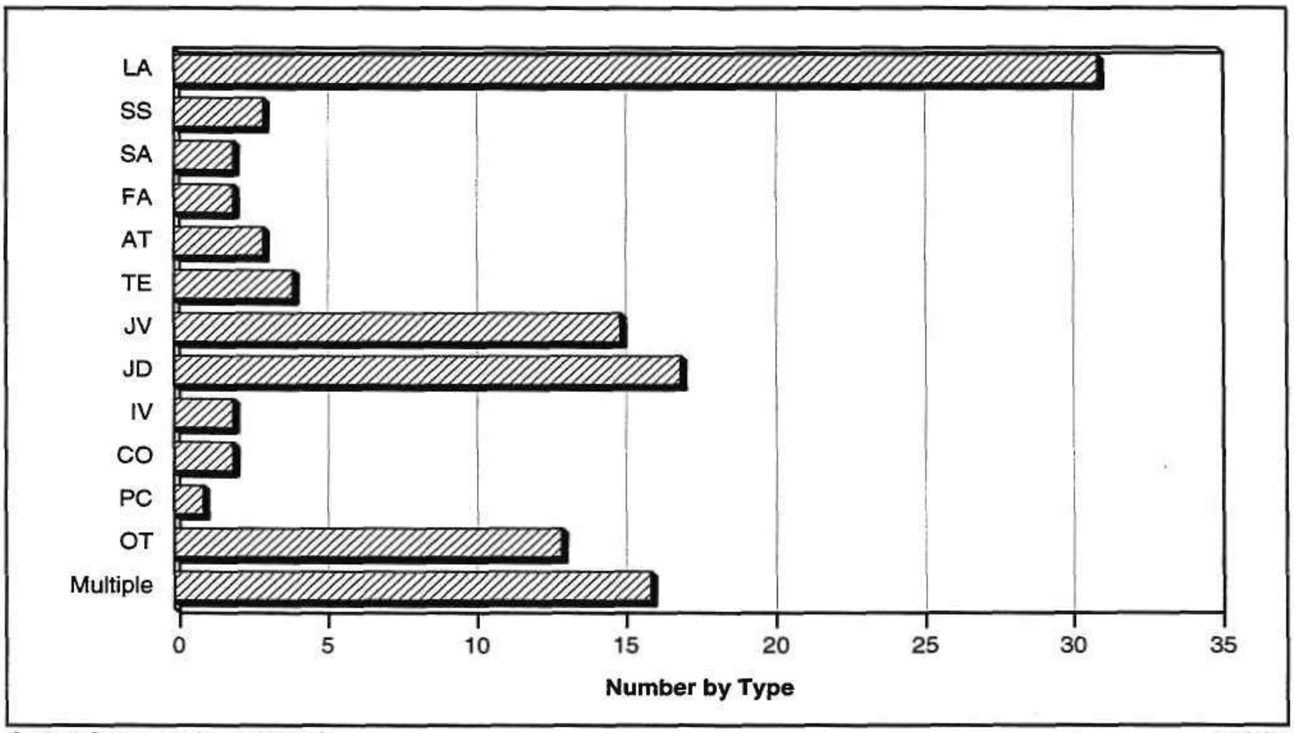
(Continued)

Table 1 (Continued)
1993 Strategic Alliances

Company A	Region	Product	Company B	Region	Product	Type	Month	Year
Ericsson	Europe	AXE public switching equipment	Tel Administration of Guangdong (GPTB)	China	Ttelecom	JV	June	1993
Viewlogic	United States	Investment	Sunrise Test Systems	United States	Software for ASIC design test	IV	June	1993
General Instrument Corporation	United States	Digital compression technology	Telecomunications Inc. (TCI)	United States	DigiCipher II/MPEG-2 cable TV	PC	June	1993
Micron Technology	United States	Patent cross license	Goldstar	Korea	Patent cross license	LA	June	1993
IBM	United States	Atmel FPGAs	Atmel	United States	License agreement on FPGAs	LA	June	1993
IBM	United States	Accelerator boards	Seattle Telecom & Data	United States	Accelerator boards	AT	June	1993
ATT	United States	Telecom switching/ 51 percent investment	Tata Industries Inc.	India	India market and 49 percent equity	JV	June	1993
IBM	United States	EDA products	Altium	United States	Desktop CAD/CAM/ CAE software	SA	June	1993
Texas Instruments	United States	Memory products	RTB Technology Inc.	United States	3-D memory cube technology	OT	June	1993

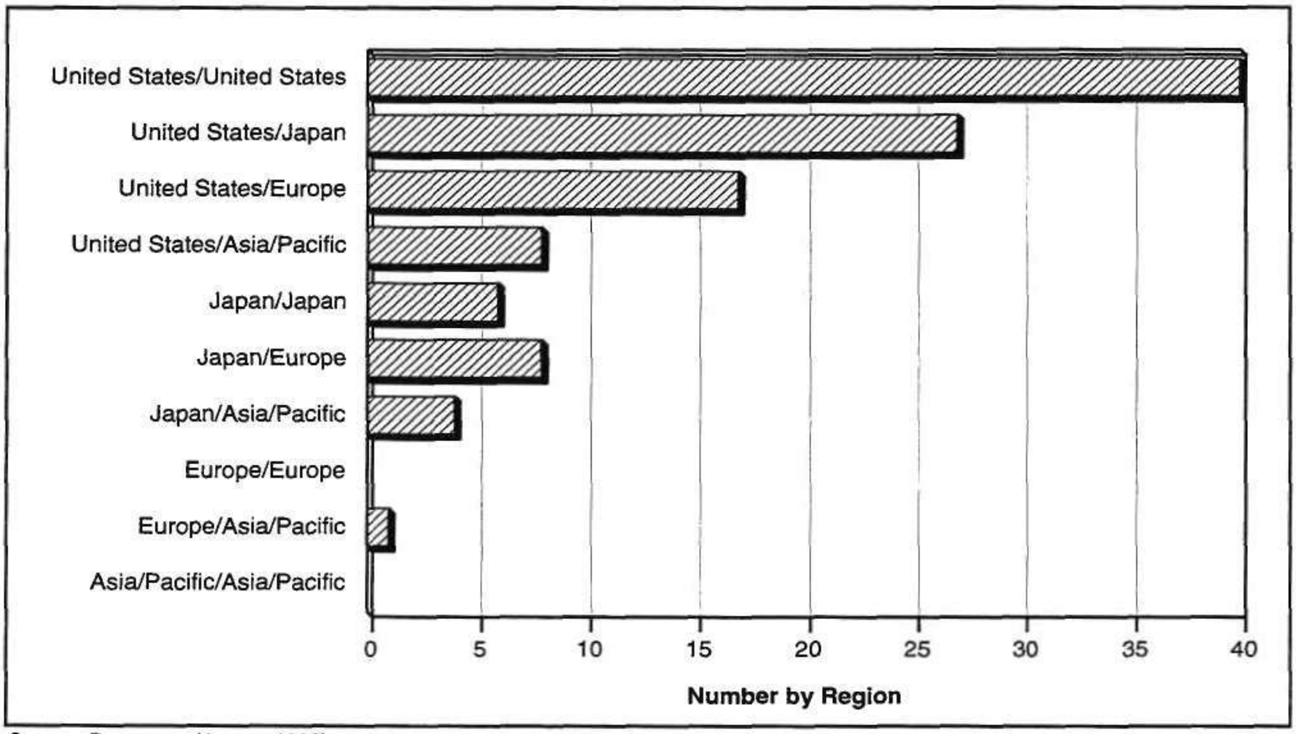
Source: Dataquest (August 1993)

Figure 1
1993 Strategic Alliances by Type



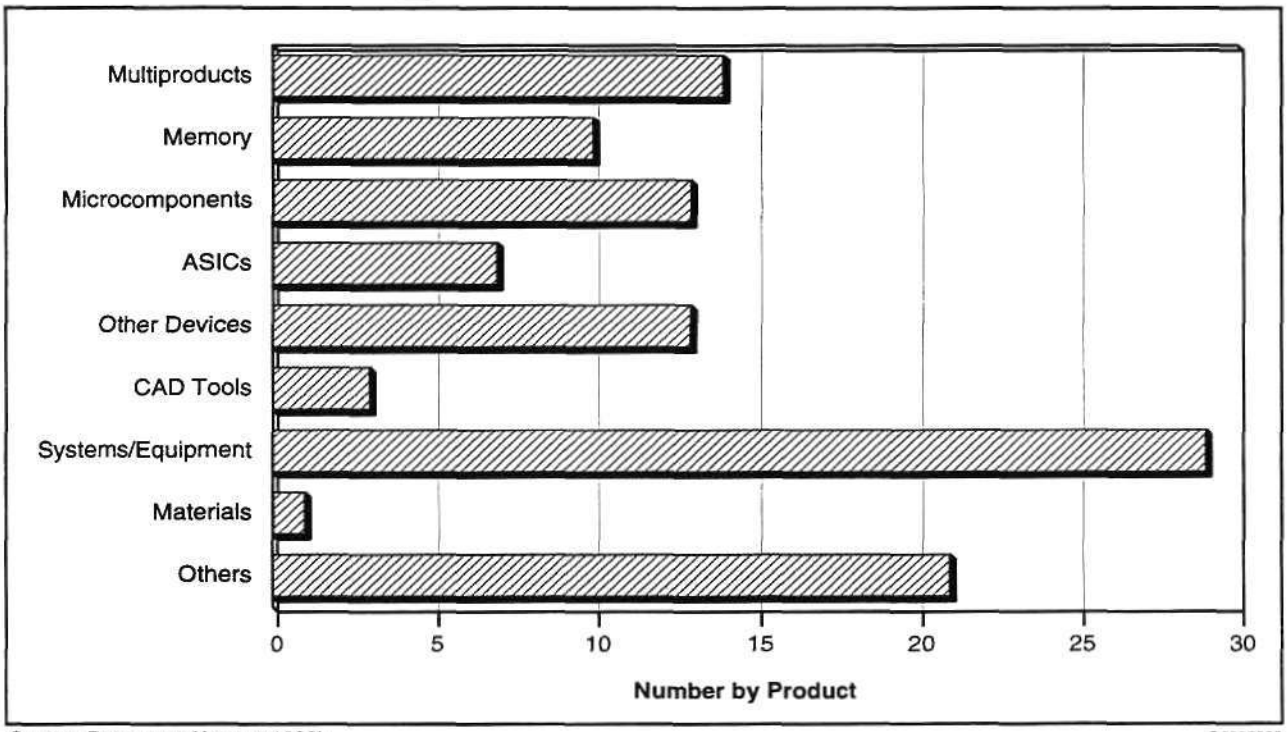
Source: Dataquest (August 1993)
G3005053

Figure 2
1993 Alliances by Regional Companies



Source: Dataquest (August 1993)
G3005054

Figure 3
1993 Alliances by Product Type



Source: Dataquest (August 1993)

G3005055

By Mary A. Olsson

N01SEMIWW SEMIWWDP9305 BH: 0 N: 1
Mr. Richard Spence
Dataquest Incorporated
300-1264
****
SJ - INTERNAL DISTRIBUTION
****

For More Information...

Mary A. Olsson, Senior Industry Analyst .... (408) 437-8674
Via fax .... (408) 437-0292

Dataquest®
a company of The Dun & Bradstreet Corporation

Q&A Dataquest Inquiry Summary

Semiconductors

Semiconductors Worldwide

April 1993

Dataquest®
a company of The Dun & Bradstreet Corporation

Program: Semiconductors Worldwide
Product Code: SCND-WW-IS-9304
Publication Date: April 19, 1993

Products

Q1

Please provide an overview on the technical specifications of the Pentium processor from Intel.

A

The technical details of the next-generation microprocessor from Intel, named Pentium, were officially released on March 22. Table 1 provides an overview of the key technical parameters of this microprocessor.

Table 1
Key Technical Parameters of the Pentium Processor

Processor Technology	
Process	BiCMOS
Lithography	0.8 Micron
Metal Layers	Three
Number of Transistors	3.1 Million
Cache Memory Cell	Six-Transistor SRAM
Die Size	640 x 640 Mils per Side
Performance	
Clock	60 and 66 MHz
SPECint '92	64.5 at 66 MHz
SPECflt '92	56.9 at 66 MHz
Power Consumption	13W at 60 MHz

(Continued)

Table 1 (Continued)
Key Technical Parameters of the Pentium Processor

Architecture	
Wordwidth	32-Bit Integer Unit
Data Path at the Pins	64-Bit Data Path
Internal Data Paths	Up to 256 Bits
Cache Size	8KB Instruction/8KB Data
Integer Unit	Dual Five-Stage Execution Units
Floating Point	Eight-Stage Pipeline

Source: Intel Corporation

By Jerry Banks

Q2

What does the increased performance of the Pentium processor mean to the average user?

A The primary short-term benefit of this higher performance will be that software written for PCs will simply run faster. According to Intel, a 66-MHz Pentium-based machine will run such popular applications as Word, WordPerfect, Excel, and dBASE IV 1.6 times faster than a system based upon an Intel 486DX2-66. Such a performance boost should be well accepted by the typical power user and for x86-based file server applications. However, before the 486 line of processors is overtaken in volume by the Pentium processor, new CPU power-hungry applications such as full-motion video, 3-D modeling of solids, speech recognition, and imaging will have to become mainstream business applications.

By Jerry Banks

Q3

What is the comparative cost per megabyte for nonvolatile memories, and how does it compare with the cost of static RAM?

A The reason for grouping static RAM with other nonvolatile memory technologies is that it is often used in applications that require nonvolatile storage. A backup battery is used to retain data when power is removed, in essence providing "nonvolatile storage." Even when the cost of the required battery for backup is taken into account, SRAMs are less expensive than EEPROMs or NOVRAMs. Furthermore, SRAMs are easy to use, and unlike flash or EEPROM, have a fast write cycle.

Table 2 shows the average cost per megabyte in 1992.

Table 2
1992 Average Cost per Megabyte

Type	Price ($)	Device Density
ROM	5.95	8Mb
EPROM	26.00	4Mb
Flash	32.00	8Mb
EEPROM	480.00	256Kb
NOVRAM	3,500.00	16Kb
PSRAM	30.00	1Mb (slow)
SRAM	73.60	1Mb (slow)

Notes: Functionality increases as one moves from the top of the table to the bottom.
The device density used to derive the cost per megabyte is that which yields the lowest cost in 1992.
Source: Dataquest (April 1993)

By Nicolas Samaras

Q4 What is Dataquest's opinion on ferroelectric memories?

A Dataquest has made a big reversal in our attitude about ferroelectrics since first commenting upon them in 1988. At that time, we believed that ferroelectrics would displace other nonvolatile technologies and would dominate the reprogrammable nonvolatile memory market by 1992. Obviously, that has not happened. This raises questions about the entire direction of the technology.

For those unfamiliar with the term, ferroelectrics are a class of materials that exhibit extremely high dielectric constants and have the ability to store a bipolar state within a molecule. The attributes of ferroelectric materials have been under study for quite a while. Dataquest has spoken with one researcher who explored this technology as long as 30 years ago.

Pioneers in the technology generally try to exploit the bipolar mechanism to manufacture extremely dense nonvolatile memories. The expected benefit is a device that will be more easily reprogrammable than are current technologies, without any of the erase/write cycle limitations now experienced in flash memories. These efforts have been slow to yield manufacturable product, and although manufacturers are reticent to discuss the reason for their slow progress, we have reason to believe that several unforeseen technical hurdles still exist that might keep the technology from ever being able to efficiently compete against its silicon counterparts. With this in mind, we move to the material's other strength, its high dielectric constant.

Typically, the dielectric constant of a ferroelectric material is more than two orders of magnitude greater than that of the silicon dioxide used as capacitor dielectrics in conventional DRAMs. A limiting factor in the density of DRAMs is the size of the capacitor used to store a single bit of data. As this capacitor shrinks, leakage effects force refresh rates to become unrealistically frequent. If we extrapolate current trends of die size and cell size, it appears that, above the 64Mb density, it will take a larger die to produce a DRAM than even the same density flash device. This is where ferroelectrics come into play.

A contemporary DRAM built using a thin-film layer of a ferroelectric material for its dielectrics would have a considerably longer refresh cycle than would its silicon counterpart. Therefore, it seems to make sense for DRAM manufacturers to explore the possibility of producing future generations of DRAM with thin-film dielectrics of ferroelectric materials to bypass the leakage problems mentioned earlier. Indeed, they are.

If a ferroelectric dielectric is substituted for standard silicon dioxide, the leakage goes way down, allowing the cell to be shrunk to a far smaller dimension than that required of the same density flash device. Die size has been traded for process complexity. This means that the point at which ferroelectrics are used for standard DRAMs will be determined by the tradeoff between the increased cost of the process' higher complexity and the die size required if ferroelectric dielectric layers are not used.

Dataquest expects ferroelectrics to find their real home only in the traditional DRAMs of the far future.

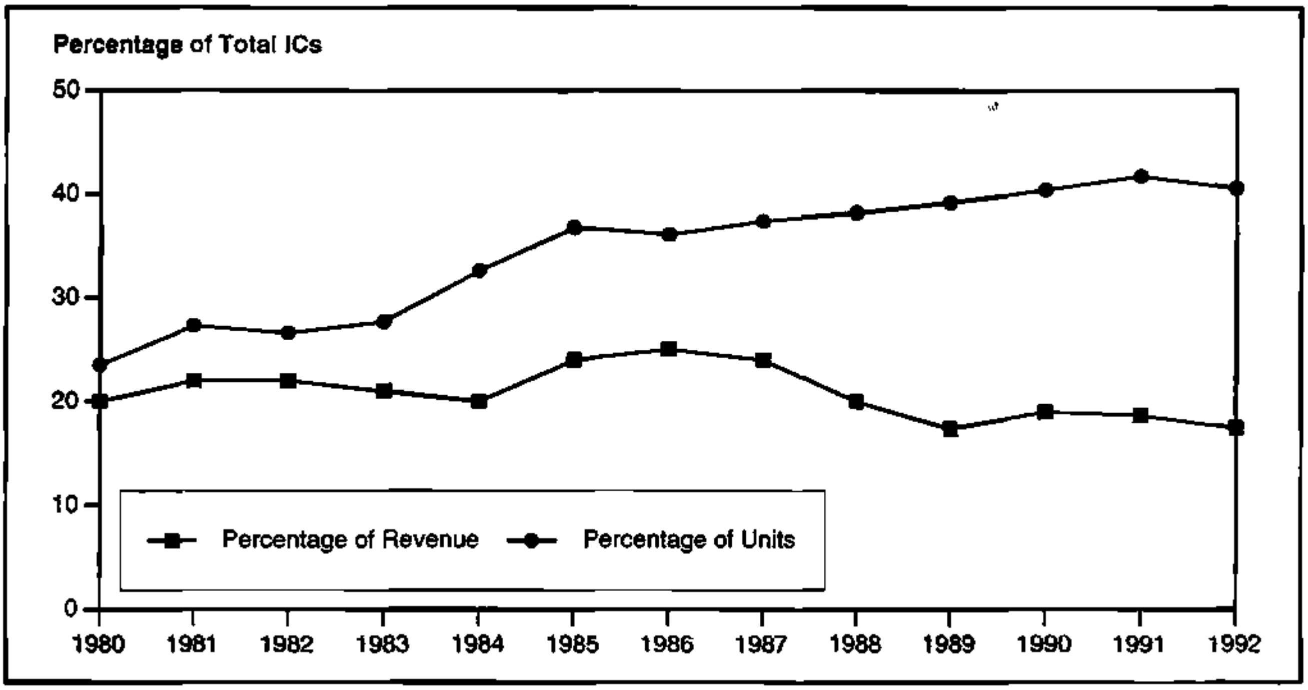
By Jim Handy

Q5 Did analog IC units continue to become a larger portion of the total IC units in 1992?

A No! The events of 1992 stopped the monotonicity of this six-year trend. Figure 1 shows WSTS revenue and unit comparisons, over a 12-year period, in terms of the percentage of analog ICs to total ICs. As a percentage of revenue, analog ICs have showed a slow decline over the past dozen years while memory and microprocessor ICs gained and digital ICs incorporated analog functions. Because analog ICs have been less impacted by high levels of integration, however, analog IC unit growth has normally been much higher than that of digital ICs, resulting in an increasing proportion of the total units consumed. In 1991, 42 percent of the IC units consumed were analog ICs. In 1992, however, analog revenue and unit growth were severely impacted by a weak consumer electronics market. Analog IC units declined 2.8 percent in 1992 over 1991, while digital ICs showed a more typical 2 percent unit growth. The result was a flat total IC unit growth and a decline in the analog units as a percentage.

It is expected that the past trend in Figure 1 will return in 1993 as the analog market, especially unit growth, recovers.

Figure 1
Analog Percentage of Total IC Units



Source: WSTS, Dataquest (April 1993) G3000308

By Gary Grandbois

Markets and Applications

Q6

What kind of growth does Dataquest expect for ASIC products in Japan and North America in 1993?

A According to Dataquest's *ASIC Consumption Forecast* (ASIC-WW-MS-9301, dated March 22, 1993), just released from the ASIC service, the 1993 MOS gate array market in North America is expected to grow 13 percent, while the market in Japan is expected to grow 9 percent. The 1993 MOS cell-based IC market is experiencing slightly faster growth than the gate array market, with North America growing 15 percent and Japan growing 14 percent. Key forecast assumptions as well as detailed ASIC forecasts by product, technology, and region can be found in the ASIC forecast booklet.

By Bryan Lewis

Q7

Who is buying multimedia PCs and upgrade kits?

A Dataquest estimates that for-the-home purchases dominated in 1992 as consumers became the surprising early adopters. Business desire for multimedia remains focused on certain segments such as publishing and corporate functions such as training. The breakouts are 70 percent for the home, 22 percent for business, and 8 percent for education.

By Greg Sheppard

Technology

Q8

What is the regional trend for fab lines over the next several years?

A Table 3 shows the merchant semiconductor manufacturers' total production and pilot lines.

Table 3
Merchant Semiconductor Manufacturers' Total Production and Pilot Lines

	1992	1993	1994
North America Fab Lines	208	212	215
European Fab Lines	90	94	96
Japanese Fab Lines	220	229	230
Asian Fab Lines	65	71	76

Source: Dataquest (April 1993)

By Mark FitzGerald

Q9

How is the shipment of dry etch systems distributed according to plasma source technology?

A The historical dry etch shipments can be segmented by plasma etch, reactive ion etch (RIE), and electron cyclotron resonance (ECR) source. Table 4 shows the historical dry etch market revenue from 1987 to 1991, segmented by plasma source. Plasma etch systems use a standard 13.56-MHz RF source to generate the plasma, are typically operated at high pressure (greater than 100 mtorr), and the wafer that is to be etched is usually placed on the grounded electrode, limiting the voltage difference that can develop between the plasma and the wafer. RIE systems also use the 13.56-MHz excitation source, but are typically operated at low pressure (less than 100 mtorr), and the wafer that is to be etched is usually placed on the RF powered electrode, which can result in a very large voltage difference between the plasma and the wafer. This gives rise to high ion bombardment energies, which play a key role in the RIE etch mechanism. ECR etch systems use a 2.45-GHz microwave source to generate the plasma outside of the etch chamber, then the plasma is allowed to diffuse through a window into the etch chamber, where it is shaped by a magnetic field whose strength, 845 gauss, creates a resonance in the free electrons in the plasma, greatly increasing the plasma density, and allowing etching to occur at low pressure.

As Table 4 shows, the use of RIE systems grew at a high rate through the late 1980s because of the RIE process improved capability for etching very small linewidths with good control, compared to plasma etching. ECR etching systems began to show accelerated sales growth in 1990, as even smaller geometries began to stretch the capability of RIE, creating the need for low-pressure, high-density plasma sources with the ability to control the bias voltage on the wafer. Dataquest believes that the emergence of other types of low-pressure, high-plasma density sources such as inductively coupled plasma and helicon wave will compete with ECR and gradually displace RIE sources as minimum feature sizes drop below 0.5 micron.

Table 4
Dry Etch System Revenue, Segmented, by Plasma Source (Millions of Dollars)

	1987	1988	1989	1990	1991
Plasma	74.9	94.1	102.3	80.8	72.1
RIE	222.1	418.5	526.6	517.0	514.5
ECR	10.4	16.6	40.6	92.6	118.1

Source: Dataquest (April 1993)

By Charles Boucher

Company and Other Issues

Q10 What is the status of rumored across-the-board 8 percent price hikes from Japanese DRAM suppliers?

A It appears that many, if not most, Japanese suppliers are attempting to pass the current exchange rate fluctuations of yen versus dollars onto their customers. The argument used is that the annual international revenue stream is based using a guard band exchange rate (for example 1993 may have been ¥120 to ¥135/U.S.$1), and if the actual exchange rate goes above or below that range, prices have to be adjusted to compensate for the difference. Because the exchange rate recently strengthened the yen against the dollar by about 8 percent (8.5 percent) since November (¥128/U.S.$1 in November 1992, ¥124/U.S.$1 in February 1993, and ¥117/U.S.$1 in March 1993), the argument follows that this cost of sale should not be suffered by the seller since it is out of direct control of the supplier.

It appears that all contracts negotiated prior to the recent exchange rate shift are being honored by Japanese suppliers, but that new contracts are using the new exchange rate as a basis, which is inflating the price on average by 8 percent. This exchange rate argument has been used in the past when there have been large swings in currency values. What is curious, however, is that it seldom is used when exchange rates go in the opposite direction (for example, if the dollar strengthens against the yen). Long-term user-supplier relationships generally have (or should have) provisions for exchange rate fluctuations (in *both* directions) that work to each party's interests over time. Although it no longer is a buyer's market, besides competition, many large corporations have regional purchasing offices. By shifting procurement to local currencies, some of the effects of these unforeseen costs can also be ameliorated.

By Mark Giudici

Q11 Where is ASM located, and is there any company update available?

A Advanced Semiconductor Materials International N.V. (ASM International) is headquartered in Bilthoven, Netherlands. Its stock is traded in the United States on NASDAQ under the symbol "ASMIF." ASM International operates 17 subsidiaries worldwide. Its business is divided into three main segments: wafer processing, assembly and encapsulation, and materials.

ASM International reported revenue of F 395.8 million in 1990 and F 506.9 million in 1991. Table 5 lists its principal facilities.

Table 5
ASM International Principal Facilities

Location	Primary Usage
Bilthoven, Netherlands	Wafer processing equipment manufacturing, research company headquarters
Herwen, Netherlands	Encapsulation equipment manufacturing, research, offices
Brunssum, Netherlands	Encapsulation equipment manufacturing and offices
Zevenaar, Netherlands	Encapsulation equipment manufacturing, research, offices, Eastern Europe equipment contract, training
Montpellier, France	Gas component manufacturing and offices
Juvignac, France	Wafer processing equipment manufacturing, research, offices
Phoenix, Arizona, United States	Wafer processing equipment manufacturing, research, offices, machine shop, storage, customer service
Tempe, Arizona, United States	Research, offices, wafer processing equipment manufacturing, storage

(Continued)

Table 5 (Continued)
ASM International Principal Facilities

Location	Primary Usage
Kwai Chung, Hong Kong	Assembly automation manufacturing, research, offices, tooling manufacturing, leadframe manufacturing
Shatoujiao, Shenzhen,PRC	Precision metal part fabrication and offices
Singapore	Bonder manufacturing, research, offices
Tama, Tokyo, Japan	Research and offices
Niigata, Japan	Wafer processing equipment manufacturing and offices
Kumamoto, Japan	Engineering facility

Source: ASM International

ASM's corporate strategy for the wafer processing equipment includes continued development of the clustered CVD equipment line—Advance 600, the vertical reactor products, epitaxy, PECVD and LPCVD/diffusion equipment products—as well as continuing support of the assembly and encapsulation equipment products. As of August 1992, ASM's assembly and encapsulation equipment business represented more than half its total revenue, up substantially from 37 percent of total revenue in 1990 and 31 percent of total revenue in 1989.

By Mary A. Olsson

Q12 What countries and regions of the world does Dataquest include in the "Rest of World" portion of Asia/Pacific-ROW? Are there any semiconductor wafer fabrication facilities in ROW proper?

A Dataquest defines ROW to include Africa, the Caribbean, Central America, the Middle East, Oceania, and South America. Although ROW certainly cannot be characterized as a hotbed of device manufacturing activity, Dataquest has identified a handful of facilities in the region. These fab lines include two facilities in Israel (Intel and the National Semiconductor/Defense Software & Systems joint venture), two in Brazil (SID Microelectronics), and two in South Africa (South African Microelectronics). Dataquest also understands that Saudi Electronic Materials and Components (SEMC) will complete a semiconductor manufacturing fab line in fall 1993. The fab will produce CCDs initially on 125mm wafers, with plans for conversion to 150mm. Dataquest believes that some of the engineering talent at SEMC was hired away from Philips. The facility is located in Jeddah, Kingdom of Saudi Arabia. Any input from Dataquest's clients on additional fab facilities in ROW would be greatly appreciated.

By Peggy Marie Wood

Q13 The Semiconductor Procurement Worldwide *Dataquest Perspective* dated February 22, 1993 (SPSG-WW-DP-9302) contained a table on benchmark best performers regarding the procurement and product development processes. What is the source of the information in this table?

A The information in Table 6 derives from a range of sources including literature searches, benchmarking conference presentations, and the judgment of Dataquest analysts. The information is not based on a "quantitative" assessment of each company's performance in the various categories. A key point is that some categories such as "procurement-design engineering integration" represent potentially best-in-class procurement practices. However, these practices do not easily lend themselves to quantitative evaluation. Another key point is that we continue to discover companies that should be added to the list. For example, our original list did not include SCI Systems, whose purchasing department recently earned ISO 9002 certification. Table 6 now includes SCI Systems as well as Compaq Computer and Solectron, the latter a 1991 winner of the Malcolm Baldrige Award..

Table 6
Benchmark "Best" Performers for Procurement and Product Development Processes

Function/Objective	Leaders
Benchmarking Methodology	AT&T,* Corning, Digital Equipment, Ford Motor, Hewlett-Packard, IBM, Motorola, Texas Instruments, Xerox
Competitive Analysis--Product	British Telecom, IBM, Ford Motor, Eastman Kodak, Xerox
Cost Accounting	Hewlett-Packard, Motorola, Tektronix
Cost Control	Advanced Micro Devices, Tektronix
Cycle Time--Order to Delivery	Domino's Pizza, Federal Express, Frito-Lay, Motorola
Cycle Time--Product Design to Market	Apple Computer, Sun Microsystems
Cycle Time--Raw Material to Finished Good	Levi Strauss
Distribution	Federal Express, L.L. Bean, Mary Kay Cosmetics, Wal-Mart
Employee Training	Disney, Ford Motor, Polaroid
Environmental Management	Ben & Jerry's, Dow, du Pont, 3M, Weyerhaueser
Intellectual Property Management. .	AT&T,* IBM, Intel ,Texas Instruments, Toshiba
Inventory Management	Apple Computer, Federal Express, Frito-Lay Marshall Industries, National Semiconductor, Westinghouse
Manufacturing	Allen-Bradley, Hewlett-Packard, IBM, Motorola, Toyota Toshiba, Yamazaki Mazak
Procurement-Design Engineering Linkage	Apple Computer, AT&T,* Hewlett-Packard

(Continued)

Table 6 (Continued)
Benchmark "Best" Performers for Procurement and Product Development Processes

Function/Objective	Leaders
Product Development	AT&T*, Beckman Instruments, Cincinnati Milacron, Digital Equipment, Hewlett-Packard, Honda, Intel, 3M, Motorola, Panasonic, Sony
Purchasing Practices	AT&T,* Compaq Computer, Digital Equipment, Hewlett-Packard, Honda, IBM, ICL, Intel, Nokia, SCI Systems, Thomson Group, Xerox
Quality Process Management	AT&T,* Florida Power & Light, IBM, Motorola, Solectron, Westinghouse, Xerox
Supplier Management	AMP, Apple Computer, Compaq Computer, Ford Motor, Levi Strauss, Motorola, Sun Microsystems, Xerox
Technology Transfer Management	3M, Square D

*Includes NCR
Source: Dataquest (April 1993)

By Ronald Bohn

Q14 Rumors have surfaced that Japanese companies are beginning to abandon their traditional policies of not laying off their employees. Some have suggested that many Japanese institutions have adopted downsizing in an effort to remain globally competitive and to maintain profitability. What is the current employment situation in the Japanese electronics industry?

A Although Japan for many years has maintained low unemployment rates and essentially guaranteed lifetime employment for workers at major electronics companies, the current economic situation has caused many companies to institute various programs for reducing their work force and eliminating nonessential personnel. In some cases, these programs have used layoffs as a means of cutting costs. Recognizing this growing trend, many of the rank and file workers, as well as some mid- and senior-level executives, no longer perceive themselves as life employees of a single company and have thus become much more receptive to employment offers from competitors or foreign companies. In this new environment of diminished long-term job security, salary and career advancement opportunities are expected to have much greater significance in an individual's choice of employer than in the past. Some recent events indicative of the employment trends in Japan are as follows:

- An announcement late last year by Pioneer Electronics Corporation revealed that it would eliminate 35 high-level management positions by the end of January through forced early retirement or dismissal. This announcement sent a clear message to workers and stockholders concerning the fate of lifetime job security in Japan.
- In February, Eastman Kodak Japan canceled its employment contracts with newly hired college seniors it had signed up during the annual recruiting period last fall. The cancellation of a group employment

contract was sufficiently unusual that the withdrawal made national headlines in Japan. Eastman Kodak Japan paid about $20,000 as compensation to each of the 80 recruits for its breach of contract.

- Fujitsu implemented an individual salary negotiation system for managers and a 20 percent reduction in administrative staff last year. More recently, Fujitsu announced that it will cut its annual rate of hiring new college graduates. The company will hire about 300 college graduates for fiscal 1994, and these will be limited to technical majors only. This number of new recruits due to enter the company in fiscal 1994 is equal to about one-seventh of the 2,200 new employees taken on by Fujitsu during fiscal 1993.
- IBM Japan urged early retirement for 1,200 employees more than 50 years old, which represents about 40 percent of its workers in that age group. The company has prepared an incentive package that includes a year's salary in addition to the standard severance arrangement.
- Hitachi will transfer 800 employees now working in four of its audiovisual production plants to some of its subsidiaries and affiliated companies. Administrative personnel in corporate headquarters will be reassigned to sales divisions to increase revenue while reducing overhead.
- NEC will also reassign 230 administrative employees to various sales divisions by July 1993.
- Sanyo plans to reduce its work force by 3,000 during the next three years.
- Oki Electric recently implemented a companywide organizational restructuring, and reduced the number of its divisions by 20 percent to 387. As a result, 89 divisional manager positions were eliminated.
- NTT plans to reduce its work force by 30,000 before April 1996 to create an organization with fewer than 200,000 employees. Specifically, it plans to close one-third of its reception counters, promote early retirement for older employees, and speed up transfers of employees to subsidiaries and affiliated companies.

By Junko Matsubara

Q15 Semiconductor distributors reportedly are playing an important role in the Japanese semiconductor market. What percentage of semiconductors is delivered through distributors in Japan?

A For the top 10 Japanese semiconductor manufacturers, 45 percent of their chips are delivered through distributors, 30 percent are marketed by semiconductor makers directly, and 25 percent are consumed by the manufacturers for their captive market use. Thus, in terms of the semiconductor merchant market in Japan, 60 percent of semiconductor chips are sold by distributors. This ratio is much different from that of the North American market, where distributors market about one-third of semiconductors.

Dataquest's Semiconductors Japan service will publish a Focus Report entitled *Japanese Semiconductor Distributors* in May, which will contain detailed information on Japanese semiconductor distributors' positions and roles.

By Satoru Oyama

SAM-1105105

Richard Spence

300-1264

Internal Distribution

For More Information...

Rick Spence, Industry Analyst .... (408) 437-8642
Via fax .... (408) 437-0292

Dataquest®
a company of The Dun & Bradstreet Corporation

Q&A Dataquest Inquiry Summary

Semiconductors

Semiconductors

March 1993

Dataquest®
a company of The Dun & Bradstreet Corporation

Program: Semiconductors
Product Code: SCND-WW-IS-9303
Publication Date: March 22, 1993

Products

Q1

What percentage of EEPROMs use a serial interface?

A

About 80 percent of all EEPROMs sold in 1992 used a serial interface. Serial EEPROMs come in 8-pin packages, at present in densities of 256 bits to 16Kb. Because they are inexpensive nonvolatile memories that come in small packages, they are used widely in consumer applications such as VCRs, camcorders, and cameras, among other uses. Microwire is the most commonly used serial interface; the I^2C two-wire bus is the second most popular.

In terms of revenue, serial EEPROMs accounted for 54 percent of worldwide EEPROM sales in 1992.

By Nicolas Samaras

Q2

How strong is the current trend to eliminate the parity bit in PCs, and how strong will it be over the next several years?

A

The parity bit was institutionalized by IBM from its first PC, and everyone who has wanted to be fully IBM-compatible has been obligated to follow suit. Apple Computer Inc., on the other hand, has always used a x8 (x32) word structure, saving 12 percent on memory cost with no apparent loss of data or of stature in the PC marketplace. So, some are asking the following questions:

- With such an improvement in memory chip reliability, do we really need parity in a PC?
- Is not IBM just migrating an uneconomic margin of safety from its mainframe business down into the low end of the computer business?
- Are there better ways to spend $12 to improve a 4MB machine that only retails for $1,200 to begin with?

Already several PC makers including Dell and Packard Bell have offered IBM-compatible machines without parity.

In the end, economics may force the parity bit aside. Just as $800 for an ounce of gold caused a mass migration to lower-cost plating alternatives for lead frames in the early 1980s, a tighter DRAM market may lead PC makers to the conclusion that parity was not all that necessary, after all.

By Lane Mason

Q3 Will synchronous DRAMs and cached DRAMs eradicate the market for fast SRAMs?

A Three DRAM technologies are vying to remove the system designer's reliance on fast SRAM caches. These DRAMs offer high-speed interfaces, rather than traditional DRAM interfaces. The three technologies are: cached DRAMs (CDRAMs), incompatible versions of which are offered by both Mitsubishi and Ramtron (whose version is known as an "Enhanced DRAM," or EDRAM); synchronous DRAMs (SDRAMs), which are being hammered out as a Joint Electronics Device Engineering Council (JEDEC) standard (announced by Samsung and NEC, and soon to be sampled by Fujitsu, and Toshiba); and the Rambus interface, a proprietary technology involving microwave techniques, which is being offered by NEC, Fujitsu, and Toshiba.

The precept behind all of these is that if the DRAM to CPU interface can be adequately accelerated, cache will become unnecessary. This makes plenty of sense in some systems, but is not really helpful in others, for the following reasons.

In the case of the Rambus and JEDEC SDRAM specifications, both the CPU and the DRAM must comply with the high-speed interface standards for the interface to give the maximum performance to the CPU in a single-CPU system. This includes some of the specifications of the CPU's cache (notably line length and certain write policies). So far, dominant CPU manufacturers have not given any indication that they plan to embrace such standards. This leaves the interface to some intervening chip, usually an ASIC, which might well end up controlling the cache. The ASIC must then contain the compatible cache, and voila, fast SRAMs become the solution, unless the designer chooses to swallow the cost of absorbing the SRAM into the ASIC. Synchronous high-speed interfaces will do a lot to accelerate DRAM performance, nonetheless. This is why both IBM and Sun Microsystems are rumored to be putting themselves behind the JEDEC effort.

The Mitsubishi CDRAM actually places the CPU cache within the DRAM, so there is no interface problem of the sort just mentioned. This would also be the case with the Ramtron EDRAM, except that there is only one address interface to the Ramtron part, making it difficult to use in as speed-sensitive of an application as a cache memory. The major problem with the two devices is that so far they are sole-sourced, a position that most often keeps a memory part from getting designed in.

Another problem we see is that there is a growing use of tightly coupled multiple processor architectures in higher-end systems. In the longer term, the architectures used in high-end systems should migrate down to PCs and portable systems. Tightly coupled multiple processor systems disallow the intimate linking between cache and DRAM required of the SDRAM, CDRAM, and Rambus interfaces. In such systems, the cache is used as a way of reducing bus traffic among the different processors and the DRAM main memory. This means that the system works best if the main memory DRAMs and the caches are in different devices. Here again, fast SRAMs are the most economical means of performing this task. As a result, high-speed SRAM manufacturers should expect little impact from improved DRAM architectures.

One final point is that, in the world of PCs, cache size has become a checklist item that naive users look for when making their system purchase. Almost nobody purchases a system based upon benchmark performance. This will be a difficult notion to shake for a number of years. Even if a system with a fast DRAM interface outperforms a competing cached system, it is likely that the cached system will outsell the other.

By Jim Handy

Q4 What is the average MOS ASIC price per gate in Japan?

A Table 1 shows the average MOS ASIC price per gate in Japan at the end of 1992. In general, full-custom ICs are cheaper than semicustom ICs such as gate arrays or cell-based ICs because they have more flexibility, which can optimize the layout and reduce the chip size. On the other hand, full-custom nonrecurring engineering charges are much more expensive than for semicustom ICs. Price per gate decreases in the case of huge lot size such as 10,000 gates or more per month. For example, most consumer application lot sizes are much larger than any other application, so the price is also the cheapest.

By Saturo Oyama (Japan)

Table 1
Average MOS ASIC Price per Gate (Yen)

Gate Size		2,000 Pieces per Month	10,000 Pieces or More per Month
Less than 10,000 Gates	Gate Array	0.10-0.12	0.08-0.09
	Cell-Based IC	0.10-0.12	0.08-0.09
	Full-Custom IC	0.09-0.11	0.06-0.08
10,000 Gates or More	Gate Array	0.08-0.09	0.06-0.07
	Cell-Based IC	0.08-0.09	0.06-0.07
	Full-Custom IC	0.06-0.08	0.05-0.06

Source: Dataquest (March 1993)

Table 2
Obtainable Chip Numbers per Wafer

					Obtainable Chip Numbers		
DRAM	Wafer Size	Actual Area Sq. in.	Actual Area Sq. mm.	Chip Size Sq. mm.	Theoretical Numbers	Effective Numbers Yield=100%	Effective Numbers Yield=85%
64Kb	4	12.2	7,852	20	393	310	264
256Kb	5	19.0	12,271	40	307	245	208
1Mb	6	27.4	17,671	50	353	288	245
4Mb	6	27.4	17,671	90	196	156	133
16Mb	8	48.7	31,419	130	242	200	170
64Mb	8	48.7	31,419	190	165	132	112
256Mb	8	48.7	31,419	285	110	88	75

Source: Dataquest (March 1993)

Q5 What is the average number of DRAM chips obtained from a wafer?

A Table 2 lists the effective chip numbers of each DRAM generation. The theoretical number is calculated simply by dividing actual area by the average chip size of each DRAM generation (this calculation is not realistic when square chips are cut from a round wafer). Effective chip numbers are shown for yields of 100 percent—the ideal—and 85 percent in DRAM volume production.

By Kunio Achiwa (Japan)

Markets and Applications

Q6 How large is the FPGA market today, and what does Dataquest project for this market?

A According to the February 22, 1993 ASIC Worldwide *Dataquest Perspective,* the FPGA market was $245 million in 1992 and is expected to exceed $750 by 1997. The FPGA market has shown stellar growth since its inception in 1986, and Dataquest expects it to continue to outpace the overall semiconductor growth rate by a factor of 1.5 to 2 over the next three to five years. FPGAs will benefit from their wide industry distribution, with 80 percent of their revenue evenly distributed among data processing, communications, and industrial sectors, making them less susceptible to industry-specific economic factors.

We base our optimistic forecast upon the following assumptions:

- Technological improvement
- Price decreases

- Migration of traditional ASIC business
- Vendor stabilization

The article entitled "Program in Another Good Year for Programmable Logic" in that *Dataquest Perspective* issue takes a long hard look at the different types of programmable logic devices (PLDs) and the market dynamics, then forecasts the PLD market by device type.

By Bryan Lewis and Robert K. Beachler

Q7

Did analog and mixed-signal ICs show growth in 1992?

A The analog IC market was mixed in 1992. The linear IC segment (only analog functions on chip) showed no growth. More than half of the linear ICs are used in consumer products. The weak consumer market, especially in Japan, had a severe impact on this product type. On the positive side, the mixed-signal segment continued the 11 percent growth rate of the past few years. Although the U.S. market was strong, the continued integration of mixed-signal functions into microperipherals and other application-specific digital functions has made the growth seem lower than it actually is. This is the reason for the rather small 7 percent growth in general-purpose data converters, at a time when data converter functions for digital audio, video, and communications are proliferating. Mixed-signal ASICs showed the strongest growth, at 16 percent over 1991.

By Gary Grandbois

Q8

Based on your unit equipment production database, could you provide the potential market size for LCDs in assorted product types for 1990, 1992, 1994, and 1996?

A Table 3 shows the estimated unit factory consumption for Europe.

By Mike Williams (United Kingdom)

Table 3
Estimated European Unit Factory Consumption (Millions of Units)

	1990	1992	1994	1996
Calculators	6.868	5.112	4.451	3.891
Cash Registers	0.261	0.255	0.264	0.276
Shelf Edge Labeling	0	0	0.050	0.600
Personal Organizers	0.120	0.500	1.125	2.531
Telephone Sets	3.914	4.486	5.150	5.869
Facsimile	0.080	0.150	0.240	0.258
PABX	3.764	4.236	4.554	4.991
Cellular Phones	1.098	1.429	2.167	3.129
Parking Meters (2)*	0.020	0.029	0.033	0.033
Medical Thermometers	0.150	0.200	0.250	0.250
Domestic Meters	1.394	4.530	9.588	17.896
Petrol Pumps (6)*	0.200	0.212	0.221	0.230
Multimeters	0.281	0.500	0.541	0.596
Microwaves	0.536	0.773	1.087	1.247
Ovens	0	0	0	0
Washing Machines	0	0	0	0
Fridges	0	0	0	0
Dishwashers	0	0	0	0
Kitchen Scales	0.903	1.000	1.103	1.216
Bathroom Scales	0.722	0.800	0.882	0.972
Food Processors	0.271	0.300	0.331	0.365
CD Players	0.617	0.756	0.965	1.220
Radio Cassette Combinations	0.464	0.527	0.533	0.540
Remote Controls	1.028	1.200	1.357	1.566
VCRs	0	0	0	0
Digital Clocks	0.130	0.156	0.188	0.213
Dashboard Display	0.260	0.492	0.640	1.050
In-Car Entertainment	0.376	0.398	0.427	0.451

*Minimum number of LCD panels per unit
Source: Dataquest (March 1993)

Q9

What are recent pricing and market trends in the flash memory marketplace?

A

The flash market remains unsettled in the aftermath of market leader Intel's inability during the second half of 1992 to ramp up supply of the 8Mb device. Intel has been working internally and with alliance partners Sharp and Nitetsu (formerly NMBS) to accelerate the 8Mb flash ramp-up. A conservative date for an increased supply of 8Mb flash memory from Intel is by or before the fourth quarter of 1993.

Table 4 summarizes results from the Semiconductor Procurement service's most recent quarterly price survey.

The strongest impact from constrained 8Mb supply has been in the 2Mb flash marketplace. There is a wide range of pricing for the 2Mb part—a reflection of unbalanced supply and demand. Lead times for users of flash memory in densities of 1Mb and 2Mb run as long as 20 weeks.

Advanced Micro Devices ranks as a major player in the 2Mb arena, as well as in lower-density segments. A host of suppliers have entered or are waiting in the wings for market entry. For example, Mitsubishi recently introduced its 1Mb flash device and plans to enter the 4Mb segment by year-end 1993. Taiwan-based Macronix—which has an alliance with NKK of Japan—has major plans for the 4Mb and 16Mb markets in 1993. Intel likely will charge Macronix, however, with violating its intellectual property rights. Hitachi and NEC Corporation are now sampling 4Mb devices but also plan to offer the 16Mb product during 1993.

Table 4
Estimated 1993 Flash Memory Price Trends—North American Bookings (12V; Volume: 10,000 per Year; Speed; 150ns; Dollars)

Product	Q1	Q2	Q3	Q4
32Kx8, PDIP/PLCC				
Minimum	4.50	4.50	4.50	4.40
Maximum	4.95	4.79	4.55	4.50
Total Respondents	3	3	3	3
64Kx8, PDIP/PLCC				
Minimum	4.70	4.50	4.35	4.20
Maximum	5.64	5.45	5.35	5.20
Total Respondents	2	2	2	2
128Kx8, PDIP/PLCC				
Minimum	6.25	6.25	6.25	6.25
Maximum	7.00	7.00	7.00	7.00
Total Respondents	4	4	4	4
128Kx8, TSOP				
Minimum	8.08	7.80	7.44	7.26
Maximum	11.00	10.00	9.25	8.50
Total Respondents	2	2	2	2
256Kx8, TSOP				
Minimum	13.03	12.75	12.50	12.25
Maximum	20.00	20.00	18.00	16.00
Total Respondents	3	2	2	2

Notes: Actual negotiated market prices may vary from these prices because of manufacturer-specific factors such as quality, service, and volume discount. These prices are intended for use as guidelines.
Source: Dataquest (March 1993)

Toshiba has formed a flash memory alliance with National Semiconductor to implement their flash strategy. Toshiba plans to skip the 2Mb segment and will offer the 4Mb density in two technologies—one device in the NAND technology and another in the NOR technology. The Toshiba-National team will ship 1Mb and 4Mb flash devices in Intel-compatible NOR technology by the third quarter of 1993. The partners will also ship 4Mb and 16Mb devices in the NAND technology. They will later produce 32Mb and 64Mb parts in an effort to make the NAND technology the industry standard. National also will use Toshiba's technology to make a line of NOR-based parts in densities from 512Kb to 8Mb.

By Ronald Bohn

Technology

Q10 What is the status of Texas Instruments' submicron CMOS fab strategy?

A Although Texas Instruments has several different submicron CMOS fab facilities, we will concern ourselves with the most recent and largest facilities (see Table 5).

TI will also begin to transition some of the 0.8-micron facilities shown in the table to 0.5-micron facilities in the next few years. For example, Avezzano, Italy should be in production with the 0.5-micron 200mm CMOS process by year-end.

Only the Dallas and Miho facilities are using both fab modules for production. The other facilities have only the first modules in either production or qualification. The existing plan calls for these other second modules to be brought into play only after the first modules are in full production at 0.5-micron with 200mm wafers.

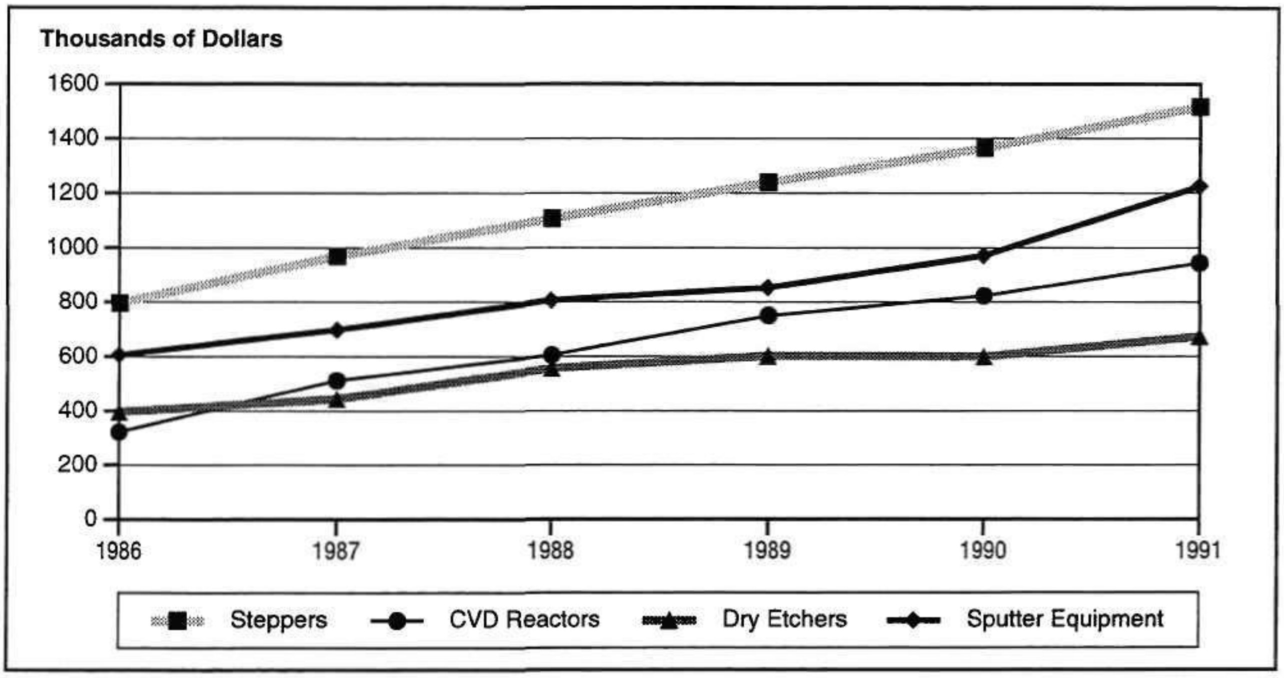
By Jerry Banks

Table 5
Texas Instruments' Submicron CMOS Fab Facilities

Facility	Location	Ownership	Status	Lithography	Wafer Size (mm)
Acer	Taiwan	Joint Venture	Production	0.8 Micron	150
Avezzano	Italy	Shared Investment	Production	0.8 Micron	150
Dallas IV	United States	T.I. Owned	Production	0.8 Micron	150
KTI	Japan	Joint Venture	Qualification	0.5 Micron	200
Miho VI	Japan	T.I. Owned	Production	0.8 Micron	150
TECH	Singapore	Joint Venture	Qualification	0.5 Micron	200

Source: Dataquest (March 1993)

Figure 1
Escalating Wafer Fab Equipment Average Selling Prices (Thousands of Dollars)



Source: Dataquest (March 1993) G3000214

Q11 How has the average selling price of major categories of wafer fab equipment changed over the past five years?

A The demand for increased technological sophistication in wafer fab equipment has translated to a dramatic increase in the average selling price of these tools. Figure 1 shows the average price for steppers, etchers, CVD reactors, and sputter equipment for the years 1986 through 1991. During this period, the compound annual growth rate for these categories of equipment has increased 11 to 24 percent per year.

By Peggy Marie Wood

Q12 What is the historical and forecast trend for minimum feature size, number of mask levels, and number of process steps used for DRAMs, starting at the 16Kb density?

A Table 6 shows the year that each DRAM density entered production, the number of process steps and mask levels used in a typical DRAM flow, the minimum feature size used, and the wafer diameters used to fabricate each DRAM generation. The projected increase in process steps and mask levels at the 64Mb and 256Mb levels is indicative of the process complexity required to fabricate those devices. Such complexity results in sharp increases in the cost of technology development and the cost of manufacturing those devices. The ability to develop and manufacture future generations of semiconductors is one of the most important issues grappled with today by integrated circuit manufacturers.

Table 6
DRAM Technology Trends

DRAM Density	Year in Production	Process Steps	Mask Levels	Minimum Geometry	Wafer Diameter (in.)
16K	1976	100	8	5 Microns	3/4
64K	1979	150	9	3 Microns	4
256K	1982	200	11	2 Microns	4/5
1Mb	1985	275	14	1.2 Microns	5/6
4Mb	1988	300	16	0.8 Microns	6
16Mb	1992	350	20	0.5 Microns	6/8
64Mb	1996	400	22	0.35 Microns	8
256Mb	2000	450	25	0.25 Microns	8/12

Source: Dataquest (March 1993)

By Charles Boucher

Company and Other Issues

Q13 What are the investment opportunities in China for semiconductor companies?

A There is little doubt about the potential for the Chinese semiconductor market, which is huge, to use an atypical market research qualifier. Consequently, many semiconductor equipment and material vendors are now talking about China as a significant market opportunity. The sheer size of the investment could revitalize the near-term lethargic growth prospects facing the global semiconductor equipment and material industries.

Our view is that China will indeed be a major device manufacturing region. The real question that companies looking to invest here must grapple with over the next several years is the timing of this market opportunity.

What Is Happening Now?

China's installed capacity is heavily weighted to discrete device production targeting consumer and industrial products. But as the demand for more sophisticated consumer electronics—that is, VCRs, data processing, and telecommunications equipment—increases, we expect the demand for advanced ICs such as memory and advanced logic device to grow rapidly.

These trends suggest that large investment in new capacity capable of producing devices with smaller line geometries will be required. Because the domestic industry lags the developed nations, Dataquest expects technology transfers from European, Korean, Japanese, and U.S. companies to be necessary for China to achieve its goals. Collaborative efforts in China are already evident in many of the projects under way.

Participation in GATT on the Horizon

China likely will join the General Agreement on Trade and Tariffs (GATT) by the end of 1993. Provisions under GATT will result in lower trade barriers for imported semiconductors and make it easier for foreign companies to set up wholly owned manufacturing plants. The government is strict about local content rules and requires technology transfers.

Dataquest Perspective

Dataquest believes that the Chinese government is pursuing a strategy similar to that used by the Taiwanese government, where emphasis is initially placed on building a position in semiconductor end-use markets (consumer electronic and telecommunications equipment). To achieve this goal, Chinese equipment makers will need access to competitively priced semiconductors. Hence, the government is willing to take a more accommodating stance toward device imports, as evidenced in its planned participation in GATT.

Ironically, better access for foreign device makers may in fact slow the growth of fab capacity in China in the near term. Overseas device makers are expected to increase their imports of ICs into China rather than invest in domestic manufacturing capacity. As their market share builds and as the political and business risks decrease, foreign semiconductor makers will follow with more aggressive investment in front-end operations. But Dataquest believes that this investment is five years away.

Entry into GATT will pose a serious challenge for China's lagging device makers. Domestic companies will need to improve their manufacturing processes to remain competitive with imported devices. Therefore, joint ventures and technology transfers between Chinese and foreign companies likely will remain as the primary growth opportunity in the semiconductor manufacturing arena for the next several years.

This developmental phase of the Chinese semiconductor industry, marked by joint ventures and technology transfers, is likely to be unexciting in terms of growth rates for semiconductor equipment and materials. But it may well prove to be an important phase for vendors to participate in because the next leg up in the growth of the domestic Chinese industry is expected to be explosive. Dataquest believes that, five years out, domestic and foreign companies will begin to launch major fab projects using leading-edge process technology. These projects may well be the payoff for equipment and material vendors solidly entrenched in China.

By Mark FitzGerald

Q14 Who are the top 10 PC manufacturers in Europe, where are they based, and what are their manufacturing activities there?

A Table 7 shows Europe's top 10 PC manufacturers. Table 8 lists their location and the activity they carry out there.

By Andrew Norwood (United Kingdom)

Q15 Which companies supply video compression chips, chip sets, and add-in boards? Which are codec chip manufacturers?

A We have a comprehensive yet incomplete list of all companies involved in the video compression chip, chip set, and add-in board market. Some of the companies also provide the software to the chips and accelerator cards. We also have a preliminary list of codec chip suppliers.

The following are video compression, graphics chips, and chip set suppliers:

- Advanced Compression Technology Inc. (Westford, Massachusetts)
- AT&T (New Jersey)
- Audio Processing Technology (APT) (United Kingdom)
- BNR Bell Northern Research (Northern Telecom) (Canada)
- Brooktree Corporation (San Diego, California)
- C-Cube Microsystems (Milpitas, California)

Table 7
1992 Top 10 Manufactures, by Format (Percentage)

Rank	Manufacture	Desktop	Laptop	Notebook	Subnotebook	1992 (K Units)
1	IBM	98.8	0	1.3	0	1,200.0
2	Compaq	73.6	0	26.4	0	690.0
3	Apple	72.9	0	27.1	0	658.6
4	Olivetti	86.8	2.9	10.2	0	547.0
5	Psion	0	0	0.4	99.6	251.0
5	Dell	82.7	0	17.3	0	251.0
7	Vobis	100.0	0	0	0	238.0
8	ICL	100.0	0	0	0	209.0
9	Hewlett-Packard	100.0	0	0	0	200.0
10	Tandon	100.0	0	0	0	160.0
	Others	91.4	0.7	7.0	0.9	1,974.2
	Total	85.7	0.5	9.6	4.2	6,378.8

Source: Dataquest (March 1993)

Table 8
1992 Top 10 PC Manufacturers' Location and Activity

Company	City	Country	Full Stuff	Part Stuff	Screw	Sub-contract	Defect Analysis	Fun Test	PCB Design	PCB Fab
IBM	Greenock	Scotland	X	X		X				
Compaq	Erskine	Scotland		X						
Apple	Cork	Ireland	X				X	X		X
Olivetti	Scarmagno	Italy	X				X	X	Yes	
Olivetti	Marcianise	Italy	X				X	X	Yes	
Olivetti (Triumph-Adler)	Nurnberg	Germany	X				X	X		
Olivetti (Triumph-Adler)	Dresden	Germany	X				X	X		
Psion	London	England	X	X			X	X		
Dell	Limerick	Ireland		X		X				
Vobis	Aachen	Germany			X					
ICL (Nokia-Data)	Ashton-Upon-Tyne	England	X				X	X	Yes	
ICL (Nokia-Data)	Kilo	Finland	X				X	X	Yes	
Hewlett-Packard	Lyon	France	X			X				X
Tandon	Vienna	Austria			X					

Source: Dataquest (March 1993)

- Cirrus Logic (Fremont, California)
- Cogent Electronics (Singapore)
- Compression Labs (San Jose, California)
- Digital Equipment Corporation (Alpha Compression Card) (Hudson, Massachusetts)
- Digital Research (subsidiary of Novell) (Provo, Utah)
- Eastman Kodak (Rochester, New York)
- Electronic Media Science (joint venture Toppan Printing/Philips) (Japan)
- Enterprise Systems, IBM (White Plains, New York)
- Exabyte Corporation (Boulder, Colorado)
- Folio Corporation (Provo, Utah)
- Franklin Electronics (New Jersey)
- Fujitsu (Japan)
- General Instruments (Chicago, Illinois)
- Hewlett-Packard (Palo Alto, California)
- Horizon Technology (San Diego, California)
- IIT Integrated Information Technology Inc. (Santa Clara, California)
- Intel Corporation (Santa Clara, California)
- Kofax Image Products (Irvine, California)
- LSI Logic Corporation (Milpitas, California)
- MicroNet (Irvine, California)
- Micronics (Fremont, California)
- Mitsubishi (Japan)
- National Semiconductor Corporation (Santa Clara, California)
- NEC Corporation (Japan)
- Netronix (Petaluma, California)
- RasterOps (Santa Clara, California)
- Rockwell International (Newport Beach, California)
- Samsung (Korea)
- Scientific-Atlanta (Atlanta, Georgia)
- Seiko Instruments USA (San Jose, California)
- Sierra Semiconductor (San Jose, California)
- Sony Corporation (Japan)

- Stac Electronics (Carlsbad, California)
- Storm Technology (Mountain View, California)
- Texas Instruments (Texas)
- Thomson Consumer Electronics (France)
- Zilog (Campbell, California)

The following are codec chip suppliers:

- Analog Devices (Massachusetts)
- Ascii Corporation (Japan)
- C-Cube Microsystems (Milpitas, California)
- Compression Labs (San Jose, California)
- Creative Labs (subsidiary of Creative Technology, Singapore) (Milpitas, California)
- Crystal Semiconductor (Texas)
- Fujitsu (Japan)
- GC Technology (Japan)
- IIT (Santa Clara, California)
- Intel Corporation (Santa Clara, California)
- National Semiconductor (Santa Clara, California)
- NEC Corporation (Japan)
- Nippon Steel Corporation (Japan)
- Toshiba (Japan)
- Victor Company (Japan)

By Mary A. Olsson

SEMMS-1746070

Mark FitzGerald
Senior Industrial Analyst

300-1264

Internal Distribution

For More Information...

Rick Spence, Industry Analyst....(408) 437-8642
Via fax....(408) 437-0292

Q&A Dataquest Inquiry Summary

Semiconductors

February 1993

Dataquest®
a company of The Dun & Bradstreet Corporation

Program: Semiconductors
Product Code: SCND-WW-IS-9302
Publication Date: February 22, 1993

Products

Q1 What is your current reading on future market development of the new architecture DRAMs such as synchronous, rambus, enhanced, and cache DRAMs?

A There is not much silicon out there yet, and the technical merits of today's parts—as great as they might be—may be of less importance than standards, marketing strategies, multiple sourcing, and key design wins. Furthermore, high-data-rate DRAM is certainly one of the most active areas in design today, and what we see today may soon be superseded by what we see tomorrow.

Mitsubishi and Ramtron have C-DRAM and E-DRAMs, respectively, but have no officially announced second sources. However, both are shipping product and getting a good reception from system designers. Toshiba and Fujitsu will have R-DRAMs this quarter. Toshiba also will have an S-DRAM early this year. All these parts are 4Mb. Most of the other activity will wait until later in 1993 and into 1994, and will take place at the 16Mb density.

Some fear that the failure to set a binding standard for the S-DRAM will lead to another "VRAM" market, with its feature content competition, inefficiently utilized silicon, lack of bona fide second sources, and high price premiums. Indeed, some DRAM vendors would like just that. On the other hand, the proprietary E-, C-, and R-DRAM programs will be managed to be fully compatible, and eliminate some of the potential market development problems brought on by "near compatibility."

Increasingly tight capacity undoubtedly will be another factor in play for the next 18 months. Historically, priority in the fab line has been given to the money-makers, which in 1993 and probably 1994 will be 4Mb DRAMs and later 16Mb DRAMs, both of which are selling into established demand, with almost guaranteed high revenue and profit per wafer. New products have a hard time getting the full attention of production control, or the necessary volumes for rapid market development.

One cannot underestimate the inertia of the market, the comfort that systems designers feel with standard DRAMs, and their ability to improvise high-speed solutions using cost-competitive wide DRAMs.

By Lane Mason

Q2

Why did semiconductor optoelectronics decline in 1992?

A

More than any other semiconductor type, optical semiconductors are dependent on one regional market: Japan represents 62 percent of worldwide consumption. A poor Japanese market for semiconductors drives the worldwide optical semiconductor market proportionately. Dataquest's preliminary numbers show that worldwide revenue for the optical semiconductor category dropped 5 percent in 1992. This product segment has some important devices in consumer electronics, notably CCDs for fax machines and camcorders, as well as laser diodes for compact disc players. The camcorder market slump was a big reason that CCDs had a precipitous 22 percent drop in revenue in 1992. On the other hand, Laser diodes saw 14 percent growth in 1992 because of the rapidly increasing CD-based products such as Diskman portables, inexpensive CD boom boxes, and CD-ROM drives. Increasing communications applications for laser diodes also contributed to the laser diode revenue growth. The more mature LED product lines saw revenue decline by 7 percent, a result that more closely tracked the general declines in the consumer market.

By Gary Grandbois

Q3

What is the recent 4Mb DRAM volume price in Japan? Is there any price premium in package type, configuration, and speed?

A

Table 1 shows 4Mb DRAM volume price in Japan by package and speed. Although the U.S. Department of Commerce announced

Table 1
4Mb Volume Price in Japan, by Package and Speed
(As of January 8, 1993)

Package		Speed (ns)	Price (Yen)
4Mbx1	SOJ	80	1,200
4Mbx1	SOJ	70	1,200-1,220
4Mbx1	SOJ	60	1,300-1,330
4Mbx1	ZIP	80	1,200
4Mbx1	ZIP	70	1,200-1,220
4Mbx1	ZIP	60	1,300-1,330
1Mbx4	SOJ	80	1,200
1Mbx4	SOJ	60	1,300-1,330
1Mbx4	ZIP	80	1,200
1Mbx4	ZIP	60	1,300-1,330
512Kx8	SOJ	80	1,260-1,350
512Kx8	SOJ	70	1,260-1,350
512Kx8	SOJ	60	1,320-1,440
256Kx16	SOJ	80	1,350-1,450
256Kx16	SOJ	70	1,350-1,470
256Kx16	SOJ	60	1,400-1,550

Source: Dataquest (February 1993)

preliminary antidumping duties levied against DRAM suppliers, there is no significant change in contract price at this time. However, the spot price has increased about 10 percent from 2 months ago. The price difference, which is derived from configuration and speed, will decrease. However, there still is about 30 percent difference in price from the lowest to the highest. The configuration price premium is about 5 to 13 percent in Japan.

By Akira Minamikawa

Markets and Applications

Q4 Who are the top 10 1992 suppliers in ASICs?

A Table 2 lists the top 10 1992 ASIC suppliers according to our 1992 market share survey. The ranking remained relatively unchanged from the 1991 ASIC rankings, with the exception of VLSI Technology moving from ninth to eighth and AMD dropping from eighth to ninth. NEC gained ground on Fujitsu and is in a close race for the No. 1 position. A detailed breakdown of all the top 10 ASIC rankings by product will soon be published in the ASIC service.

Table 2
Preliminary Top 10 1992 ASIC Suppliers, Worldwide
(Millions of Dollars)

Rank	Supplier	1992 Revenue
1	Fujitsu	727
2	NEC	724
3	LSI Logic	570
4	Texas Instruments	480
5	AT&T	465
6	Toshiba	432
7	Hitachi	393
8	VLSI Technology	286
9	AMD	276
10	Motorola	250

Note: Estimates do not include full-custom ICs.
Source: Dataquest (February 1993)

By Bryan Lewis

Q5

How does Dataquest estimate Japanese application market growth in 1993? Which application is expected to grow in 1993?

A

Dataquest estimates total Japanese electronic equipment production growth of 2.1 percent on a value basis to ¥21,659 billion in 1993. The Japanese economy is still depressed and could get worse this year. The general macroeconomic picture does not look good; most Japanese companies expect lower revenue and profits in 1993.

Personal consumption will not grow as expected in the first half of 1993 because of shrinking bonuses and extra pay for overtime work. These conditions contributed to declines of 17.3 percent and 14.2 percent in the critical consumer and industrial equipment markets, respectively, in 1992. These markets are expected to remain unchanged in 1993.

The communications equipment market is expected to have the highest growth, 4.7 percent, mainly driven by infrastructure in radio communications in the Japanese applications market. Data processing and transportation equipment markets are expected to grow 0.9 percent and 0.1 percent, respectively, in 1993.

Dataquest believes that 1993 is the first year of the multimedia era in Japan. The minidisc will revolutionize music media and the way we think about things. Matsushita will introduce a new TV video game platform with 3-D, which will evolve into a multimedia player for home use. Several companies have plans to produce personal digital communicators such as Sharp and Apple's Newton and Casio's Zoomer. Toshiba and Fujitsu also are expected to join the market in the near future with their own platforms. The multimedia market will be one of the most attractive among 1993 Japanese electronic equipment markets.

By Kun Soo Lee

Q6

Please list the top flash memory players and their 1992 market share.

A

Table 3 shows the top flash memory companies, along with their market share in 1992.

Table 3
Preliminary Flash Memory 1992 Worldwide Market Share

Rank	Company	Market Share (%)
1	Intel	68.9
2	AMD	18.9
3	Atmel	4.8
4	Hitachi	2.2
5	Catalyst	1.3
6	Toshiba	0.9

Source: Dataquest (February 1993)

Dataquest's preliminary worldwide market estimate for flash is $228 million in 1992. Intel's market share dropped from 85 to 69 percent, a result of the well-publicized high-density flash supply problems with its foundry NMB semiconductor. AMD, Atmel, Hitachi, and Catalyst won market share at Intel's expense. Toshiba's drop to No. 6 in rank resulted from a rather constant flash memory output (at a relatively low level of about $2 million) in an expanding marketplace. The top six players controlled 97 percent of the worldwide flash memory supply.

By Nicolas Samaras

Q7

What are the key application drivers for programmable DSP processors?

A Ever since Texas Instruments first successfully commercialized programmable DSP processors, they have been used in an ever widening number of applications. However, Table 4 shows a few key drivers that account for most of the DSP revenue.

Table 4
Key DSP Revenue Drivers

Region	Key DSP Drivers
North America	Telecommunications
	Data communications (particularly high-speed modems)
	Hard disk drives (head positioning and servor control)
	Multimedia (voice and image compression, digital audio, telephony)
	Automotive (suspension control and audio entertainment)
Europe	Telecommunications (digital cellular and digital cordless)
	Data communications (modems)

Source: Dataquest (February 1993)

As applications become more cost sensitive, there is a tendency to migrate from the power and flexibility of a programmable DSP to a more cost-effective dedicated (nonprogrammable) IC.

By Jerry Banks

Technology

Q8

What is the status of the 100-Mbps Ethernet upgrade?

A A standards effort known as "fast" or 100-Mbps 802.3 (the Ethernet IEEE standard) is under way. Insiders say a draft will be on the street by October 1993. There are several proposed approaches, most of which limit the distance to 100 meters to minimize radiation emissions. The most visible proposal is that made by Hewlett-Packard and AT&T (100Base-VG), but it entails a radical departure from CSMA/CD access to demand priority. Dataquest believes that one of the other "full duplex" proposals with advanced low emission signaling from Grand Junction Networks (Union City, California) or Lan Media of (Santa Clara, California) most likely will be the emergent draft. This proposal is in an R&D horse race with efforts such as dedicated 10 Mbps, copper FDDI, and ATM. However, all three technologies could conceivably coexist in the market in different applications.

By Greg Sheppard

Q9 Where is the industry going in terms of surface-mount assembly board types?

A Of the four typical types of board assembly being used for surface-mount components (SMCs)—Type I, Types IIA and IIB, and Type III—70 percent are of mixed technology, while the remainder is considered pure surface-mount technology (SMT). Types IIA and IIB, and Type III represent mixed technology using both SMCs and through-hole (TH) devices, while Type I is exclusively SMT. As a general description, Type I makes use of either single- or double-sided mounting and allows use of any SMC on one or both sides. Type I boards typically are populated with more highly dense components than on any of the other board types. Type I allows for the best SMT density, unit area, and sophistication of design. Although users have become more comfortable with implementation of SMT, not all devices are readily available in SMT. Equipment application and component location on the board also heavily dictate the type of board used. Hewlett-Packard's latest calculator model implements Type I board assembly as a cost-effective board assembly solution.

Type IIA implements mixed technology with the topside of the board containing any SMC and TH component, while the bottom side contains only simple SMC. Simple SMCs are defined as metal electrode face bonding devices, passive chip components (resistors and capacitors), small outline transistors, and small outline ICs. Type IIA board assemblies are the most commonly used among the mixed technology boards, especially in the industrial and consumer segments.

Type IIB boards are of mixed technology, with any SM or TH components on either the top or bottom side of the board. The more complex devices, those packaged in PLCC, LCC, and QFP designs, usually are on the bottom. Camcorder boards typically are Type IIB boards.

Type III boards are also of mixed technology but have TH components on the topside and only simple SMCs on the bottom side.

Satellite applications that implement Type III boards have 94 components mounted on both sides of the board.

By Mary A. Olsson

Q10 Who is on the PCI bandwagon? Who is supporting the VL-bus?

A Personal computer architecture is constantly undergoing changes. Now that the world has accepted caches, EISA/MCA, and file servers, the march is moving to very high speed local buses. System designers have discovered a need for a second bus within the PC to handle numerous very high speed interconnections that should not be burdened with the low-speed general-purpose bus used to service less-taxing I/O devices such as floppy drives, modems, and keyboards. Vendors have found a strong advantage to standardization in such areas, and two rival specifications are now lobbying for support: PCI (for peripheral component interconnect), and VL-bus (for VESA local). Either bus requires special signaling for any device that attaches to the bus, meaning that ICs are designed to perform to one standard or the other.

The specifications for PCI and VL-bus differ, so semiconductor manufacturers need to look at the support each camp has garnered in order to make the best strategic decision. Table 5 shows who is in which camp as of late 1992.

Table 5
Support for Competing Local Bus Standards

	PCI	VL-Bus
Semiconductor Manufacturers		
ACC Micro		X
Adaptech	X	
Advanced Logic		X
Anybus Technology		X
Appian Technology		X
ATI	X	X
Chips & Technologies		X
Cirrus Logic	X	X
Data Technology		X
Efar Microsystems		X
Headland Technology	X	X
Integrated Information Technologies		X
IMS		X
Intel	X	
National Semiconductor	X	

(Continued)

Table 5 (Continued)
Support for Competing Local Bus Standards

	PCI	VL-Bus
NCR Microelectronics	X	X
Oak Technology		X
OPTi		X
Primus Technology		X
S3	X	X
Texas Instruments	X	
Trident Microsystems		X
Tseng Labs	X	X
ULSI Systems		X
VLSI Technology	X	
Weitek		X
Western Digital	X	X
System Manufacturers		
Acer	X	
Actix Systems		X
Advanced Integration Research		X
Advanced Logic Research	X	
Alpha Research		X
American Megatrends	X	X
Artist Graphics		X
AST Technology	X	
ATI Technologies		X
CMS Enhancements		X
Compaq	X	
CompuAdd		X
Data Technology		X
Digital Equipment Corporation	X	
Dell	X	
DFI		X
Diamond Computer Systems		X
Digital Air Systems		X
Elanex		X
Epson	X	
Everex		X
Fujitsu	X	
Gateway 2000	X	X
Genoa Systems		X
Hewlett-Packard	X	
Hyundai Electronics		X
IBM	X	
Matrox	X	X
Media Star		X

(Continued)

Table 5 (Continued)
Support for Competing Local Bus Standards

	PCI	VL-Bus
Micronics	X	
Mitsubishi	X	
NCR	X	
NEC	X	
Northgate Computer Systems		X
Oakleigh Systems		X
Oki	X	
Olivetti	X	
Orchid Technology		X
Point Corporation		X
Raster Ops		X
Siemens	X	
Sigma Designs		X
Tandy	X	
STB Systems		X
TMC Research		X
Ultrastor		X
Unisys	X	
Vidtech Microsystems		X
Zeos		X
ZDS	X	
Software Vendors		
American Megatrends	X	
IBM	X	
Logic Modelling	X	
Meta-Software	X	
Microsoft	X	
Phoenix	X	

Source: Dataquest (February 1993)

By Jim Handy

Company and Other Issues

Q11 Does the North American Free Trade Agreement (NAFTA) have a provision similar to the European Community's requirement that domestic semiconductors are defined as those that are diffused in the region? That is, to prevent or avoid duties or tariffs, will foreign semiconductor manufacturers have to build fabs within the Canada-United States-Mexico region?

A The fine print of the NAFTA mentions domestic origin in terms of "harmonized schedule numbers." These numbers define domestic "regional" semiconductor manufacture and rules of origin by product type. Because the NAFTA is not yet ratified, we will keep a close watch on any developments. For further information on the details of NAFTA and how it affects the semiconductor market, please contact Laura Gaughan of the U.S. Department of Commerce at (202) 482-0300.

By Mark Giudici

Q12 What is the status of the Posco-Hüls silicon wafer plant in Korea?

A Posco-Hüls is a joint venture among Pohang Iron and Steel (40 percent), MEMC Electronic Materials (40 percent), and Samsung (20 percent). The joint venture has constructed a wafer plant south of Seoul, South Korea, an investment of $110 million dollars. The plant is built to manufacture 6-inch and 8-inch wafers. Qualification runs began in November 1992.

By Mark FitzGerald

Q13 Please provide us information regarding benchmarks on inventory turns and/or work-in-progress (WIP) turns among semiconductor manufacturers.

A Dataquest's research shows that the following companies, among others, have been used to benchmark inventory management performance, including inventory turns and WIP turns: Apple Computer, Federal Express, Frito-Lay, National Semiconductor, and Westinghouse.

Using information contained in a "FORM S-3" filed by National Semiconductor (dated August 25, 1992) with the Securities and Exchange Commission, we made the following estimates of National Semiconductor's annual inventory turns, measured in dollars for the period of June 1, 1991 to May 31, 1992: 8.29 inventory turns, and 12.72 WIP turns.

By Ronald Bohn

Q14 Please provide recent agreements the telecommunications company Ericsson has made within the last year.

A Ericsson is considered a strong player in international telecommunications and is well known for its advanced systems and products for wired and mobile communications in public and private networks, as well as electronic defense systems. Ericsson received quite a bit of press in 1992. Key developments during that period were as follows:

- Ericsson signed a general purchasing agreement valued at $13 million for a project to expand the telecommunications network in Argentina.
- Ericsson received a $200 million contract from the Swedish Defense Material Administration for six Erieye airborne early warning radar.
- Ericsson was awarded a contract from the Ministry of Interior of the Republic of Poland for delivery and installation of a new digital mobile radio system called EDACS. The order was initially valued at $16.5 million. The EDACS system for Poland was manufactured by Ericsson GE Mobile Communications in Lynchburg, Virginia.
- Ericsson signed an agreement to create a joint venture with several local partners in the Guangdong province in China. The new company, Guangzhou Ericsson Communications Company Ltd., will be responsible for marketing, sales, and support of the analog TACS mobile cellular systems in China.
- Ericsson and Hewlett-Packard announced formation of a joint venture company to develop and market network management systems for telecommunications operators and service providers around the world. The new company will begin operations in the first quarter of 1993 and will start shipping products immediately.
- Ericsson was chosen by Deutsche Bundespost Telekom as one of three suppliers for a broadband network pilot project, which will begin in 1994. The order is a confirmation that Ericsson will be a major player in the emerging broadband market.
- Ericsson began deliveries of its new TDMA digital hand-held cellular phones to Pacific Link, the first delivery of TDMA digital phones in Asia.
- Ericsson received a $16 million order from Mobile Telephone System Co., the cellular operator in Kuwait, for expansion of the country's cellular telephone network.
- Ericsson's subsidiary in Mexico, Teleindustria Ericsson, signed a contract with Telefonos de Mexico (Telmex) regarding the 1993 delivery program covering 780,000 AXE lines. This is part of a five-year general purchasing agreement reached in 1990 between Ericsson and Telmex, and is the third such contract signed since the privatization of Telmex.
- Ericsson was awarded a $16.5 million contract by the Ministry of Communications in Tunisia for AXE digital switching equipment to expand the Tunisian telecommunications network. The contract covers new digital switches as well as extension and upgrading of existing switches.

- Ericsson was awarded a $95 million contract from Central Japan Digital Phone Co. Ltd. for a cellular system that will cover the region of Tokai, which includes Nagoya and metropolitan areas. The system will be delivered in fall 1994 and have an initial capacity of 50,000 subscribers. The contract is Ericsson's third for a cellular system in Japan.

By Rick Spence

Q15

A new company, Spectrum Sciences, has entered the ion implantation equipment market. Please provide information about this company and its product focus.

A

Spectrum Sciences Inc. is located in Santa Clara, California and is the sister company of Ion Implantation Corporation (IICO), a Silicon Valley-based company that provides ion implantation services to semiconductor device manufacturers. In September 1992, it was announced that Wright Laboratory (Wright-Patterson AFB), an agent for DARPA, had awarded a manufacturing equipment contract to Spectrum Sciences to develop a fully automated prototype implanter for manufacturing active matrix LCD displays that are 350mm x 450mm in size. Under the terms of the contract, Xerox PARC will be responsible for evaluating the prototype implanter. The implanter being developed by Spectrum Sciences is for use in the fabrication of polysilicon thin film transistors (TFTs). Xerox PARC is one of the leading companies in the development of polysilicon TFT active matrix displays.

The majority of active matrix displays being manufactured today use TFTs to switch pixels in the display on and off. Almost all of the manufacturing activity to date has focused on amorphous silicon TFTs. One reason for this is that amorphous silicon TFTs can be processed at lower temperatures so that inexpensive glass substrates can be used. Polysilicon TFT displays, with their higher-temperature processing requirements, still are in the development stage. One major advantage of polysilicon TFT technology stems from the ability to fabricate the IC drivers directly on the panel during the regular fabrication process. This may in the long run be less costly than the parts and assembly of external drivers in amorphous silicon TFT displays. However, the advantages of polysilicon TFTs must be balanced by the relatively lower cost of the more mature amorphous silicon technology. Many of the transistor fabrication process steps for amorphous silicon and polysilicon TFTs are the same, such as lithography, deposition, and etch. Polysilicon TFTs, however, do require two additional processing steps: hydrogenation and ion implantation. In these areas, process equipment able to handle large substrates still needs to be developed, hence the reason behind the DARPA contract to Spectrum Sciences.

The prototype ion implanter contract awarded to Spectrum Sciences is for $5.0 million. The contract was awarded as part of the DARPA High Definition Systems Program. This program, which awarded about $75 million in contracts in fiscal 1991 to manufacturers and researchers of high-definition systems, is funded by a special vote of the United States Congress.

By Peggy Marie Wood

Richard Spence
300-1264
Internal Distribution

SAM-1332048

For More Information...

Rick Spence, Industry Analyst .... (408) 437-8642
Via fax .... (408) 437-0292

Dataquest Inquiry Summary

Semiconductors

January 1993

Contents

Dataquest®
a company of The Dun & Bradstreet Corporation

Program: Semiconductors
Product Code: SCND-WW-IS-9301
Publication Date: January 25, 1993

Products

Q1 What is Dataquest's current worldwide consumption forecast of the 64Mb DRAM, in units? In which year will it peak, and what are the assumptions behind the forecast?

A Table 1 is our 64Mb DRAM forecast, which shows consumption peaking in 2002.

Assumptions

The forecast includes the following assumptions:

- Steeply rising cost of process development will result in longer life cycles, for example, 12 quarters peak to peak, which if historically true will drift to 14 quarters for 4Mb, 15 to 16 quarters for 16Mb, and 17 to 18 quarters for 64Mb.
- The slowdown in bit rate growth will continue.
- Rich user-friendly software with rich graphics will drive memory demand in PCs and workstations.
- Average memory per office user of a personal computer will require 12Mb.
- Demand for specialty memories, wider/higher bandwidth, plus requirement of smaller memory increments (read bytewide) will continue.
- 64/256Mb transition will truly be a watershed, with possibly no more than four or five globally aligned consortiums (for example, IBM, Toshiba, and Siemens) surviving the financial burden.

Table 1
64Mb DRAM Outlook (Millions of Units)

Year	Estimated Market
1996	3
1997	25
1998	125
1999	285
2000	425
2001	550
2002	700
2003	600
2004	520
2005	400

Source: Dataquest (January 1993)

By Bipin Parmar and Lane Mason

Q2

Why does Dataquest not track dual-port SRAMs? What is the market like?

A

The dual-port SRAM market, excluding dual-port SRAM modules, is less than U.S.$50 million worldwide. Because it is so small, Dataquest does not track it formally, but the following is a snapshot.

Major manufacturers are IDT and Cypress, with some offerings from AMD, SGS, Fujitsu, and Matra.

Probably about 20 fundamentally different products are available, each offered in a variety of speeds, packages, and operating temperature ranges. As a result, prices fall over a wide range. The lowest prices are about U.S.$3 and are charged for the oldest device, a 1Kx8 master, in the slowest speeds in plastic packages, commercial temperature range. This part originally was conceived by Synertek in the early 1980s, before it closed. It is now the most widely sourced dual-port. Top prices tend to be for high-speed 16-bit devices. Dataquest has seen some offered at prices higher than U.S.$85. Naturally, prices for military versions are substantially higher, up to a maximum of about U.S.$300.

By Jim Handy

Markets and Applications

Q3

What is the main reason that Japanese video equipment production decreased dramatically in 1992?

A

Japanese video equipment production on a value basis decreased by about 20 percent during the period from January to August 1992, compared with the same period of 1991. The major reason is the sluggish VCR and video camera markets.

Television sets, VCRs, and video cameras are three major products in the Japanese video equipment market. Although production of television sets declined by 7.5 percent from January to August 1992 during the same period of the previous year (see Table 2), VCR and

Table 2
Production of Major Video Equipment in Japan: January-August 1992 (Billions of Yen)

	Production	Growth Rate (%) (1991-1992)	Percentage of Decreased Amount	
			Domestic	Overseas
Television Sets	538	-7.5	94	6
Videocassette Recorders	528	-23.2	39	61
Video Cameras	409	-28.8	13	87

Note: All numbers calculated on a value basis.
Source: Dataquest (January 1993)

video camera production dropped dramatically by 23.2 percent and 28.8 percent, respectively. The difference comes from dependence on the overseas market.

Production of TV sets declined 7.5 percent to ¥538 billion; 94 percent of this decline was in the Japanese domestic market. Therefore, it could be concluded that Japanese TV set production mainly depends on the domestic market. However, VCR and video camera production depends on the overseas market, thus a large portion of the decrease in production value occurred in the overseas market: 61 percent for VCR and 87 percent for video camera.

Consequently, a recovery of TV set production depends on end users' demand in the Japanese domestic market, while production of VCRs and video cameras mainly depends on a recovery of the overseas video equipment market.

By Naotoshi Yasuhara

Q4 The transportation industry is increasing the use of semiconductors in the final product. What is the history and forecast of worldwide semiconductor consumption for the period from 1989 through 1996? What is the share for each application market?

A Table 3 provides semiconductor consumption history and forecast numbers from 1989 through 1996.

By Ronald Bohn

Table 3
Worldwide Semiconductor Consumption (Millions of Dollars)

	1989	1990	1991	1992	1993	1994	1995	1996
Total	54.3	54.6	60.0	62.9	72.7	82.6	88.1	95.0
Application Market As a Percentage of Total Consumption								
Communications	12.5	13.7	13.5	13.5	13.5	13.3	13.4	13.6
Consumer	19.9	20.7	21.3	21.0	20.4	20.0	20.7	20.7
Data Processing	47.1	44.3	44.5	45.6	46.6	47.5	46.3	46.0
Industrial	10.1	10.8	10.3	10.3	10.3	10.4	10.7	10.8
Mililtary/Aerospace	5.5	5.3	4.7	4.5	4.1	3.8	3.7	3.7
Transportation	4.8	5.1	5.2	5.1	5.1	5.1	5.2	5.4

Note: Columns may not add to 100 percent because of rounding.
Source: Dataquest (January 1993)

Q5 What is Dataquest's forecast for wafer fab equipment?

A The year 1992 was painful for the worldwide wafer fab equipment market (see Table 4). The total worldwide market was down 15.5 percent from about $6 billion in 1991 to about $5.1 billion in 1992. Much of this decline can be attributed to the massive capital spending cuts on the part of Japanese semiconductor manufacturers, resulting in a precipitous 30 percent drop in wafer fab equipment sales in Japan, which represented 50 percent of the worldwide wafer fab equipment market in 1991. The only region exhibiting any growth in wafer fab equipment consumption in 1992 was Asia/Pacific-Rest of World, led by 4Mb and 16Mb DRAM capacity expansion in Korea and continued fab construction in Taiwan and Singapore.

Dataquest forecasts a meager 1.2 percent growth worldwide in 1993, propelled by 13 percent growth in North America and 5 percent growth in Asia/Pacific. Dataquest does not expect Japanese equipment spending to show any signs of recovery until the end of 1993 at the earliest. The real turnaround in the global wafer fab equipment market is anticipated in 1994: Dataquest predicts an 11 percent increase in wafer fab equipment spending. Continued growth in North America and Asia/Pacific, combined with expected recovery in Japan and Europe, should result in healthy growth.

Table 4
Worldwide Wafer Fab Equipment Market, by Region—1991-1994 Forecast (Millions of Dollars)

	1991	1992	1993	1994
North America	1,536.3	1,516.7	1,711.0	1,947.5
Percentage Growth	-3.8	-1.3	12.8	13.8
Japan	3,016.7	2,108.0	1,960.5	2,102.9
Percentage Growth	1.0	-30.1	-7.0	7.3
Europe	633.6	596.0	566.2	628.8
Percentage Growth	-17.5	-5.9	-5.0	11.1
Asia/Pacific-ROW	852.3	883.3	928.0	1,053.5
Percentage Growth	63.9	3.6	5.1	13.5
Worldwide	6,038.9	5,104.0	5,165.7	5,732.7
Percentage Growth	2.9	-15.5	1.2	11.0

Source: Dataquest (January 1993)

By Charles Boucher

Q6

What is the current status of the flash memory market?

A

As Intel's 8Mb flash foundry, NMB, continues to stumble in getting the recipe for this part, this sole-sourced market is in an ultra-allocation mode. Intel is applying heavy resources to fix the process problem, but it looks as though it will be mid-1993 at the earliest before any production volumes will result from the current corrective actions. Lower-density flash memory also are experiencing availability problems because unforecast demand surges have forced some suppliers to allocate 2Mb parts with resulting opportunistic pricing. At this time, availability for densities of less than 1Mb remain good, but the spillover effect of suppliers shifting capacity to higher demand and higher densities may end up impacting these parts also.

By Mark Giudici

Technology

Q7

National Semiconductor has done some first-rate technology licensing in the nonvolatile memory (NVM) arena, but still is relatively quiet about its ultimate intentions. Where do you think it is headed in 1993 and into 1994 in flash, EEPROM, and EPROMs?

A

It is hard to tell, but at its annual meeting late last year National was developing a plan that would be formalized some time early this year. Just last month it licensed the NAND flash technology from Toshiba, and it now has the Alternate Metalless Gate (AMG) EPROM technology implemented in its 1Mb-and-higher-density EPROM line. It continues to be among the top tier in the lower-density serial and parallel EEPROMs market, as well.

But National's management has consistently made a point of wanting to avoid "commodity markets" such as the EPROM market is now, and the flash market promises to become. Though its earnings for the second fiscal quarter were up to record levels, its stock dropped $3 because the analyst community believed that the company was failing to deliver on its strategy of improving margins by shifting its product mix more toward proprietary and differentiated products with higher margins. Even an $18 million royalty income earned in the second quarter carried no apparent weight with the security analysts.

Now, with the turmoil in the flash market and price stability in EPROMs, both brought on primarily by Intel's poorly executed transition from flash to EPROM, National will have to decide whether to heed the siren's call to profit, enlarge its presence in EPROMs, and get on the flash bandwagon. Or, it could stay the course, avoid the volatile commodity memory markets, and pursue only differentiated product markets.

The next few months should tell whether NSC will pursue what is perhaps a transient profit opportunity in commodity NVM (where it now has technology equal to the best), or leave the money on the table and stick to its original strategy.

By Lane Mason

Q8 What impact will the movement to local bus have on the PC semiconductor market?

A We believe that the majority of PC OEMs are either introducing or designing local bus-based systems. Their motivation is to move beyond the limiting 8-MHz bus rates found with ISA/EISA-based systems. The majority of OEMs to date have adopted the VESA VL standard, although several have proprietary pixel buses.

The impact on the semiconductor market is enormous as new system logic chip sets, graphics controllers/window accelerators, storage interfaces, and higher-speed DRAM/VRAM video buffers are needed for the changed speed (100 MB/sec) and access requirements. The move to local bus also removes one of the road blocks to digital video because less "lossey," higher data rate compression can be employed. The adoption of a local bus architecture has the potential of shortening the lives of EISA and possibly the MCA/32 buses.

Intel's PCI approach is expected to gain strength during 1993 as it is adopted as a higher-performance alternative to VL. PCI will be helped further by Intel's recent announcement to drop plans for charging licensing fees. Dataquest believes that one standard will dominate by 1994: the one that impacts material costs the least. Stay tuned.

By Greg Sheppard

Company and Other Issues

Q9 As IBM comes into the merchant semiconductor market, will it be allowed to sell its own versions of the 486 MPU on the open market?

A IBM now is selling motherboards that have 486s it has made itself, as well as IBM-made DRAMs, to several PC makers. According to the 10-year agreement between Intel and IBM signed in November 1991, IBM is entitled to make the 486 for its own use and sell boards containing the chip to the market. It is not allowed to sell standalone 486 chips.

So as not to create a component-level competitor, the agreement contains some financial considerations for Intel for 486s made and used by IBM, either in its own PCs or in boards it sells to others.

Furthermore, IBM is entitled to sell variations of the 486 agreed to by IBM and Intel at their joint development effort at the Robert Noyce Center in Boca Raton, Florida.

By Lane Mason

Q10 Please provide some information on the number of fab lines in Japan and their productivity.

A As of December 1992, 251 semiconductor production lines were in Japan (excluding assembly lines). Table 5 shows the number of existing fab lines in Japan, by company.

Table 5
Existing Fab Lines in Japan, by Company (Total 251)

Company	Fab Lines	Company	Fab Lines
Aishin Seiki	2	Nissan	1
Canon	2	NKK	1
Canon Denshi	1	NMB Semiconductor	3
Casio	1	Oki	8
Clarion	1	Olympus	1
Fuji Electric	2	Omron	2
Fuji Film Microdevice	1	Origin Electric	1
Fuji Xerox	1	Pioneer Video	1
Fujitsu	16	Ricoh	3
Hamamatsu Photonics	1	Rohm	4
Hitachi	27	Sanken	3
Honda	1	Sansha	1
IBM	2	Sanyo	11
Iwatsu	1	Seiko Epson	4
JVC	1	Seiko Instruments	2
Kawasaki Steel	1	Sharp	10
Kodenshi	1	Shindengen	7
KTI Semiconductor	1	Sony	11
Kyoto Semiconductor	1	Stanley	1
Matsushita	16	Sumitomo Metal Industry	1
Meidensha	1	Texas Instruments	5
Mitsubishi	15	Tohoku Semiconductor	2
Mitsumi	1	Tokin	1
Moririca Electronics	1	Toko	2
Motorola	1	Torex Semiconductor	1
Murata Manufacturing	1	Toshiba	24
NEC	19	Toshiba Components	2
New Japan Radio	4	Toyoda Automatic Loom Works	1
Nihon Inter Electronics	1	Toyoda Machine Works	1
Nihon Semiconductor	1	Toyota Motor	1
Nippondenso	2	Unizon	1
Nippon Precision Circuit	2	Yamaha	3
Nippon Steel	1	Yokogawa IMT	1

Source: Dataquest (January 1993)

Dataquest estimates that 1992 semiconductor production in Japan amounts to about $29.2 billion, with average production per line equal to about $116 million.

By Kaz Hayashi

Q11 What is the Computer Systems Policy Project (CSPP)?

A The CSPP is a coalition of 13 U.S. computer companies founded in 1990. CSPP initially was formed as the computer industry's lobby group in the United States to ensure an open market that would guarantee a steady supply of state-of-the-art semiconductors at reasonable prices from many sources, including the United States. During the last three years, the CSPP group has worked with the SIA in representing the user side of the semiconductor industry during trade negotiations, the National Research and Education Network (NREN) in gaining access to increased federal research funds for private industry, and the U.S. Department of Energy in developing guidelines for Cooperative Research and Development Agreements (CRADAs) to ease joint federal and private technology research. CSPP members include such notable companies as IBM, CRAY Research Inc., Digital Equipment Corporation, Hewlett-Packard, Sun Microsystems, Compaq, and Apple.

In October 1992, the CSPP published its first report, *Perspectives on U.S. Technology Policy: The CSSP Agenda for the 103rd Congress.* The report included recommendations for increased government investment in research and development, development of a high-speed information and communications network in the United States, a program now under development at Microelectronic and Computer Technology Corporation (a U.S. research consortium), and more stringent laws against product dumping in the United States.

By Mary Olsson

Q12 What are the regional trends in capital spending?

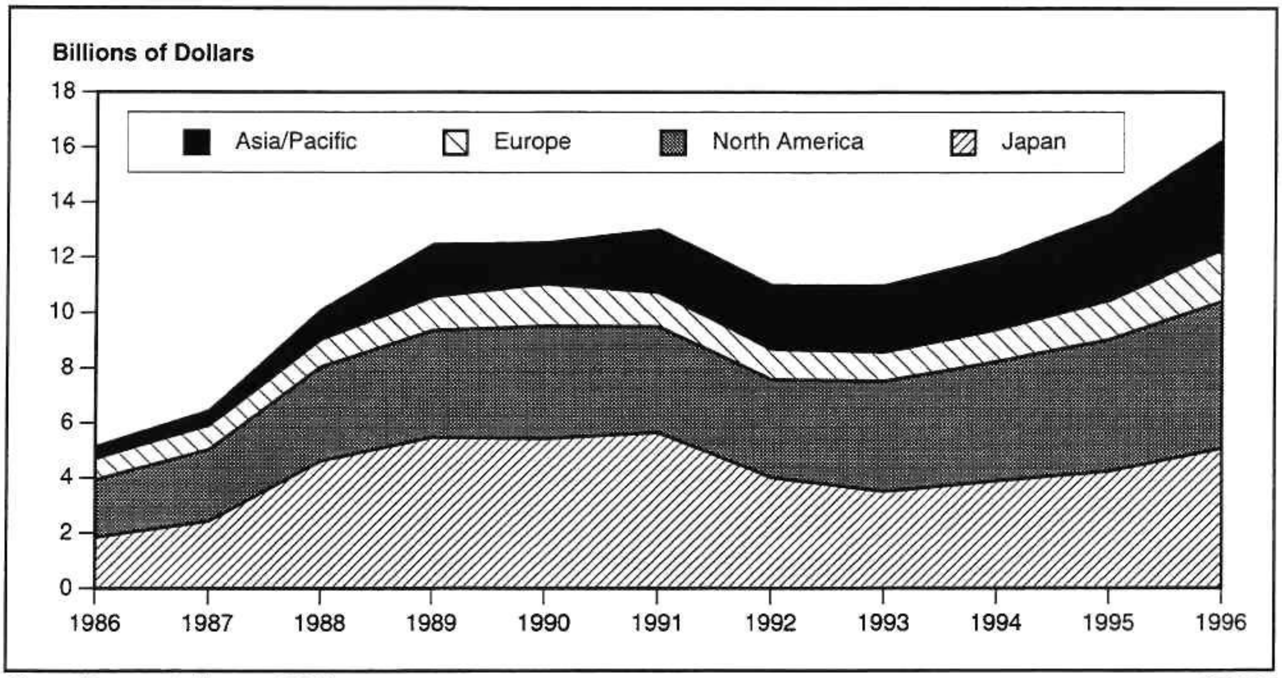
A

Japan

The first thing we notice when looking at trends in capital spending is the big surge in Japan during the years 1987 through 1991, when it rose to a peak of $5.6 billion in 1991 (see Figure 1). In 1992, spending in Japan dropped almost 30 percent to $4 billion, and will decline further in 1993 to $3.5 billion. Capital spending in Japan will rebound in 1994, but we do not expect capital spending to reach the 1991 peak of $5.6 billion, even by 1996. Part of the slower growth of capital spending in Japan can be attributed to two reasons, as follows:

- The troubled domestic economy
- The increasing overseas investment of the Japanese semiconductor manufacturers, which diverts investment away from Japan

Figure 1
Estimated Worldwide Capital Spending, Merchant and Captive



Source: Dataquest (January 1993)
G3001005

North America

Capital spending in North America also fell in 1992, but only by 8 percent. For 1993, Dataquest expects North American capital spending to be up 13 percent. It will reach $4 billion in 1993, and will continue to increase at a double-digit, or near-double-digit growth rate through 1996. Interesting to note is that spending in Japan outstripped spending in North America during the years 1988 through 1992, but we are forecasting that spending in North America will be larger than that in Japan during the years 1993 through 1996. This is really a piece of good news for the U.S. domestic equipment producers.

However, the growth in capital spending in North America will not be spread evenly across all semiconductor companies in North America, but will heavily depend upon the semiconductor company's product portfolio and end markets for its chips. Companies such as Intel are doing exceptionally well and will make investments accordingly, while companies such as IBM will trail in their capital spending plans, at least in the near term.

Downward pressure on growth of capital spending in North America include the following:

- The decline in investment in North America by Japanese semiconductor manufacturers

- The pursuit by U.S. semiconductor companies of high-value-added niche applications that concentrate on design and the use of overseas foundries to manufacture the chips

Asia/Pacific

The forecast for capital spending in Asia/Pacific remains bright. Although capital spending in Japan, North America, and Europe all decreased in 1992, spending in Asia/Pacific in 1992 still increased a modest 2 percent, despite the cancellation or "push-out" of plans for new fabs in Asia/Pacific. We are forecasting 1993 to be another modest year of 4 percent growth, and 1994 to be up 9 percent. We expect capital spending in Asia/Pacific to kick into 20 percent or so growth rates for 1995 and 1996.

In other areas of Asia/Pacific, Asian governments are targeting the semiconductor industry as a cornerstone of their industrial policy. We expect China, India, Malaysia, and Thailand to win a larger share of the capital spending in the region. In 1991, capital spending in Asia/Pacific accounted for 17 percent of all worldwide semiconductor investment, and will reach 22 percent as soon as 1994. That is, nearly a quarter of all semiconductor equipment will be sold into this region in the near future. Because of the growth opportunities in Asia/Pacific, we expect a lively scramble among the Japanese and U.S. equipment companies to get the business.

Europe

Growth in capital spending in Europe continues to be unexciting. It declined 18 percent in 1991, another 12 percent in 1992, and is forecast to decline 4 percent in 1993. We are forecasting 20 to 30 percent growth for the years 1995 and 1996. However, our forecast for 1995 and 1996 is with much trepidation because there is so much uncertainty surrounding Europe. Capital spending in Europe was surpassed by capital spending in Asia/Pacific in 1988 and today accounts for only about 10 percent of all worldwide semiconductor investment. An interesting perspective is that in 1993 capital spending in Europe will be only $1 billion, which is considerably less than the $1.6 billion that Intel plans to spend in 1993.

If we could succinctly characterize the whole capital spending situation, we would say that the capital spending cycle just concluded was characterized by Japanese company dominance, but that the next phase will be characterized by the emergence of the Asia/Pacific semiconductor industry.

By Joe Grenier

SEMMS-1318019

Mark FitzGerald
Senior Industrial Analyst

300-1264

Internal Distribution

For More Information...

Rick Spence, Industry Analyst .... (408) 437-8642
Via fax .... (408) 437-0292

Dataquest®

a company of The Dun & Bradstreet Corporation

Dataquest®

Semiconductors

Trends in the DRAM Market

MarketTrends

1993

Program: Memories Worldwide
Product Code: MMRY-WW-MT-9302
Publication Date: November 22, 1993

Dataquest®

Semiconductors

Trends in the DRAM Market

MarketTrends

1993

Program: Memories Worldwide
Product Code: MMRY-WW-MT-9302
Publication Date: November 22, 1993

Table of Contents

List of Figures

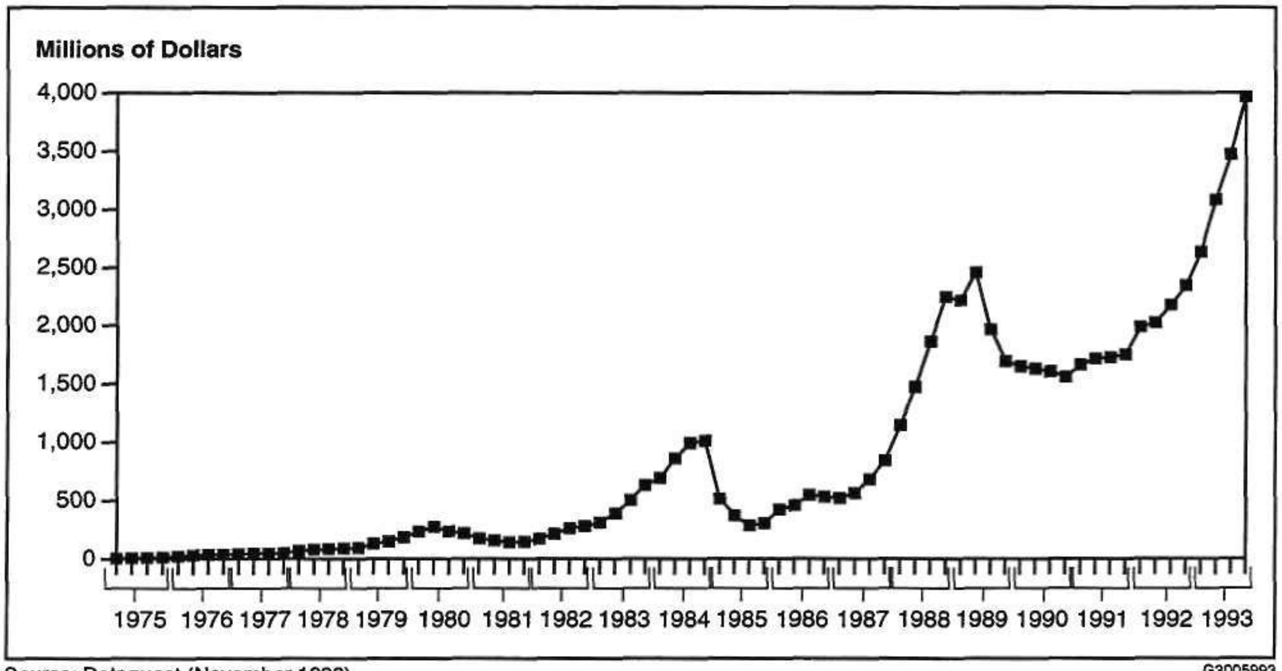
List of Tables

Trends in the DRAM Market

Although the DRAM market is one of the largest semiconductor device markets, it is subject to highly volatile pricing, a need for spiraling capital equipment investment, and cost-based pricing. Only the strong seem to be able to survive the rigors of DRAM manufacture.

Figure 1 shows quarterly worldwide DRAM sales in dollars from 1975 to 1993. This *MarketTrends* report delves into the reasons behind the motions in this chart.

Figure 1
Quarterly DRAM Worldwide Sales: 1975 to 1993



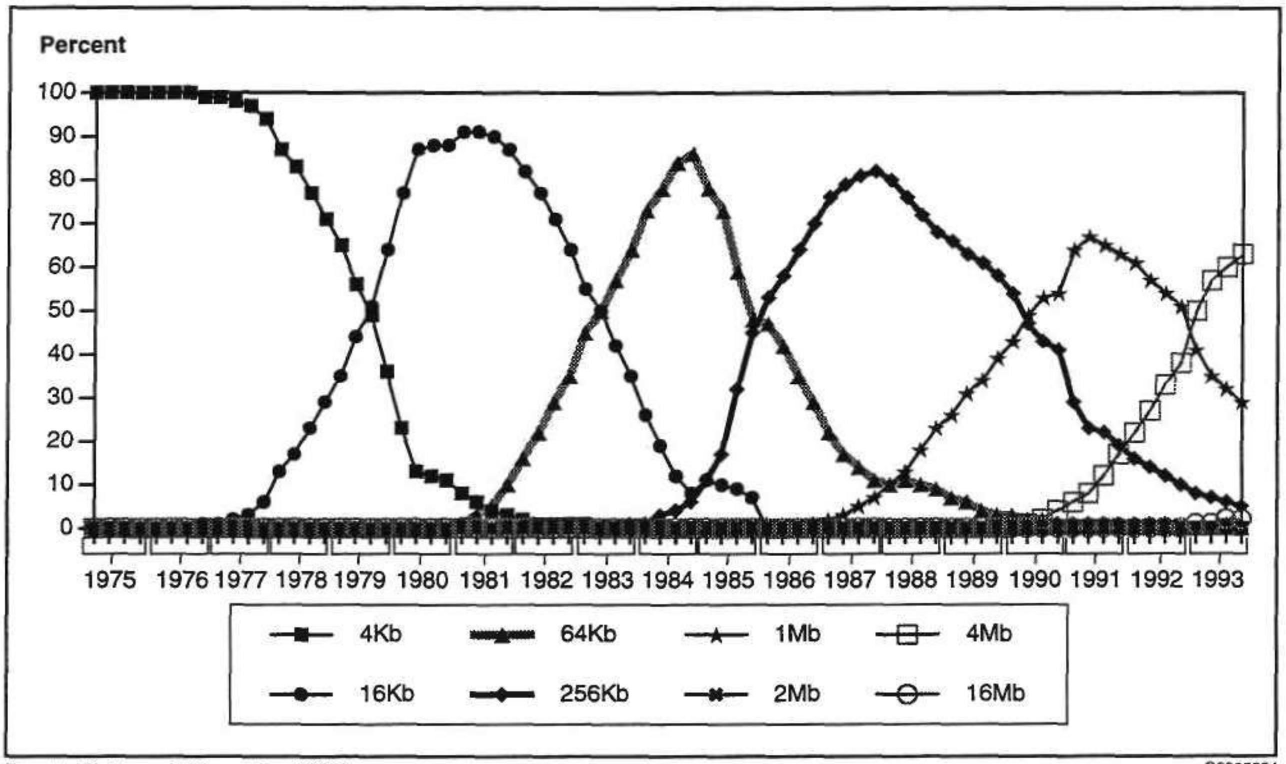
Source: Dataquest (November 1993) G3005993

Business Cycles

DRAMs follow certain highly predictable cycles. Back in the 1970s, Gordon Moore, chairman of Intel Corporation, coined what is now referred to as "Moore's Law." This observation, which holds true to this day, is that the density of memory devices tends to quadruple every three years. Standard DRAM densities are always produced in multiples of four times the preceding density, and Figure 2 illustrates the percentage of overall unit shipments by density for all the quarters that Dataquest has tracked the DRAM market.

The reason that percentages were used for Figure 2, rather than simple units, is that this approach helps remove the distraction of upward and downward trends in the overall market. These fluctuations are a result of the economy, rather than of the technology.

Figure 2
Each DRAM Density as a Percentage of Overall Unit Shipments



Source: Dataquest (November 1993)

G3005994

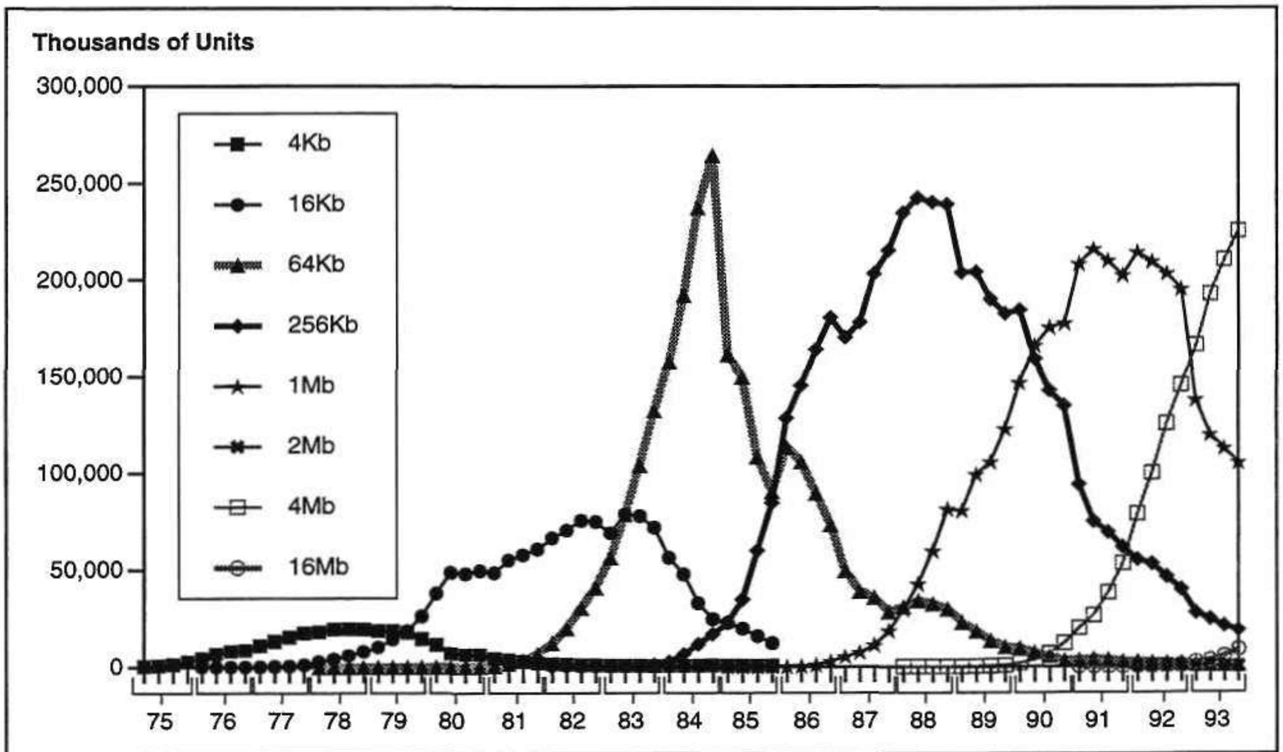
If we look at unit shipments, shown in Figure 3, we see relatively low unit shipments for early generations (4Kb and 16Kb densities) followed by a peak at the 64Kb density in 1984. In fact, the 64Kb DRAM was the first density to ship to a greater-than-250-million-units-per-quarter plateau, which has been nearly maintained by every density since the 64Kb. Peak unit shipments for subsequent DRAM densities have been slipping only slightly ever since. Dataquest believes that this trend is likely to repeat itself throughout the foreseeable future.

The phenomenal peak in 64Kb shipments coincides with the general acceptance of personal computers, systems that are far more important to the DRAM market than were previous generations of computers. Dataquest estimates that 63 percent of all DRAM revenue comes from the personal computer market.

The personal computer brought the DRAM into consumer applications, a fact that pops out when annual bit growth of DRAM and SRAM are superimposed (see Figure 4). DRAM and SRAM bit growth are not at all interrelated until 1985, when they fall into step with each other. SRAMs have always found a large percentage of applications in end-user types of equipment, devices that tend to follow consumer spending patterns to a large degree.

Figure 5 shows a third view of the unit shipment by density data. This figure shows the crossover from one generation of DRAM to the next, and

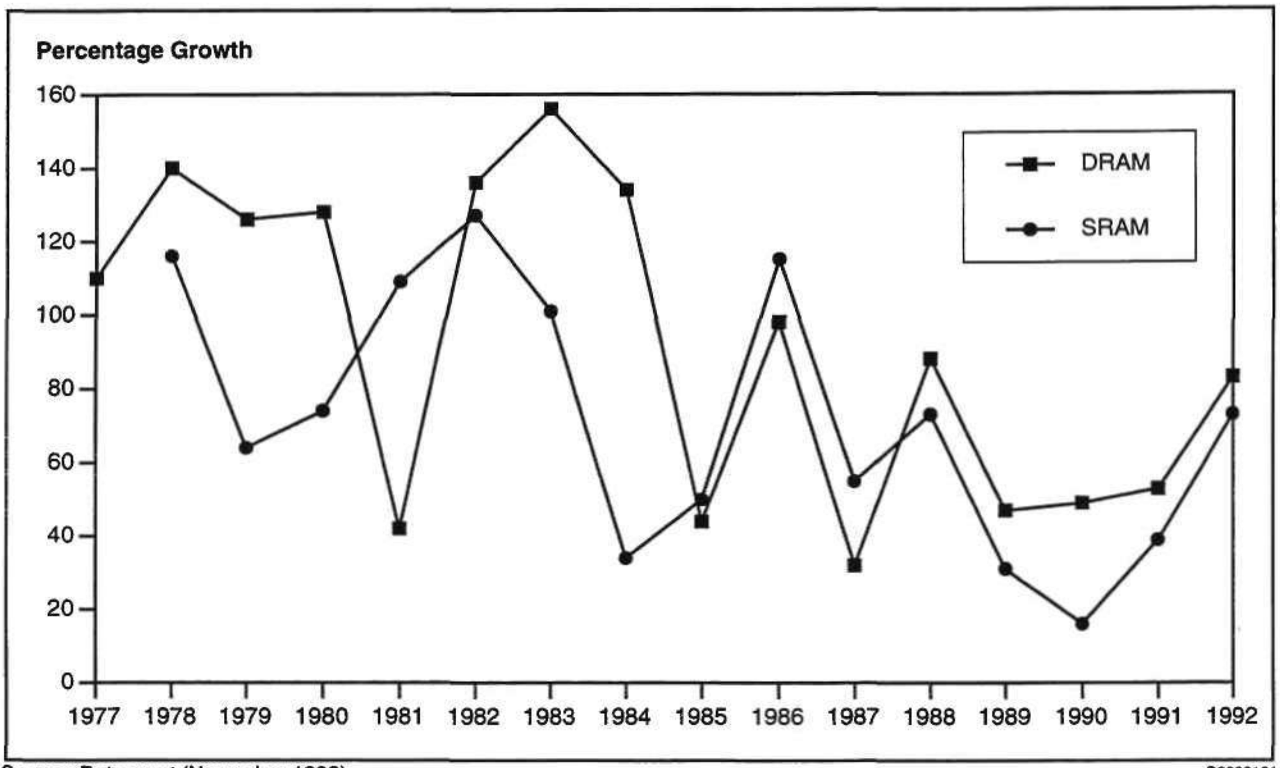
Figure 3
DRAM Quarterly Worldwide Unit Shipments by Density



Source: Dataquest (November 1993)

G3005995

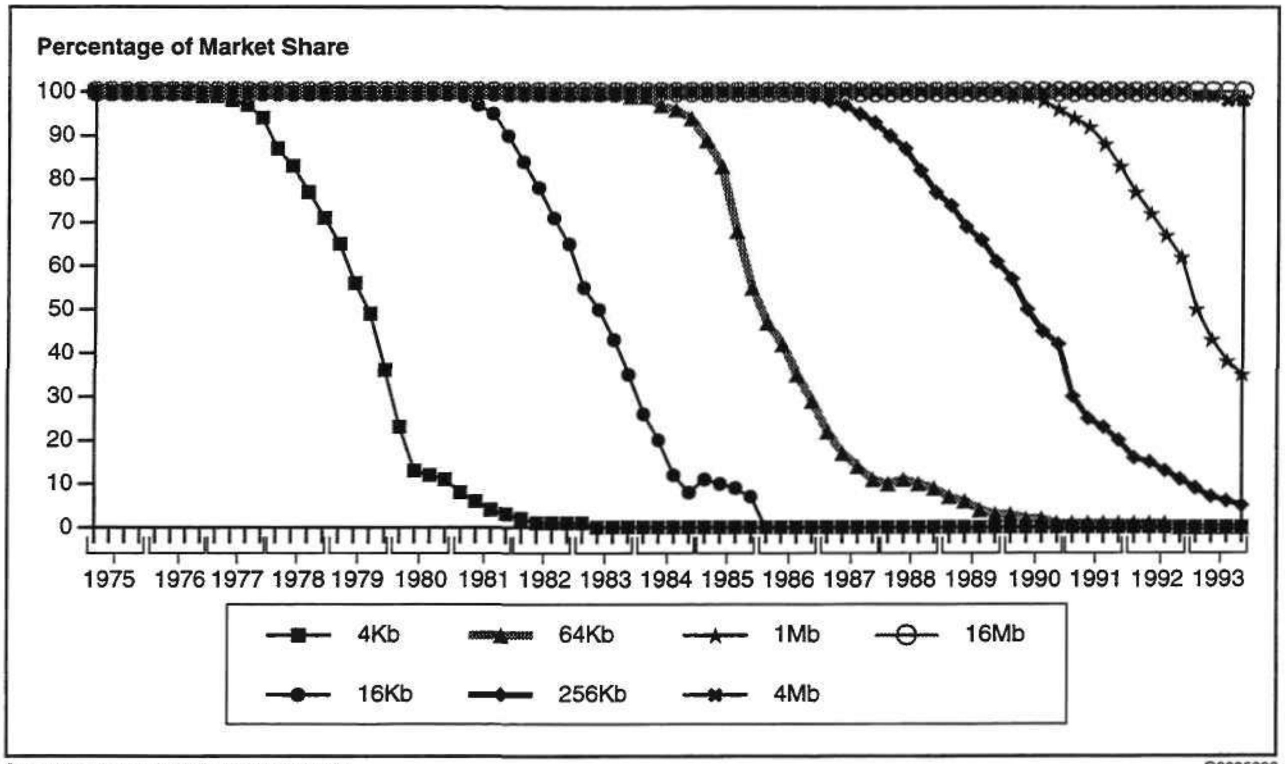
Figure 4
Bit Growth Rate: DRAM and Slow SRAM



Source: Dataquest (November 1993)

G3002181

Figure 5
Percentage of DRAM Unit Shipments by Density



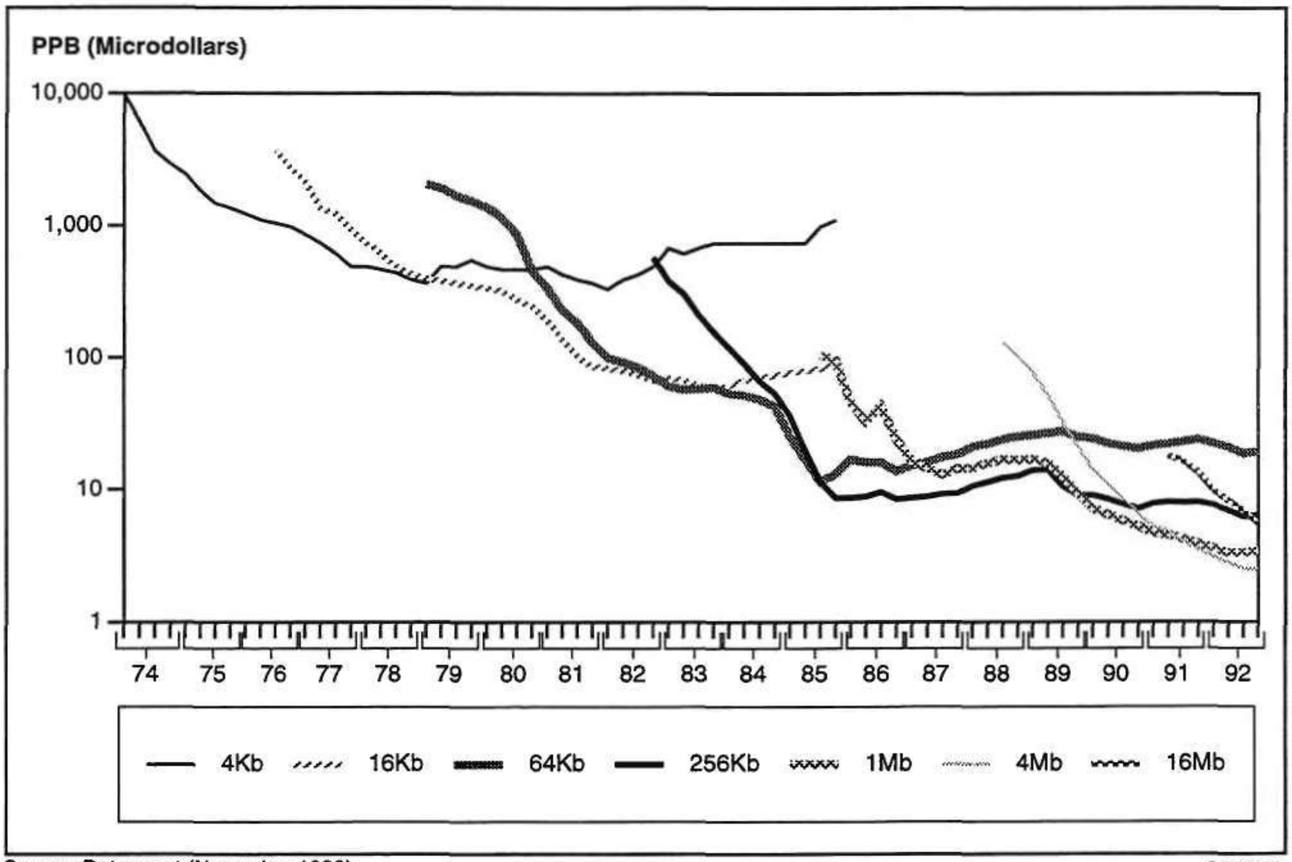
Source: Dataquest (November 1993)

confirms the lack in the DRAM market of the substantial overlap in densities seen in other memory markets such as SRAM and nonvolatile memories. There are never appreciable shipments of three densities of DRAM at the same time. Crossovers from one density to the next are very certain and extremely orderly. This trend is also expected to continue into the foreseeable future.

Possibly the most-watched parameter in the realm of DRAM statistics is the crossover in price per bit (PPB) from one DRAM density to the next. System designers use this parameter as a gauge to decide when designs using the next density should be put into production. Figure 6 shows historical PPB crossovers for all densities of DRAMs. The curves in this figure represent PPB for each density of DRAM.

Another telling curve is the PPB learning curve shown in Figure 7, which shows the PPB in comparison to the cumulative bit shipments of DRAMs. Dataquest has found that this relationship is strong enough that it can be used to help forecast pricing of future generations of DRAMs. The trend is relatively solid, with fluctuations largely attributable to shortages and subsequent upward price movement. In times of oversupply, PPB follows the cost of manufacture. This is supported by the scatter chart in Figure 8, which plots quarter-to-quarter growth in bit shipments against quarter-to-quarter growth in DRAM revenue. These follow a marked trend. Historical trends of bit growth and revenue growth are superimposed in Figure 9.

Figure 6
Historical PPB Crossovers, All DRAM Densities



Source: Dataquest (November 1993)
G3005997

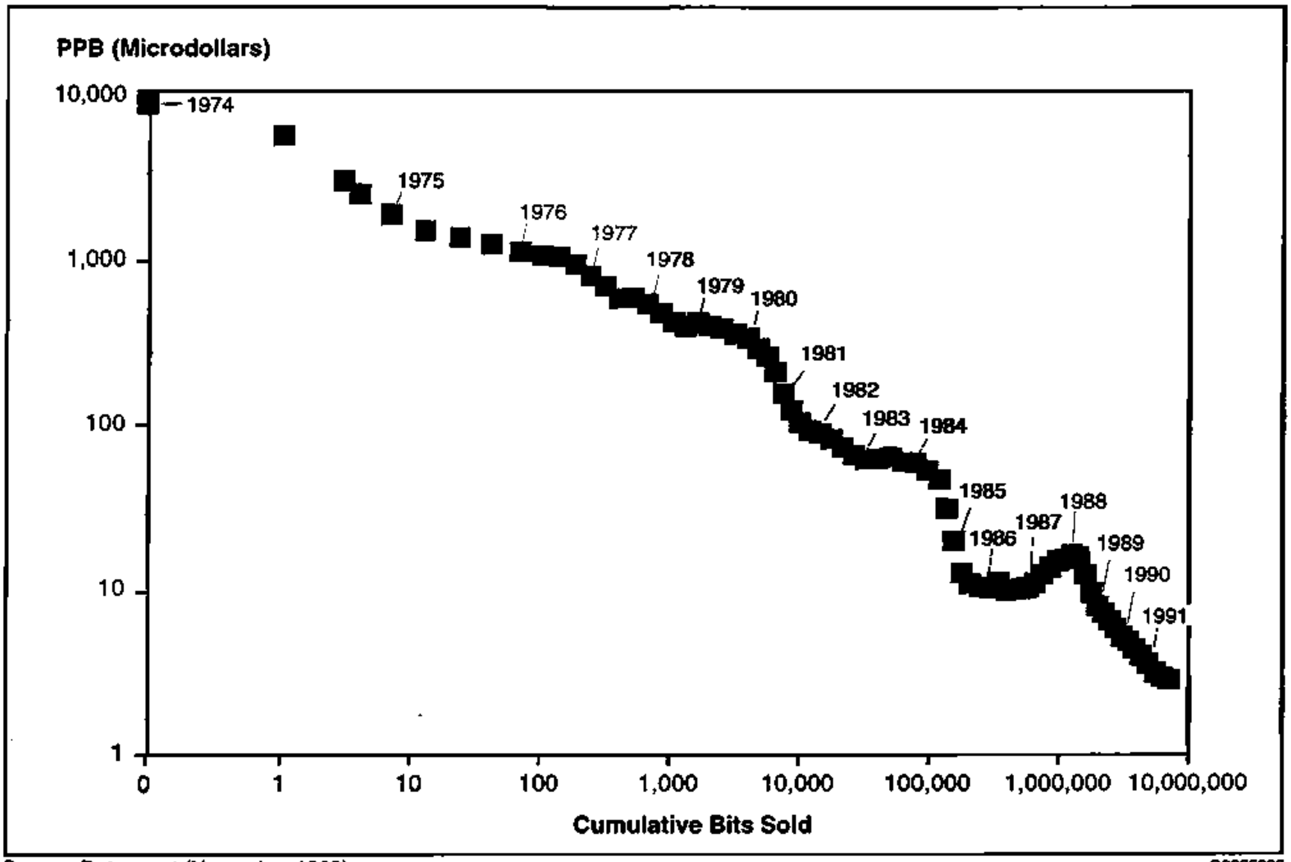
Technology Trends

DRAMs are consistently being manufactured using shrinking process geometries. Table 1 compares the processes Dataquest expects to be used for the bulk of different generations of DRAMs. Along with these process shrinks come various technology difficulties that, although initially hard to master, are eventually overcome in time to allow the natural progression of densities to continue without significant impediment.

As the industry continues to push into the submicron era, process complexity and fabrication technology requirements continue to increase dramatically. Lithography, deposition, and etch/clean equipment continue to be the technology drivers that fuel the wafer fabrication equipment industry's growth.

Dataquest expects i-line technology to dominate the stepper product mix for new system shipments from 1991 to 1996. I-line will be the stepper technology of choice as advanced microprocessor and ASIC designs push below 0.8-micron geometries. Advanced resolution techniques, such as phase-shift masks and newly announced illumination modification techniques, push i-line resolution to the 0.35-micron regime with improved

Figure 7
PPB Learning Curve



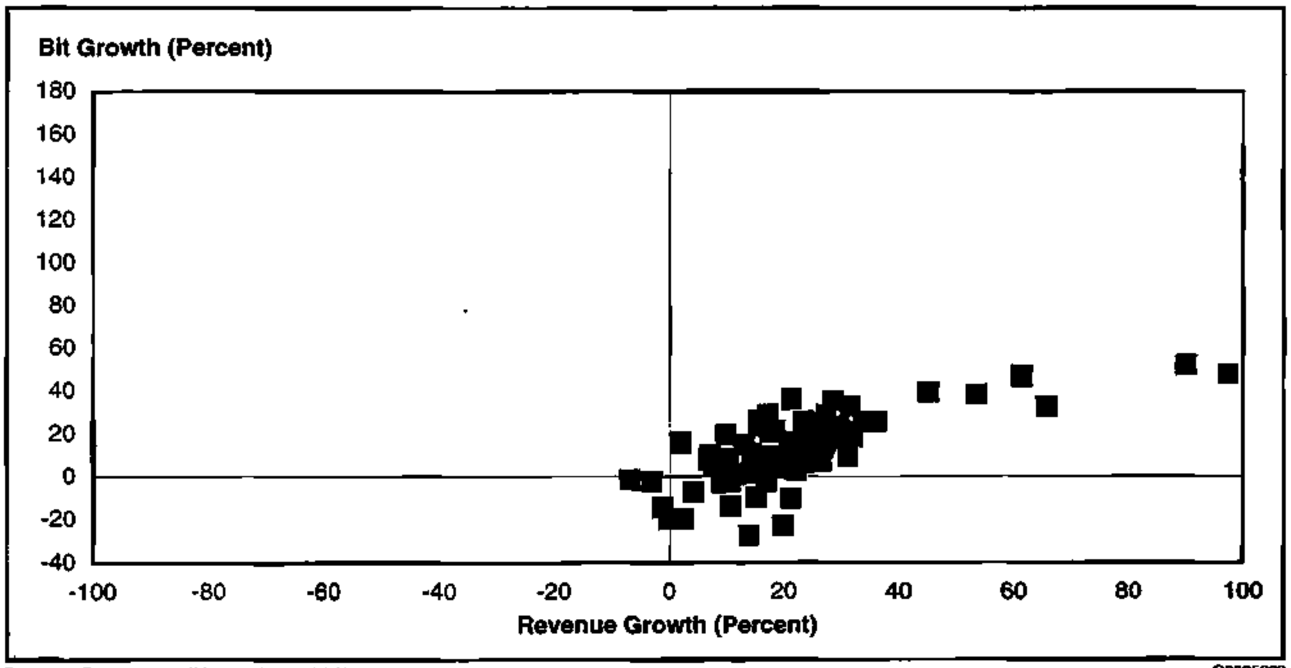
Source: Dataquest (November 1993) G3005998

depth of focus. Although such techniques are suited only for highly repetitive device patterns such as DRAMs, conventional i-line lens systems are available that provide sub-0.5-micron lithographic capability regardless of the device pattern being printed. We expect excimer/deep-UV systems to continue to gradually increase as a percentage of new stepper shipments through 1997 as device manufacturers pursue R&D programs for 64Mb and 256Mb DRAM processing.

The adoption of double-level metal technology for the 16Mb DRAM generation, together with the rapid move toward three-level and even four-level metal for MOS microprocessor and ASIC devices, will continue to push the CVD, PVD, and dry etch thin films technology to outstrip progress in the overall wafer fab equipment technology. Dry etch equipment will be used more and more because of the increased number of process etch steps, complex new plasma source technologies, and the need for tighter process control at sub-0.5-micron geometries.

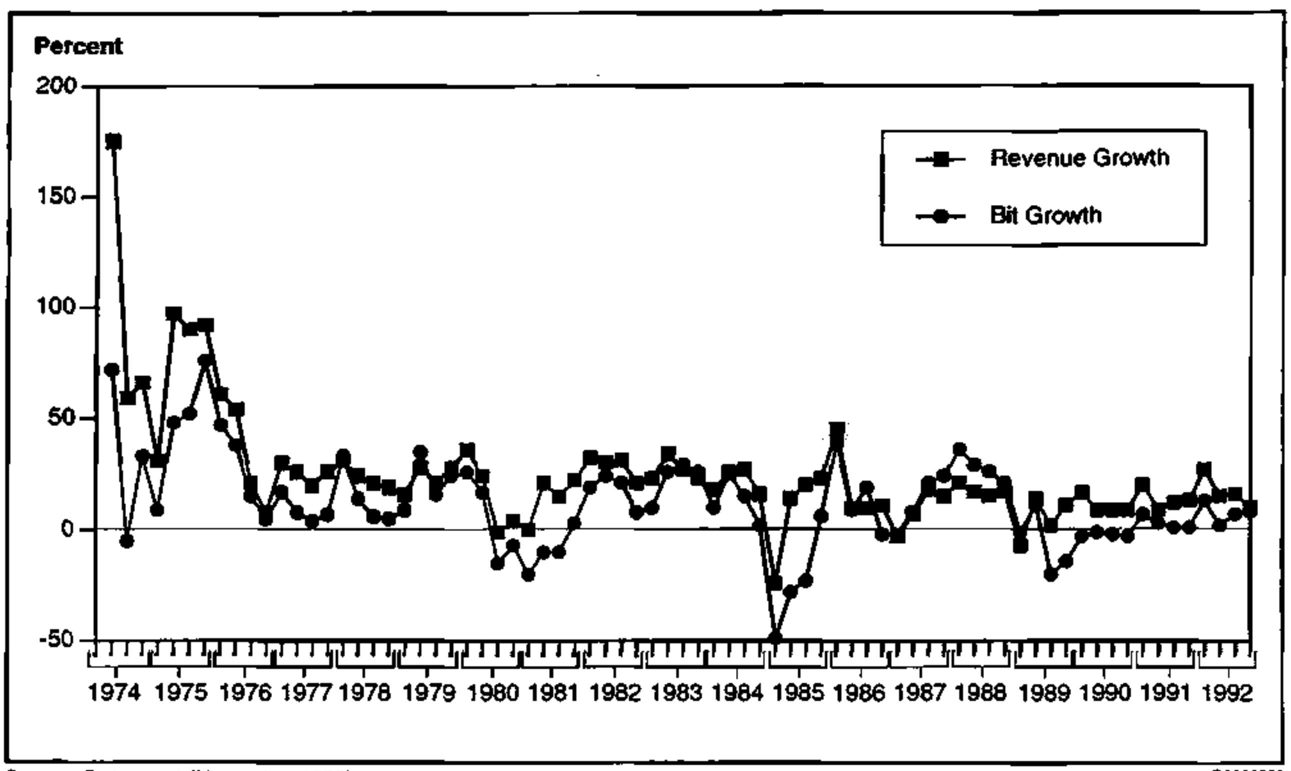
In addition to the well-established low temperature, plasma-enhanced CVD reactor methods, thermal CVD methods (including metal CVD and thermally driven atmospheric and low-pressure CVD) will experience

Figure 8
Revenue Growth versus Bit Growth



Source: Dataquest (November 1993) G3005999

Figure 9
DRAM Quarterly Revenue Growth and Bit Growth



Source: Dataquest (November 1993) G3006000

Table 1
Design Rules Expected for Production of Various DRAM Densities

Density (Mb)	Design Rules (µm)	Die Size (mm^2)
16	0.45 to 0.5	100 to 105
64	0.3	150 to 155
256	0.2	200

Source: Dataquest (November 1993)

increased adoption during the next five years because of a growing need for planarized device topologies. New organic CVD precursor sources will lead to precisely tailored metal and dielectric CVD films that exactly satisfy specific device topology requirements. Concurrently, new advances in PVD technology such as advanced barrier metallization, laser reflow, and planarization of sputtered aluminum will lend impetus to increased use of PVD equipment. Sputter equipment will continue to be widely used because of its excellent step coverage capability at a very attractive cost of ownership.

Not only does the equipment change substantially over time, but the techniques to get the absolute most from a given linewidth become more sophisticated simultaneously, enhancing the ability to squeeze more bits onto a given die area. When DRAM cells needed to shrink to a level where the size of a silicon dioxide capacitor would limit the device's ability to hold bits for the duration of an entire refresh cycle, the trench capacitor was devised, and a large capacitor was folded into the sides of a much smaller trench. When the silicon dioxide trench ran out of steam, the stacked nitride capacitor was conceived. It appears likely that, when the stacked nitride capacitor becomes too small, DRAM manufacturers intend to use ferroelectrics as the dielectric in the capacitor for each bit.

Capital Investment Trends

To support the development of the technologies just mentioned, DRAM manufacturers must continually purchase equipment that did not even exist for the prior generation of product. Also, because the DRAM market is cost-driven, with cost-based pricing and strong competition, competitors continually try to assure that they use a process that affords them more economies of scale than that used by their competitors. Wafer fabrication plants must be continually updated, or new ones must be built to support newer, more aggressive line geometries.

Some recent economic events that have put an unfamiliar twist on the way that plant upgrades have been approached are as follows:

- The 1991 recession in most of the world put Japanese DRAM vendors in a difficult position. Any capacity additions in anticipation of an upturn, or for use in next-generation products, would be counted against these companies' current revenue in the computation of fair-market-value sales into the United States. This not only postponed these manufacturers' ability to migrate rapidly to the 16Mb density, but it also caused the U.S.- and Japan-based semiconductor capital equipment markets' first-ever quarterly shrink in semiconductor capital equipment shipments.

- Current economic woes in Japan not only make it very difficult to add capacity because of the unavailability of investment capital, but have also led Japanese managers to doubt the strength of the recovery in the rest of the world, causing them to add capacity in tiny increments only when it is absolutely necessary.
- The conversion rate from U.S. dollars to yen has decreased significantly during the last year, removing most of the benefits of the sizable growth in the North American DRAM market from the yen-based revenue figures of Japanese DRAM manufacturers. In other words, the fact that the North American DRAM market has grown is largely lost to Japan-based manufacturers.

Add the recent antidumping duties leveled by the U.S. Department of Commerce (DOC) against Korean companies, and their response of rerouting their capital additions to other less-cost-sensitive products such as SRAMs, and the overall picture is one of capacity to meet, but never to exceed demand.

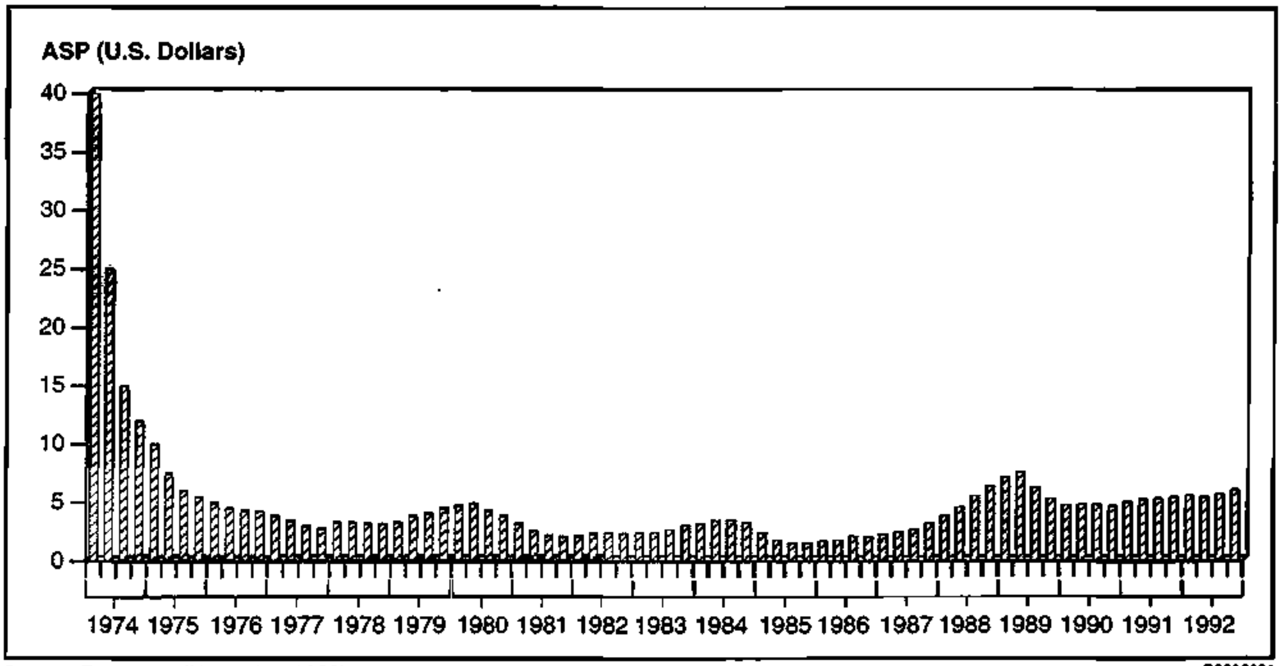
Still, all participants in the DRAM market expect to continue to make capital additions to support the next generation of business. There is almost a three-to-one difference between the average cost of a state-of-the-art 1Mb fab in the past and expected costs of a 64Mb fab in the future. These spiraling costs are not expected to be entirely offset by equivalent economies of production, so the net expectation is that the average selling prices (ASPs) of DRAMs must rise to cover the difference. Figure 10 shows the trend of historical DRAM ASPs; ASPs are seen to have leveled off to a relatively stable level since the mid-1970s.

Another indicator of the financial side of the DRAM market is the index of capital in play (CIP). This index is a function of the amount of capital being used to produce DRAMs (see Figure 11). The enormous growth in capital expenditure is evident, but the payoff is revealed when the CIP is plotted against the logarithm of DRAM bits shipped per year (see Figure 12). The trend in this figure is very close to a straight line, indicating that the ability to produce DRAMs is closely linked to the manufacturers' commitment in capital.

DRAMs and International Trade

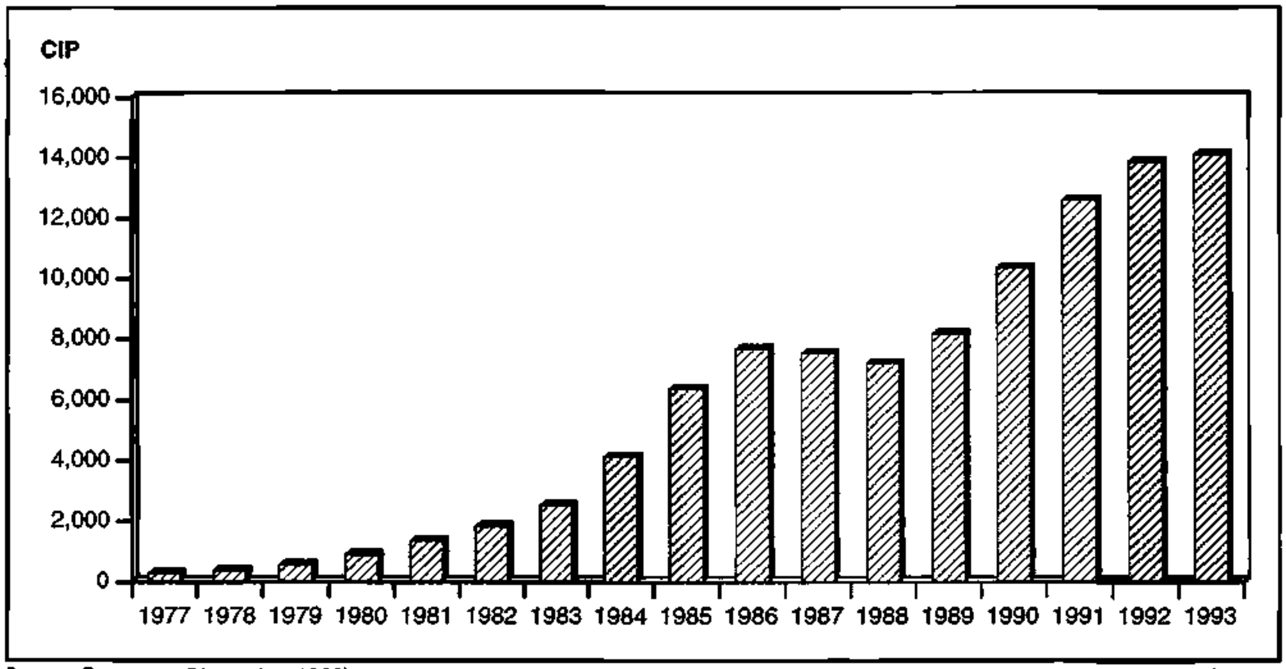
The high volume of sales and the Far Eastern makeup of the majority of DRAM vendors combine to make the market the focus of much international diplomacy. Partnerships are formed to manufacture DRAMs, like those pioneered between Motorola and Toshiba, IBM and Siemens, and GoldStar and Hitachi. Foreign plants are established to try to rectify balance of trade disagreements—fabs such as NEC's Roseville, California plant, and Fujitsu's Gresham, Oregon plant, which has recently been

Figure 10
Overall DRAM ASPs, Independent of Density



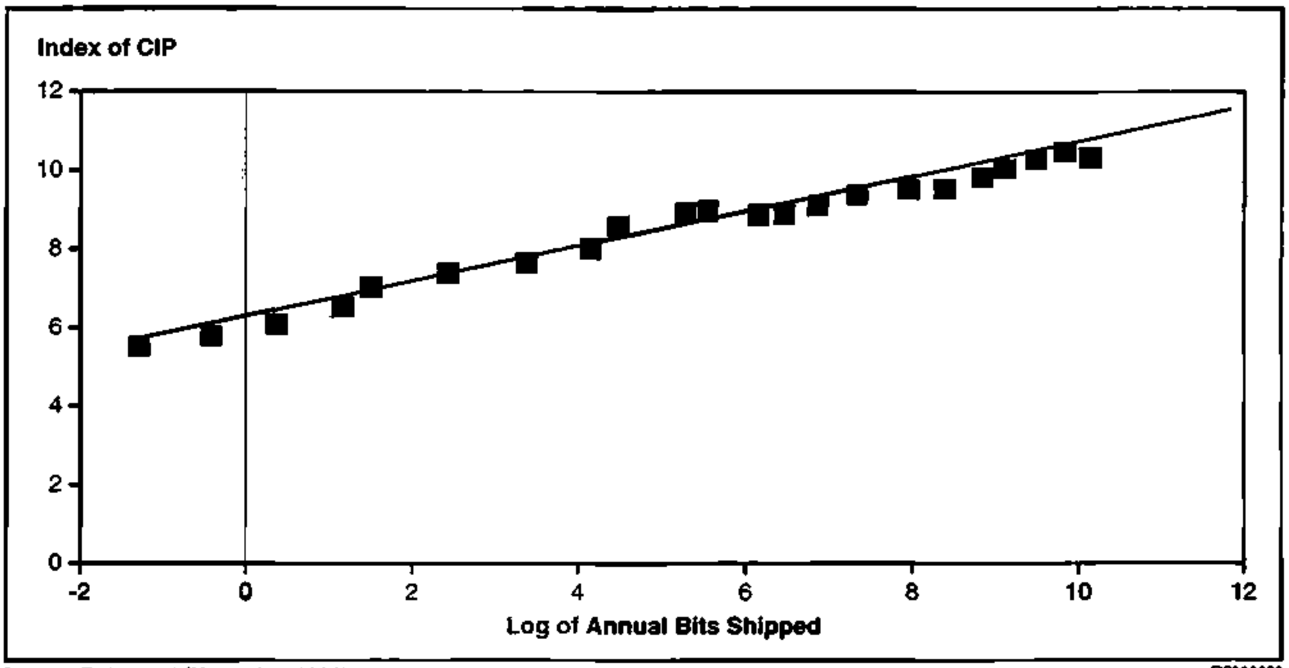
Source: Dataquest (November 1993) G3006001

Figure 11
Estimated CIP: 1977 to 1993



Source: Dataquest (November 1993) G3006002

Figure 12
CIP and DRAM Bits Shipped: 1978 to 1993



Source: Dataquest (November 1993) G3006003

partially leased to Hyundai to allow onshore manufacture of DRAMs for the United States market.

Sometimes intellectual property is part of the bargain when such alliances are put together. The DRAM market is perhaps second in stature to the microprocessor market in the zeal with which intellectual property issues are pursued. Texas Instruments is reputed to be the strongest holder of DRAM patents and has realized significant revenue ($168 million in the last quarter) simply from licensing its technology to its competitors.

Costs in the market are sensitive to international sales, and dumping becomes an issue. A dumping suit was filed against Japanese DRAM manufacturers eight years ago, and more recently a European Community dumping suit was initiated against Korean DRAM manufacturers. In May 1992, Micron Technology filed dumping charges with the U.S. DOC against three Korean DRAM manufacturers. Micron alleged that these sources were selling DRAMs in the United States below their cost of manufacture, because Micron believed that its own cost of manufacturing was the lowest in the world. The cost calculations used by the DOC include an 8 percent profit. So, Micron's complaint that began this process last May has proven that technically, between November 1, 1991 and April 30, 1992, Samsung and all other Korean suppliers sold DRAMs at only a small profit. Table 2 shows the initial and final dumping penalties leveled against Korea's DRAM manufacturers.

Table 2
Dumping Penalties (Percentage of Sales)

Company	Final	Preliminary	1992 U.S. DRAM Market Share
Samsung	0.820	87.40	14.4
Goldstar	4.975	52.41	6.3
Hyundai	11.450	5.99	5.3
Other Korean Suppliers	3.890	61.88	-

Source: Dataquest (November 1993)

The impact on the overall market of this duty will historically be seen as a nonevent. The penalty findings of the DOC will not appreciably affect DRAM supplies, availability, or pricing in the U.S. market. In May 1994, the DOC will review shipment and cost data from the November 1992 to December 1993 time frame to reassess any potential dumping activities of the major Korean DRAM suppliers.

Application Trends

DRAMs are easy enough to find. With certain very minor exceptions, all are used as either main memory or screen memory in data processing systems that use magnetic media for mass storage. This puts them into all computing systems, from corporate supercomputers down to laptop computers, but excludes them from being used for PCMCIA-based personal digital assistants.

The following sections describe Dataquest's view of the direction these systems are taking.

System Shipments

Table 3 shows data processing unit shipments worldwide. The figures are Dataquest's shipments estimates from 1990 to 1992, and our forecast from 1993 to 1997. We expect growth in all categories, with the exception of the mainframe computer, which is expected to decline at an average rate of 4.1 percent during the next five years.

Memory per System

Table 4 shows Dataquest's estimates of the amount of DRAM in megabytes to be expected to ship with each computer. These follow the typical rise of a doubling every three years. To determine overall DRAM usage, the data in Table 4 can be multiplied by the system sales in Table 3.

Table 3
Data Processing Unit Shipments Forecast by Product Segment (Units)

Historical			1990	1991	1992	CAGR (%) 1990-1992
Supercomputer			1,000	1,013	1,074	3.6
Mainframe			15,131	13,587	9,434	-21.0
Midrange			718,683	695,641	545,658	-12.9
Workstation			407,624	527,551	584,544	19.8
Personal Computer			23,738,460	27,264,999	32,406,879	16.8
Total			24,880,898	28,502,791	33,547,589	16.1
Projected	**1993**	**1994**	**1995**	**1996**	**1997**	**CAGR (%) 1993-1997**
Supercomputer	1,217	1,409	1,615	1,829	2,050	13.8
Mainframe	9,023	8,729	8,432	8,113	7,650	-4.1
Midrange	554,709	591,064	623,164	642,563	655,000	3.7
Workstation	622,165	679,320	776,040	865,945	978,585	10.9
Personal Computer	37,869,000	44,006,000	50,906,000	57,774,000	65,480,000	15.1
Total	39,056,115	45,286,522	52,315,251	59,292,450	67,123,285	14.9

Source: Dataquest (May 1993)

Table 4
Main Memory Size in Megabytes per System

Historical			1990	1991	1992	CAGR (%) 1990-1992
Supercomputer			1,600	3,000	3,700	52
Mainframe			350	512	768	48
Midrange			20	25	32	26
Workstation			20	20	28	18
Personal Computer			1.8	3.2	5.6	32
Projected	**1993**	**1994**	**1995**	**1996**	**1997**	**CAGR (%) 1993-1997**
Supercomputer	5,500	7,000	9,000	11,500	14,000	26
Mainframe	1,024	1,400	1,800	2,500	3,600	37
Midrange	40	50	60	70	80	19
Workstation	34	43	52	61	68	19
Personal Computer	7.9	12.5	13.0	16.4	19.0	25

Source: Dataquest (November 1993)

Dataquest Perspective

The DRAM market is poised for continued growth, only to be enjoyed by those willing to make a high level of expenditure in return for participation in a tight margin scenario. Although the technology exists and is understood to maintain business cycles that have become customary, the equipment required to compete is expensive and is moving in the direction of becoming prohibitive.

There is healthy growth in the markets that drives DRAM usage, and Dataquest expects to see the market evolve without much change from the path it has taken in the past 19 years.

For More Information...

Jim Handy, Senior Industry Analyst .... (408) 437-8228
Via fax .... (408) 437-0292

Dataquest®
a company of The Dun & Bradstreet Corporation

Dataquest®

a company of The Dun & Bradstreet Corporation

Corporate Headquarters
Dataquest Incorporated
1290 Ridder Park Drive
San Jose, California 95131-2398
United States
Phone: 01-408-437-8000
Facsimile: 01-408-437-0292

Dataquest Incorporated
550 Cochituate Road
Framingham, Massachusetts 01701-9324
United States
Phone: 01-508-370-5555
Facsimile: 01-508-370-6262

Invitational Computer Conferences (ICC)
3990 Westerly Place, Suite 100
Newport Beach, California 92660
United States
Phone: (714) 476-9117
Facsimile: (714) 476-9969

Dataquest Japan Limited
Shinkawa Sanko Building
1-3-17, Shinkawa, Chuo-ku
Tokyo 104
Japan
Phone: 81-3-5566-0411
Facsimile: 81-3-5566-0425

Dataquest Korea
Trade Tower, Suite 3806
159 Samsung-dong
Kangnam-gu, Seoul 135-729
Korea
Phone: 011-82-2-551-1331
Facsimile: 011-82-2-551-1330

European Headquarters
Dataquest Europe Limited
Roussel House, Broadwater Park
Denham, Uxbridge
Middlesex UB9 5HP
England
Phone: 44-895-835050
Facsimile: 44-895-835260/1

Dataquest GmbH
Kronstadter Strasse 9
8000 Munich 80
Germany
Phone: 011-49-89-930-9090
Facsimile: 011-49-89-930-3277

Dataquest Europe SA
Tour Gallieni 2
36, Avenue du General de Gaulle
93175 Bagnolet Cedex
France
Phone: 011-33-1-48-97-3100
Facsimile: 011-33-1-48-97-3400

Representative Agencies in
Bangkok, Hong Kong,
Kronberg, North Sydney,
Singapore, Taipei, and Tel Aviv

0015391

Dataquest®

Semiconductors

DSP—A Market View

Focus Report

1993

Program: Semiconductors Worldwide
Product Code: SEMI-WW-FR-9302
Publication Date: December 13, 1993

Dataquest®

Semiconductors

DSP—A Market View

Focus Report

1993

Program: Semiconductors Worldwide
Product Code: SEMI-WW-FR-9302
Publication Date: December 13, 1993

Table of Contents

List of Figures

List of Tables

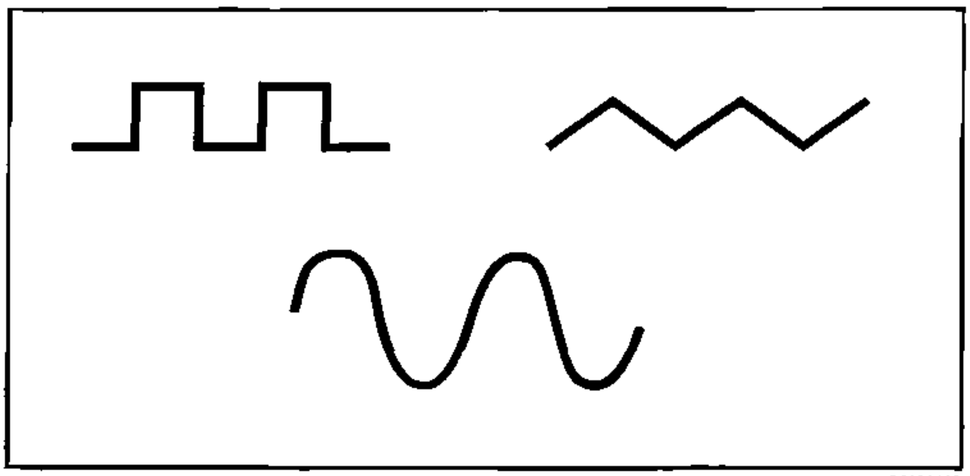
Chapter 1
Signal Processing Overview

Signal processing is an important segment of electronics that has to do with audio, visual, and other physical occurrence information rather than the numeric data that has dominated the information processing market. Because signals originate in physical phenomena, signals are characterized as being in "real time," having an immediacy that numeric information does not have. For example, audio cannot be processed at any speed other than the rate at which it occurs, without serious degradation, nor can portions be readily thrown out to reduce this real-time demand without complex algorithms such as those found in Motion Pictures Electronic Group (MPEG) audio.

In electronics, signals are represented by the electrical analogs of current, voltage, impedance, or frequency. These electrical analogs are capable of taking on a continuous range of values, analogous to the phenomena they represent. It is important to realize that they do not have to be time-varying. An electrical analog of the altitude of Denver will show little change in time, but it remains an analog signal nonetheless.

Figure 1-1 shows three electrical signals. Some may misinterpret the square wave as being "digital" because the amplitude is constrained to two states (binary), but this happens to be a signal where the information is carried in an analog format of frequency or duty cycle; the binary amplitude format merely acts as a carrier. This raises the issue of what constitutes analog or digital. For an electrical "signal" to be digital, it must carry numeric information, because digital is the domain of numbers. This numeric data is encoded when transmitted in a two-wire binary pulse code modulation (PCM) system.

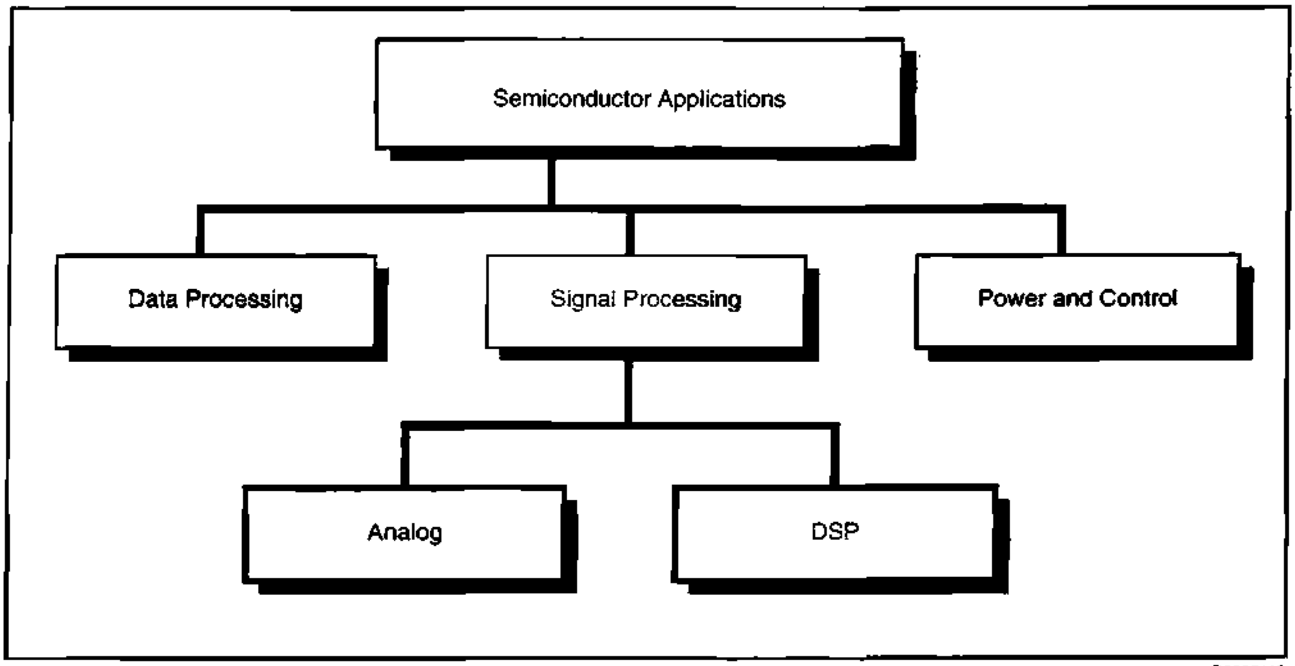
Figure 1-1
Representative Signals



Source: Dataquest (December 1993) G3006109

Signal processing is one of the three major groupings of semiconductor applications (see Figure 1-2). The issue for this *Focus Report* is the split of signal processing, which began more than a decade ago, into the two categories of analog signal processing (ASP) and digital signal processing (DSP).

Figure 1-2
Major Semiconductor Application Groups

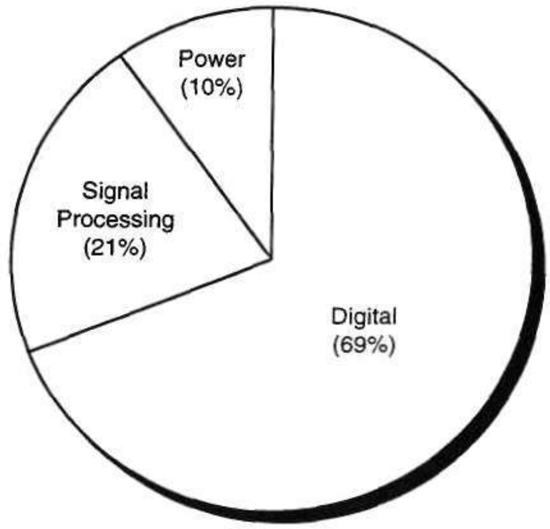


Source: Dataquest (December 1993) G3006110

Signal processing applications accounted for 21 percent of semiconductor revenue in 1992 (see Figure 1-3). The growth in data processing during the past four decades has fueled much of the growth in semiconductors and has made data processing digital applications predominant.

The calculating power of microcomponents and storage capability of memory ICs is moving beyond mere number-crunching into the realm of human and environmental interface. Many traditionally analog signal processing applications such as consumer audio, video, and telecommunications are jumping on the digital bandwagon, adding digital processing power to signal processing systems. Also, signal processing systems for audio, video, speech recognition, and pen-based inputs are being added to traditionally "digital" products such as personal computers. In fact, digital computers have always used signal processing in their mass storage components where the stored parameter is a magnetic "signal."

Figure 1-3
1992 Semiconductor Revenue by Use



Source: Dataquest (December 1993)

G3006111

Signal Processing—A Brief History

Signal processing began in 1876 as Alexander Graham Bell developed a telephone using the idea of "undulatory" currents, which were analog signals that carried the range of human vocal frequencies. This was a breakthrough in communications that overwhelmed the "digital" method of communications involved in the Morse code telegraphy scheme. Analog signal voice communications eliminated the middlemen (human encoders/decoders) and offered the privacy and human qualities that coded messages did not. Also, elimination of the need for a specialized encoder/decoder function meant that telecommunications could move into the home. Digitally encoded communications are as old as human history—American patriot Paul Revere's "one if by land, two if by sea" code for the arrival of the British forces in 1776 is one of the more famous examples. The "ON-OFF" encoding of electricity was an obvious use when electrical circuits were first implemented. Electrical signals provided a major technology leap in the flow of information, highlights of which are in Table 1-1.

Table 1-1
Highlights in Signal Processing History

1838	Morse code telegraphy begins
1876	Age of signals begins (Bell's undulatory currents)
1906	Analog modulation of radio
1922	Electronic phonograph recording
1925	TV experiments
1951	First Univac sold (not a signal processing event but one that will eventually have enormous repercussions)
1977	"Digital audio processor" IC (Rockwell)
1978	Texas Instruments (TI) offers "Speak and Spell" product
1982	Texas Instruments offers first programmable DSP
1982	Telecom T1 equipment available commercially
1984	Compact disc arrives

Source: Dataquest (December 1993)

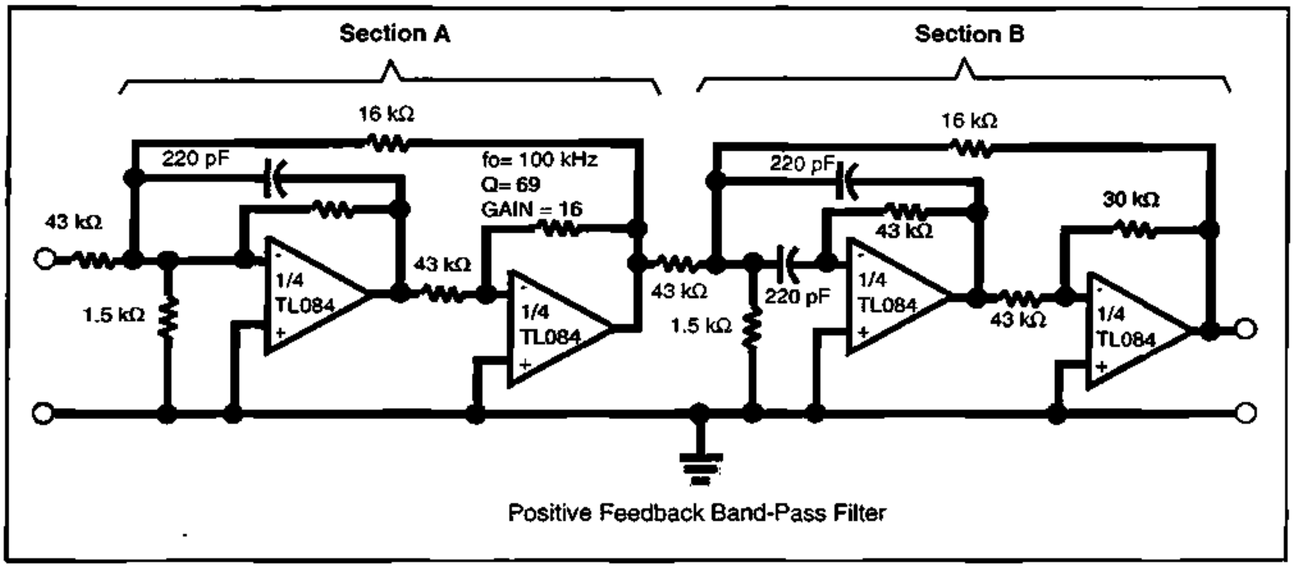
ASP enjoyed a century of dominance from 1876 to the mid-1970s when DSP emerged from the laboratory into commercially available products. Outside of the PCM transmission in the telephone T1 system, digital encoding, processing, and transmission of signals did not catch on greatly until the late 1980s. The first driving force was the appearance and subsequent rapid growth of digital audio as embodied in the compact disc (CD) format. The other driving forces were at the component and software level, as the DSPs became much less expensive and libraries of algorithms became available.

What Is DSP?

Just as data conversion is a technique (although there are dedicated data converter ICs), DSP is a technique and not specifically an IC family. DSP is a technique in which signals that originated in analog form are converted into a digital format and processed within the digital domain. Figure 1-4 shows a typical ASP function, a filter. The important point is that analog circuit diagrams invariably show the signal in transition, from left to right, input to output, suggesting time as a dimension on the x axis. Analog processing is not limited to a single signal flow path, but can have multiple analog functions doing processing in a parallel configuration. One problem with this ASP function is that it is hard-wired to do a specific function. To change its function, wiring would have to be altered and different analog functional blocks may have to be introduced.

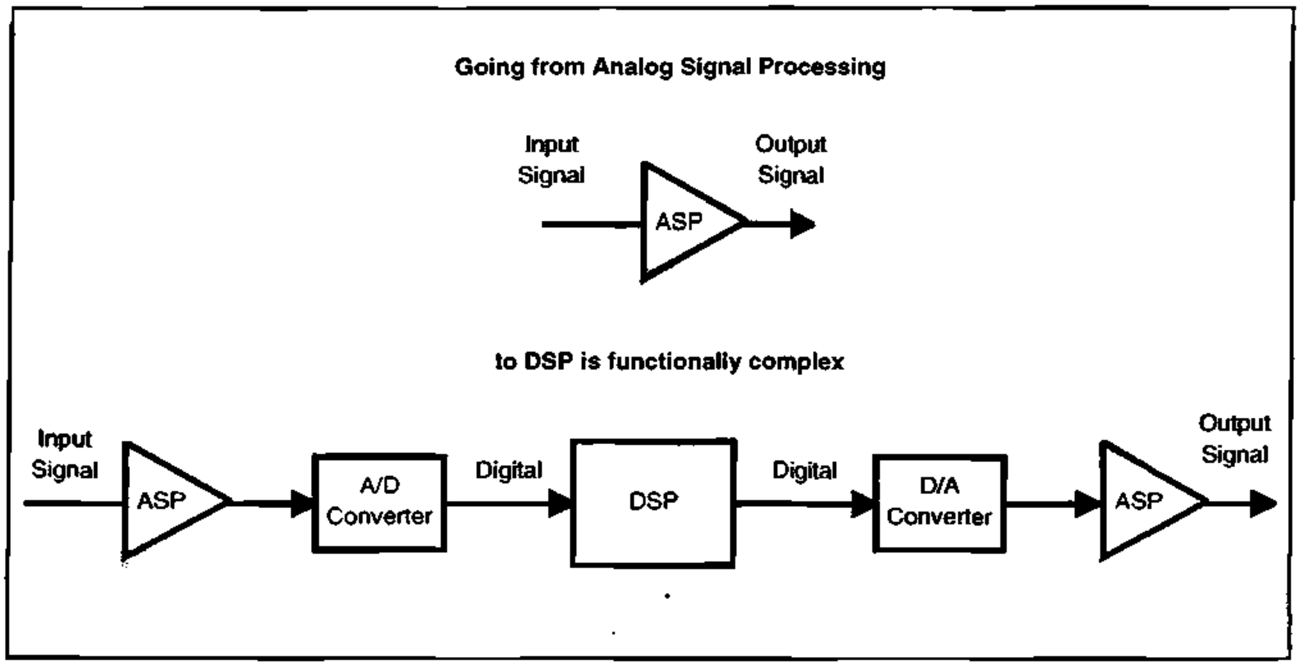
Figure 1-5 looks at signal processing in a block diagram format but retains the left-in, right-out time flow. In this case we have reduced an ASP function to a signal block for simplicity. This is contrasted with the DSP version, where the signal must traverse a variety of formats and conversions before it emerges at the output. ASP is still needed in a DSP system to match the amplitude and impedance interfaces at both the input and output as well as to provide some additional processing.

Figure 1-4
Analog Signal Processing Circuit Schematic



Source: Texas Instruments G3006112

Figure 1-5
Signal Processing—ASP and DSP



Source: Dataquest (December 1993) G3006113

This view of DSP shows it to be very functionally complex, and this is true; it is far more functionally complex than ASP. The advantage of DSP is not simplicity, at least not functionally, but its ability to handle signals in the digital domain and to be tied into the faster rate of advances in digital ICs. A summary of the advantages of DSP is as follows:

- Minimize/eliminate signal degradation
- Provide faster level of feature/function integration
- Provide signal storage capability
- Many functions more easily done in digital domain
- Products can be upgraded in software/firmware
- End products can do multiple tasks with same hardware

The following paragraphs provide brief explanations for each point.

Signal Degradation

The elimination of signal degradation is the great advantage of working with numbers in the digital domain. By encoding numbers into easily resolvable states (that is, 0V and 5V for a binary system) and adding error correction algorithms, digital "signals" will not suffer the inherent noise, drift, and nonlinearities seen in analog processing.

Feature/Function Integration

Besides degrading the signal, analog processing ICs have limitations in configurability and functional complexity. Unlike the rapid pace of integration in digital ICs, analog ICs have not been able to take advantage of functional integration. This has occurred for two reasons. First is the fact that analog transistors require a certain silicon area defined by current, voltage, and noise considerations; they cannot simply shrink proportionately as feature size declines. Because digital functions do shrink proportionate to feature size, functionality can expand with the increasingly available silicon. Second is the fact that analog functions are invariably hard-wired with little chance for reconfiguration. Compounding the problem is the need for analog components to interface with a myriad of signal types and levels. Without the programmability offered by a microprocessor-type core, a myriad of signal- and function-specific ICs would have to be offered. Each of these would be low-volume ICs with few features and little hope of upgrading without a hardware change. This is why analog IC vendors offer about 15,000 simple analog functions. To serve the total market with more functionally integrated products would require an exponentially larger number of products.

Signal Storage Capability

Analog signals are very difficult to store without degrading because they exist in time. Prior to digital techniques, signal storage typically involved transferring electronic signals into mechanical (records) or magnetic (tape) mediums. This involved slow write and read times and random-access difficulties. By converting signals to numbers, however, signals can be stored in electronic memories with fast and random access. Many applications, such as filtering, merely involve time delays. Digital techniques are always superior in providing controlled long-time delays.

Compression

Compression techniques, readily done in DSP, can allow significantly more information to be stored or transmitted than can be done with analog techniques. Compression is not new; ASP has used many time and frequency multiplexing schemes to provide more information in the same channel. DSP has an edge in getting the maximum signal compression.

Special Functions in Digital

Besides the ability to delay and store signals, digital techniques can add new capabilities difficult or impossible in the analog domain. Color-key systems used by TV weather reporters to change backgrounds are examples of a DSP technique not possible with ASP. Picture-in-a-picture TV is another example. In fact, adding and merging pictures is always best done by DSP.

Products Upgradable with Same Hardware and Multiple Tasks with Same Hardware

These two advantages of DSP depend on the software programmability of the DSP functions on a system. For example, a single add-on PC board could provide multimedia sound generation, a fax/modem function, telephone answering machine functions, and data compression/decompression, with only the analog interfaces providing the application specificity. The DSP system would simply run alternative programs when a new function was needed. Of course, these time-multiplexed functions should typically not be needed concurrently. Also, this board could add greater features and functions (and corrections for bugs) by allowing either firmware or downloadable software changes.

Limitations of DSP

Despite the many features offered by DSP, it cannot and will not take over all signal processing. The three major limitations of DSP are cost, bandwidth, and physical reality.

Cost

DSP is a complex process, requiring special signal processing and conversion even before the DSP techniques can be applied. Many simple signal processing functions can be done with less than 50 cents' worth of analog components (a filter, for example). DSP implementations may start in the $5 range and go up exponentially. DSP is elegant and powerful, but will not often be cost-effective in low-cost products and simple applications.

Limited Bandwidth

Analog signals go from DC into the tens of gigahertz in bandwidth. DSP is limited to the 10-MHz-and-below region, mainly baseband audio and video. Radio frequency (RF) functions will continue to be handled with ASP components for the foreseeable future. DSP in the 10-MHz-or-greater infrared frequency range cannot be readily handled by programmable DSPs, but can be done with dedicated DSP building block functions.

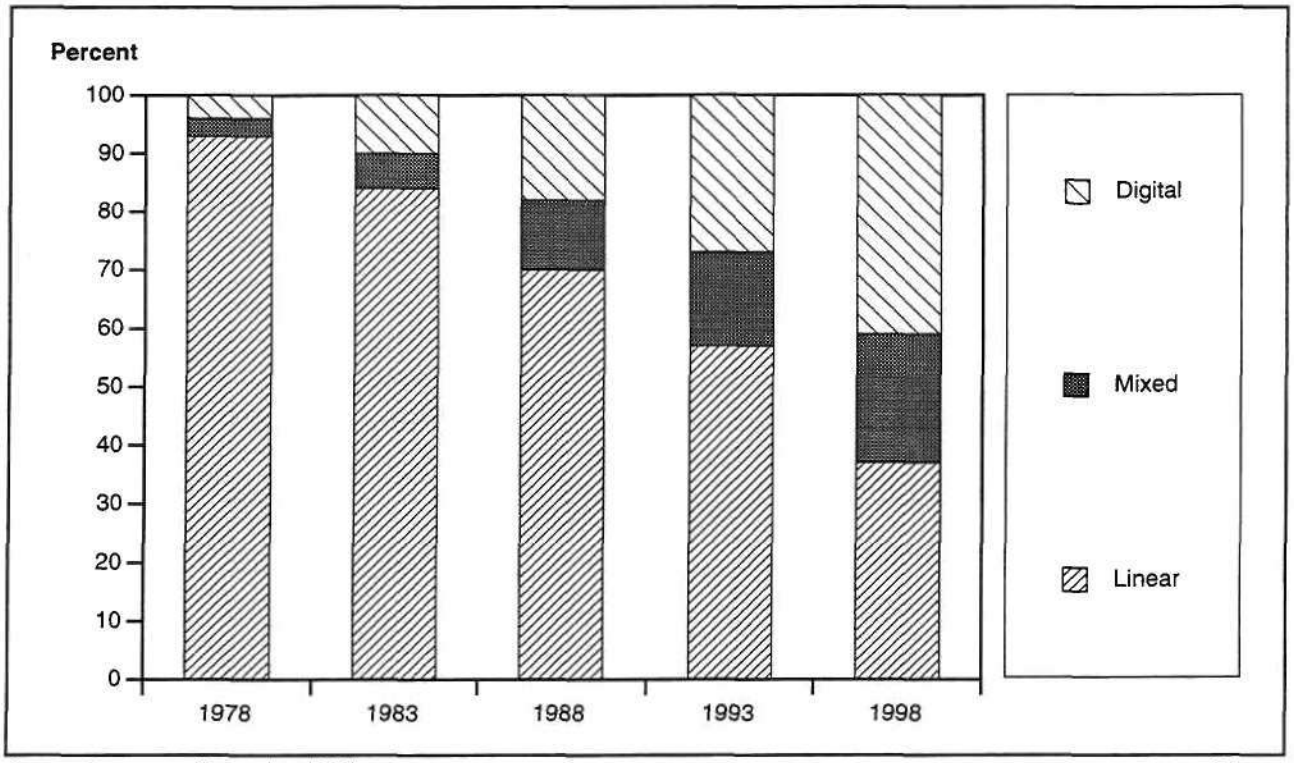
Physical Reality

DSP is a technique, a technique with great power, but one that cannot really change the nature of the analog world it interfaces with. Error correction schemes help, but DSP is still bound by the limits imposed by the analog transducers as well as the same rules of chemistry and physics that ASP is. Despite claims to the contrary, a noise-canceling freeway wall cannot be created using DSP techniques. Three-dimensional noise sources must be canceled at the source to achieve a wide-area, noise-free environment.

Chapter 2
Semiconductor Consumption for Signal Processing

The signal processing changeover from analog to digital represents a new wave of technology and one that is rapidly changing the nature of signal processing. Figure 2-1 shows that the semiconductors used in signal processing were mainly linear semiconductors in the late 1970s. The growth of digital T1 PCM public telephone transmission and digital PBXs, along with the emergence of digital audio toys and the digital audio offered by the CD player, has enabled the phenomenal growth in speed of the mixed-signal and digital ICs used in signal processing.

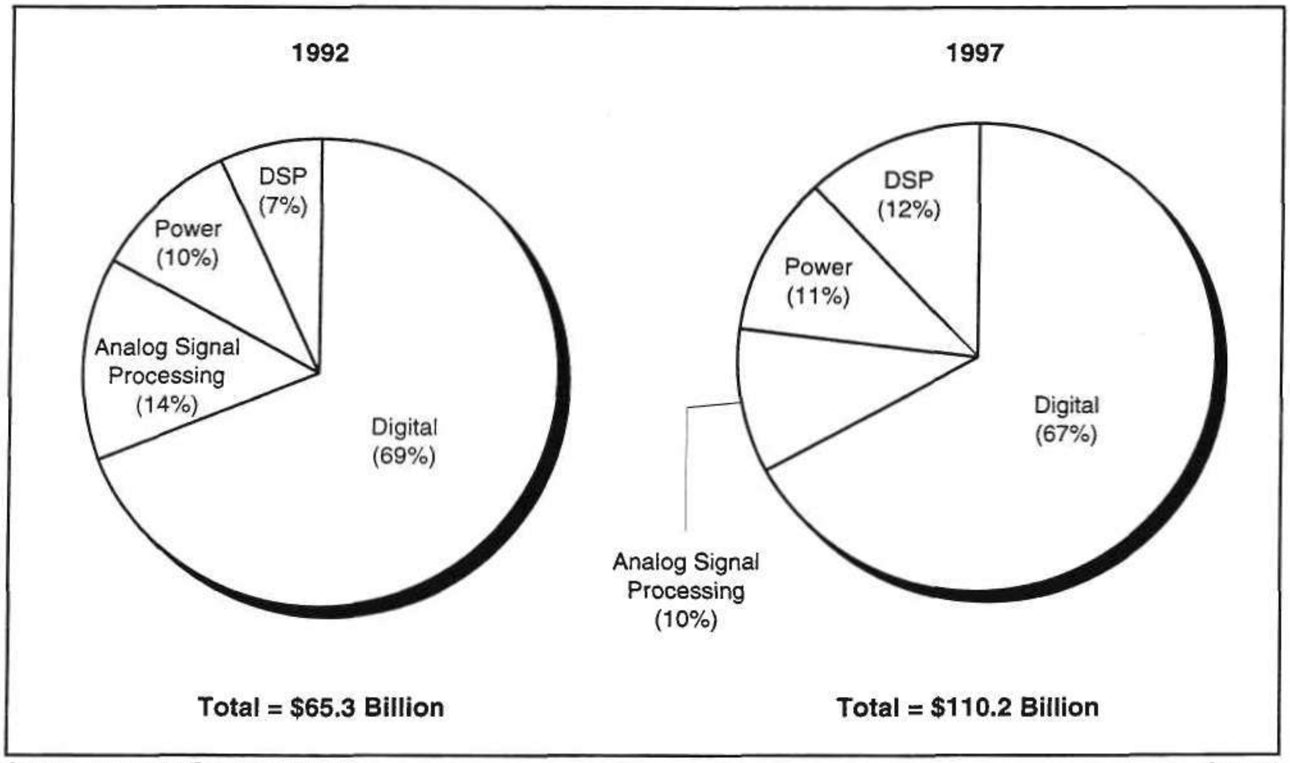
Figure 2-1
Signal Processing Revenue by Type



Source: Dataquest (December 1993)
G3006114

In 1992, about two-thirds of the semiconductor revenue assigned to signal processing applications was for ASP. Because of the lower revenue per equipment in ASP (that is, "Walkman" cassette player versus a "Discman" CD player, or an analog cellular phone versus a digital cellular phone), ASP still represents a much higher ratio of end equipment than the revenue ratios suggest. Figure 2-2 shows two important trends: first, that the signal processing revenue is shifting rapidly to DSP; and second, that DSP is actually invigorating the signal processing portion of electronics, growing it faster than the maturing digital data processing segment. This shows up as an increased portion of semiconductor consumption going toward signal processing over time.

Figure 2-2
Semiconductors by Use, 1992 and 1997



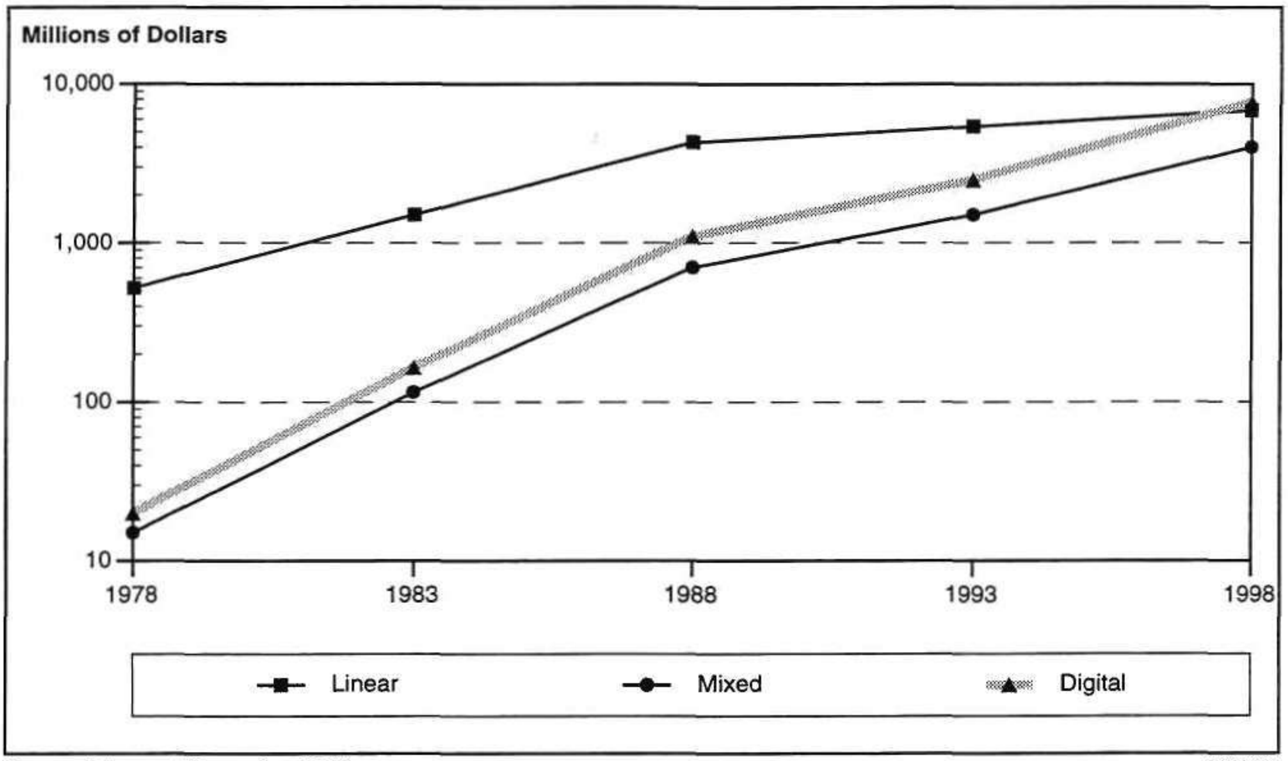
Source: Dataquest (December 1993) G3006115

Figure 2-1 showed that this movement away from ASP to DSP is having a significant effect on the growth of the semiconductor categories used in signal processing. Figure 2-3 shows the forecast revenue data for linear, mixed-signal, and digital ICs. Although linear ICs are declining as a percentage of the total signal processing revenue, we expect linear signal processing to grow slightly, even as DSP generates strong growth for digital and mixed-signal ICs. Linear ICs and ASP will remain important in three main applications, as follows:

- Pre- and post-DSP signal processing
- Lowest-cost, no-frills processing
- High-frequency processing, less-than-20-MHz signals

Figure 2-1 and 2-3 have only shown the IC segments of the signal processing markets. Actually, signal processing uses the full range of semiconductor devices, including discrete devices and optical semiconductors. Optical semiconductors such as CCDs provide video signals while photosensors, LEDs, and lasers are found in digital fiber-optic communications. Discrete devices are found in TV and audio amplifier products.

Figure 2-3
Signal Processing, Revenue Forecast by Product Type



Source: Dataquest (December 1993)
G3006116

Figure 2-4 gives the estimated signal processing breakdown by product type, including the non-IC components of discrete and optical semiconductors.

The following paragraphs provide brief descriptions of these devices.

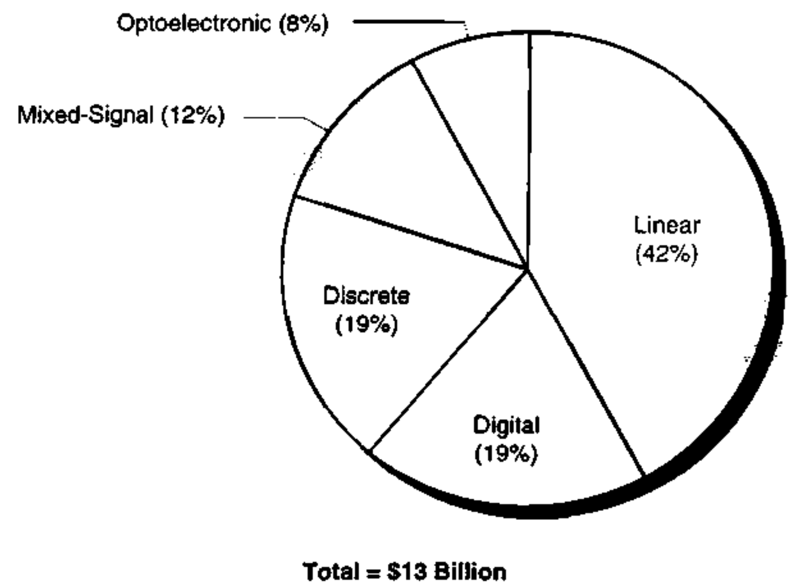
Linear

Linear semiconductors provide ASP functions. Some linear ICs are used in pre-DSP and post-DSP signal processing, but the most common use of linear ICs is for ASP. A good portion of the special consumer analog ICs are linear ICs that process audio or video analog signals for consumer entertainment products.

Mixed-Signal

Mixed-signal ICs combine linear and DSP functions on a single IC. Data converters have been the traditional mixed-signal device with inputs and outputs in both the analog and digital worlds. Greater levels of integration driven by size and cost constraints are making the mixed-signal ICs a major portion of the DSP semiconductor market.

Figure 2-4
Semiconductors Consumed for Signal Processing, 1993 Estimate



Source: Dataquest (December 1993)

G3006117

Digital Logic and Memory

Logic and memory represent digital support functions for DSP. DSP functions may be done by any number of ICs. Programmable DSPs (pDSP) represent only the user-programmable IC visible within a named "DSP" category. Many other microperipherals (MPRs) such as fax/modem chips, sound synthesis, and video compression do the DSP function. ASIC ICs with a DSP core or performing DSP functions are also involved. Dataquest breaks the DSP function down into two categories, pDSP and dedicated DSP (MPR/ASIC/others).

Discrete Devices

Discrete devices essentially are individual transistors used in signal processing. These include RF power transistors, audio transistors, and other signal processing transistors, either small-signal or power.

Optical Semiconductors

These devices represent the interface from light to electrical signals. Optical CCDs are found at the image end of video cameras and camcorders, fax machines, and scanners.

Table 2-1 lists the 1992 revenue and forecasts five-year growth rates for some of these major category splits.

Table 2-1
Forecast Growth Rates for Signal Processing Semiconductors

Product	CAGR (%) 1992-1997
Linear ICs	5
Mixed Signal ICs	27
Digital ICs	29
Discrete Devices	6
Optical Semiconductors	10

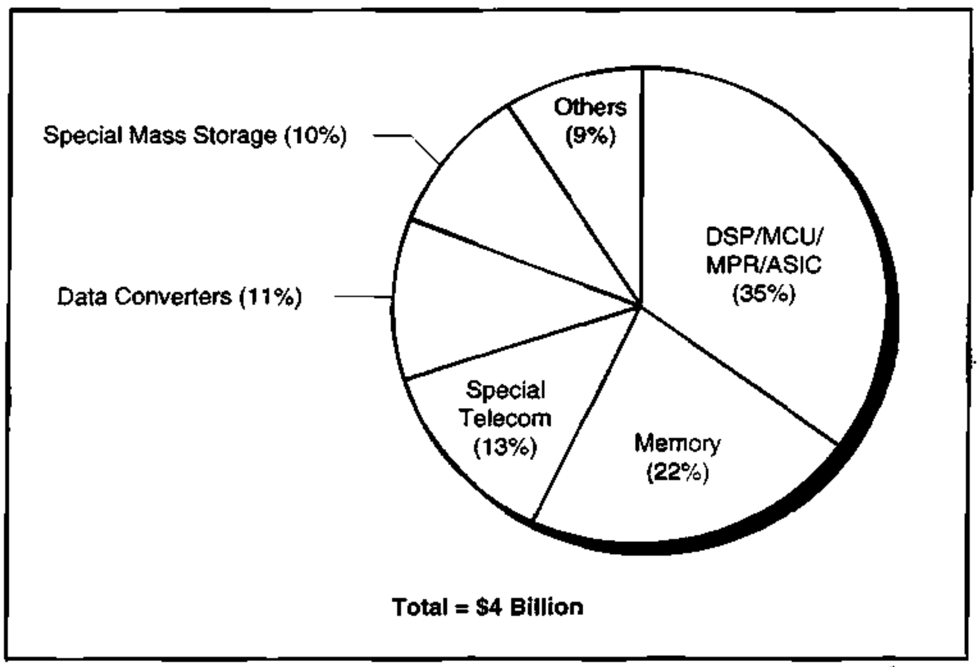
Source: Dataquest (December 1993)

Semiconductors for DSP

The semiconductors used for ASP differ substantially from those used for DSP. Figure 2-4 showed the combined makeup of the semiconductor types consumed in both analog and DSP. About 31 percent of the total semiconductor revenue for signal processing are for ICs used in DSP. We expect this market to be about $4 billion for DSP ICs in 1993; an estimated breakdown by type is in Figure 2-5.

From this point on, the discussion will focus on estimated revenue for DSP ICs only.

Figure 2-5
ICs Consumed for DSP, 1993

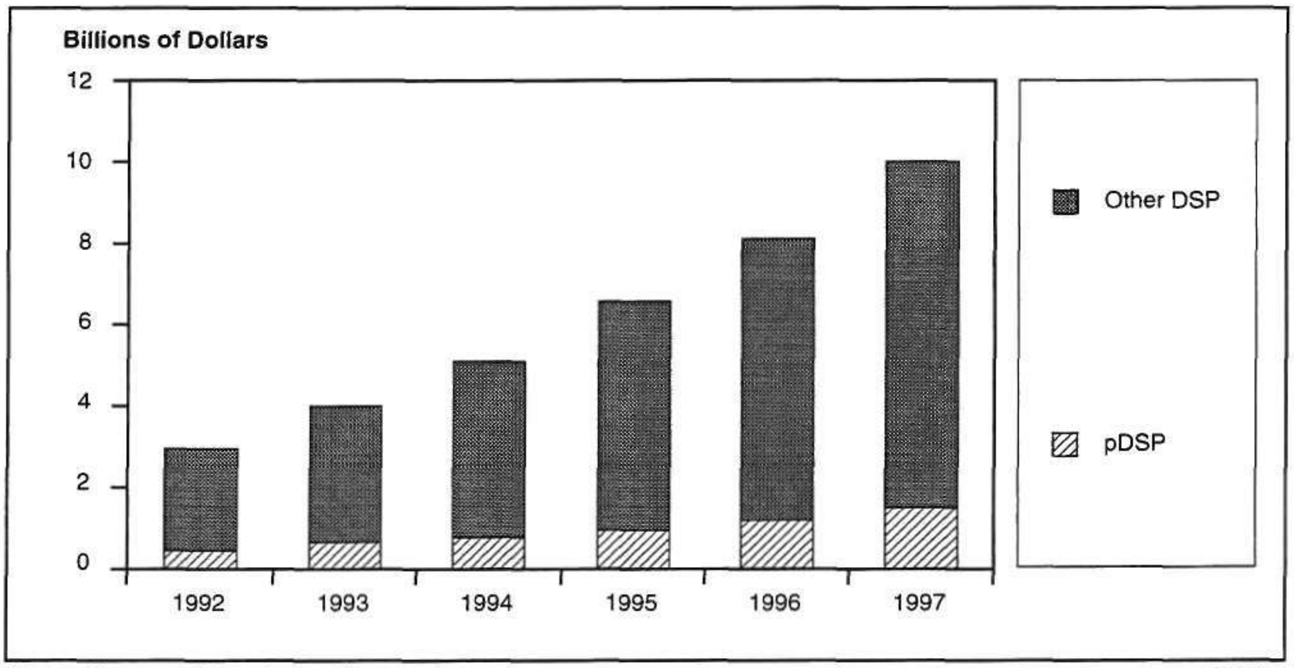


Source: Dataquest (December 1993) G3006118

Chapter 3
DSP IC Forecast

Dataquest's DSP semiconductor forecast is shown in Figure 3-1. In 1992, DSP accounted for 5.5 percent of all IC revenue. With a growth rate of almost 28 percent, DSP is becoming a greater portion of the IC revenue, and will reach nearly 9 percent in 1997. This is strong growth, and the ending years of this five-year forecast do not show any significant decline in the growth rates. The growth of DSP in communications, computer, and consumer products will continue unabated beyond this forecast period.

Figure 3-1
DSP IC Revenue Forecast



Source: Dataquest (December 1993) G3006119

The forecast shown in Figure 3-1 is broken into two parts, pDSP revenue and the other ICs used in DSP. Table 3-1 shows a more detailed forecast by product.

Figure 3-2 shows revenue growth for the major product segments over this forecast period.

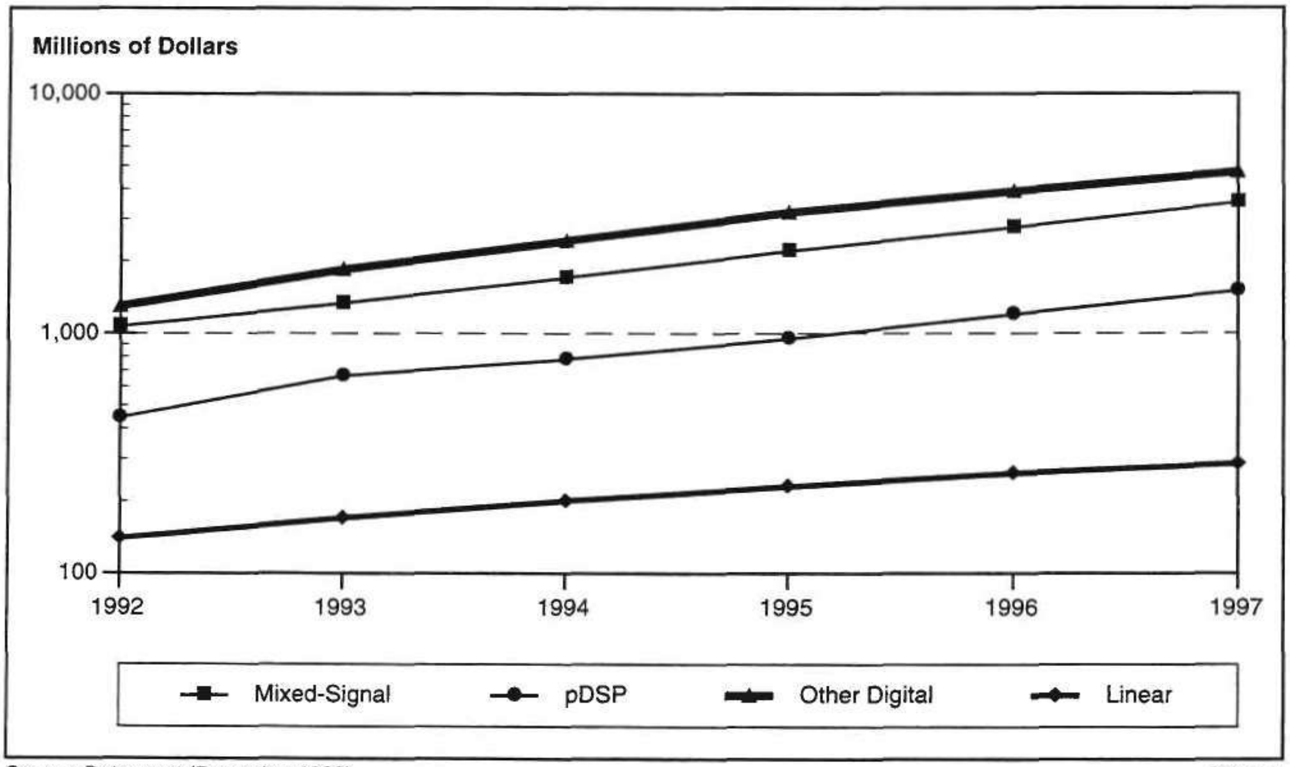
Although digital functions gain slightly over time in this forecast, it may be surprising to see that all product families, except for linear ICs, remain relatively static in their proportion to the whole. pDSP and mixed-signal ICs remain at 15 percent and 36 percent of the total, respectively. The other digital ICs (exclusive of pDSP) grow from 44 percent to 47 percent during the five-year period.

Table 3-1
Worldwide Signal Processing Consumption Forecast, 1992-1997 (Millions of Dollars)

	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
Digital	1,740	2,500	3,200	4,140	5,100	6,200	28.9
pDSP	444	664	780	950	1,200	1,500	27.6
MPR/ASIC	500	810	1,150	1,650	2,050	2,500	38.0
Other Logic/ Microcomponent	196	276	380	480	550	610	25.5
Memory	600	750	890	1,060	1,300	1,590	21.5
Analog							
Mixed-Signal	1,070	1,330	1,700	2,200	2,760	3,515	26.8
Linear	140	170	200	230	260	285	15.3
Total	2,950	4,000	5,100	6,570	8,120	10,000	27.7

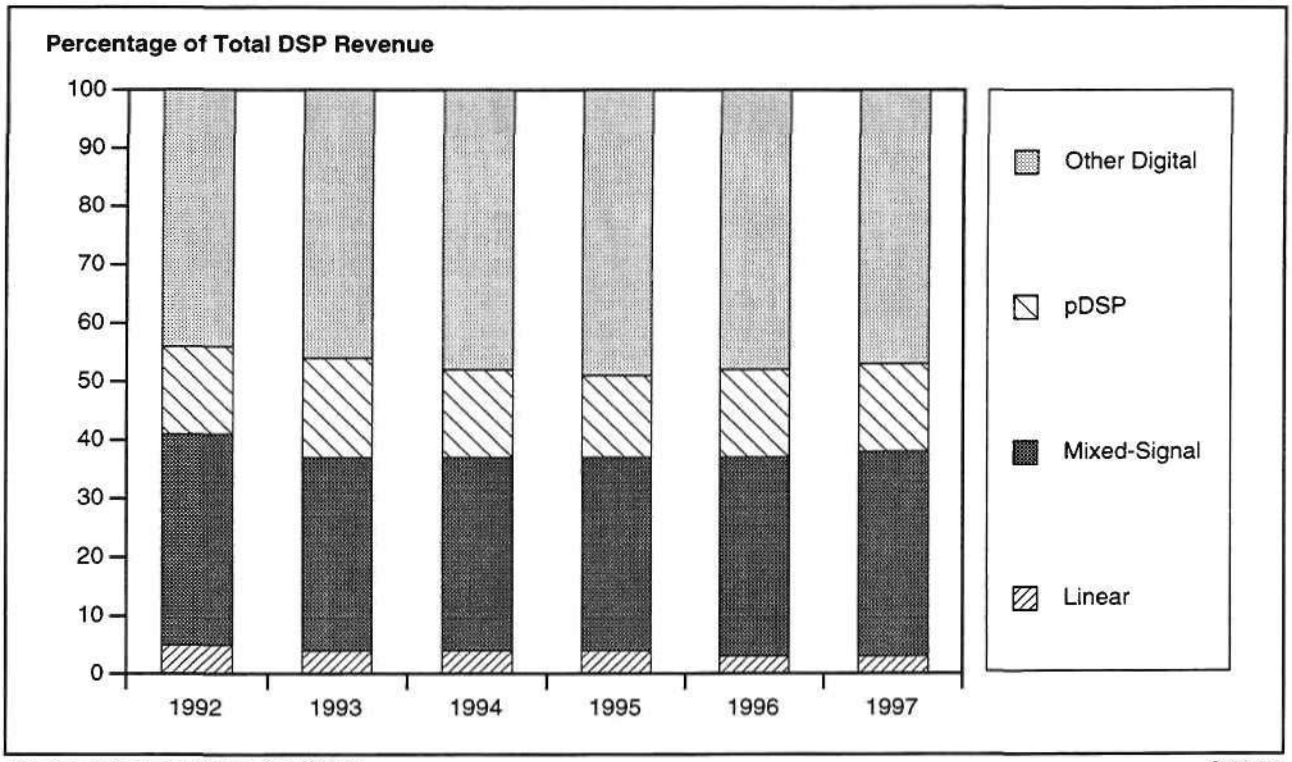
Source: Dataquest (December 1993)

Figure 3-2
Five-Year Forecast by Product Type



Source: Dataquest (December 1993)
G3006120

Figure 3-3
Five-Year Forecast as a Percentage of Total DSP



Source: Dataquest (December 1993) G3006121

Digital ICs

pDSP Forecast

The forecast shows that pDSP represents about 15 percent of the DSP revenue and remains pretty much in this position throughout the period of the forecast. This surprising forecast is supported in the additional forecast detail presented in Table 3-2, which shows a phenomenal unit growth rate of 58 percent being offset to a large degree by a rapid price erosion. The resulting revenue growth is less than 28 percent and is below that of the dedicated DSPs found in the MPR and ASIC categories, which are expected to show a 40 percent revenue growth rate over the forecast period. Part of the driving force for the price erosion in pDSP will be the competition between programmable and dedicated DSP solutions, with the dedicated ICs having the cost edge.

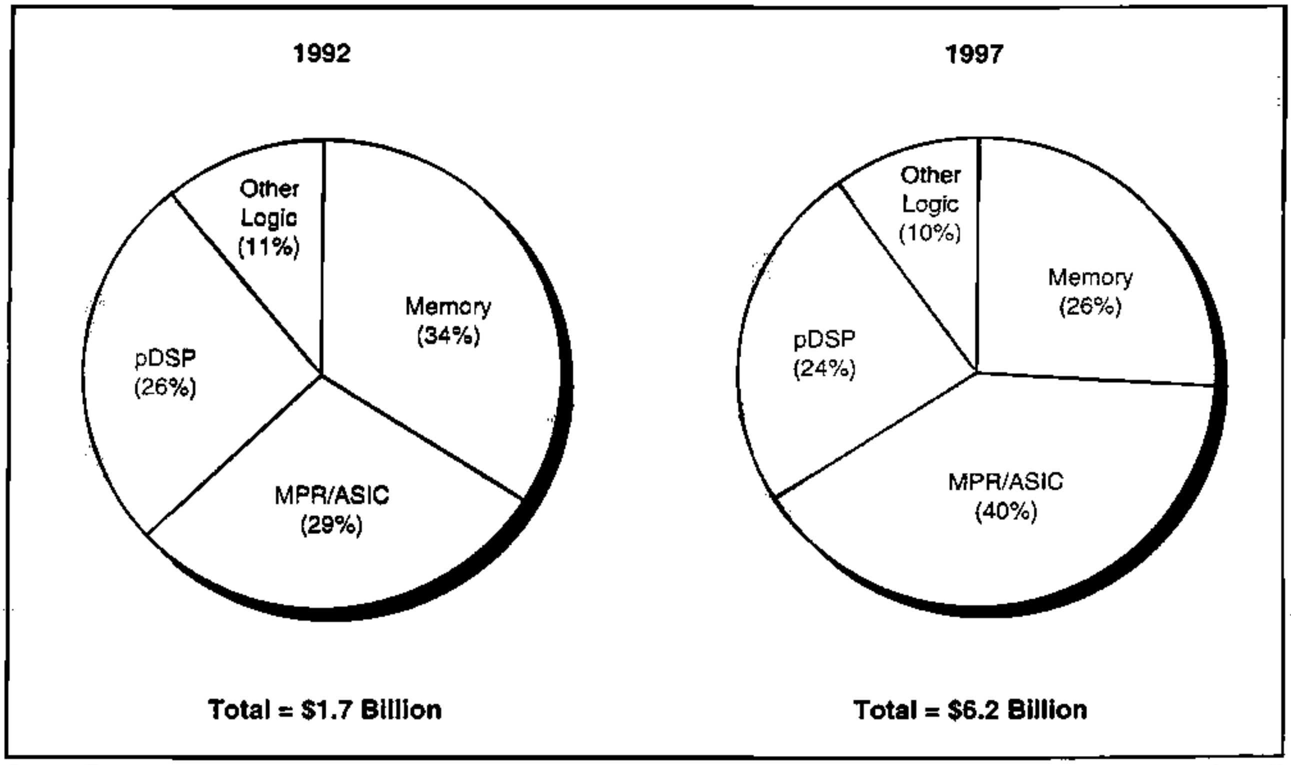
The difference in growth rates between pDSPs and the dedicated functions found in the MPR and ASIC categories results in the dedicated functions gaining in importance. Figure 3-4 looks at these digital components as part of the total digital IC revenue for DSP, showing that pDSPs are expected to merely hold their relative revenue position as the more dedicated ICs will advance.

Table 3-2
pDSP Forecast

	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
pDSP							
Revenue ($M)	444	664	780	950	1,200	1,500	27.6
Units (M)	34	60	105	165	240	340	58.5
ASP ($)	13.06	11.07	7.43	5.76	5.00	4.41	-19.5

Source: Dataquest (December 1993)

Figure 3-4
DSP Digital IC Forecast by Type



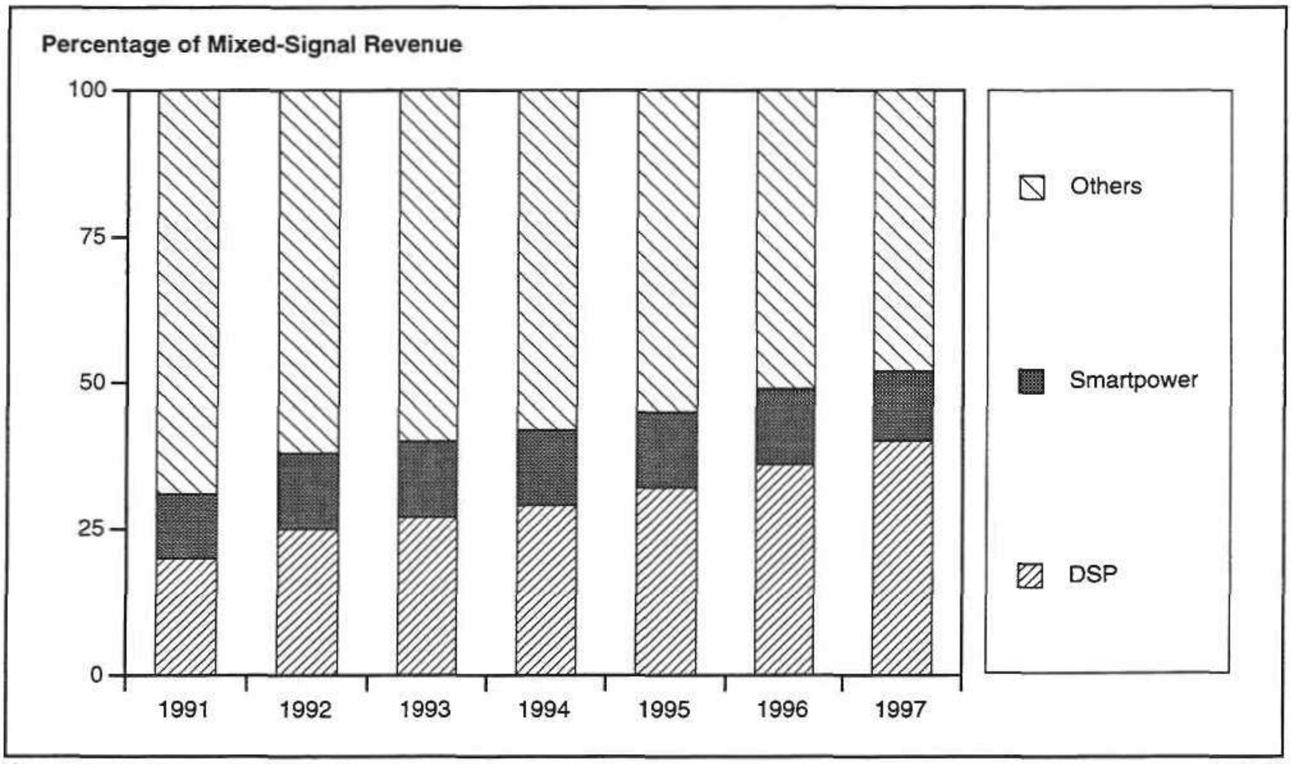
Source: Dataquest (December 1993) G3006122

The forecast clearly shows that we believe in a more rapid growth path for the dedicated DSP functions that would be found in the MPR/ASIC categories over the growth of pDSP. Although pDSP offers the flexibility, upgradability, and fast time to market needed in an era of rapidly changing products and "standards," fixed-function DSPs offer advantages in both cost and performance. We expect video compression and decompression, special consumer DSP, special mass-storage DSP, and special telecommunications DSP to be mainly done by dedicated DSP functions.

Mixed-Signal ICs

Although mixed-signal ICs are used for many product areas, at present only about 25 percent are used in DSP applications. DSP represents one of the fastest-growing areas of mixed-signal ICs, however (see Figure 3-5). With a forecast growth of almost 27 percent in the DSP market over the coming five-year period, the growth of mixed-signal ICs is strongly dependent on this market. The forecast shows that 40 percent of mixed-signal revenue will come from DSP applications by 1997.

Figure 3-5
Mixed-Signal IC Forecast by Use



Source: Dataquest (December 1993) G3006123

Because DSP cannot reasonably be done without a data converter, data converters used in DSP might be expected to show a strong growth rate. Dataquest is only forecasting a 17 percent compound annual growth rate (CAGR) for data converters used in DSP, a rate substantially less than the growth of DSP. The reason is that, although the growth of data converter functions will be high, many of the data converters needed for DSP will be integrated into other mixed-signal ICs or onto the pDSP, MPR, or ASIC. pDSPs or DSP-core ICs used for digital cordless or digital cellular phones will have integrated delta-sigma codecs. Higher-speed or high-resolution converters used in DSP will be the only ones to remain categorized as general-purpose data converters. This integration of analog and mixed-signal functions onto chips defined within the "digital" categories results in a lower mixed-signal IC forecast than common sense would allow. The mixed-signal pDSPs and MPRs are not accounted for in the mixed-signal category.

Linear ICs show little growth because many of the functions will be eliminated or integrated onto mixed-signal ICs.

Chapter 4
DSP Application Markets

DSP has been used in military applications for decades, but the communications market is where it has found much of its growth in the 1980s. In 1992, the communications market consumed 41 percent of the ICs used in DSP. The growth in digital phones, video teleconferencing, and personal communications devices will help this market remain important. However, two lesser markets for DSP in 1992—computer and consumer—are expected to show greater growth. Table 4-1 gives the DSP IC forecast by application market.

Table 4-1
DSP by Market (Millions of Dollars)

	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
Computer	537	900	1,220	1,700	2,120	2,500	36.0
Communications	1,220	1,580	1,950	2,400	2,870	3,500	23.5
Consumer/Automotive	736	1,000	1,250	1,810	2,400	3,200	34.2
Industrial/Military	457	520	580	660	730	800	11.8
Total	2,950	4,000	5,100	6,570	8,120	10,000	27.7

Source: Dataquest (December 1993)

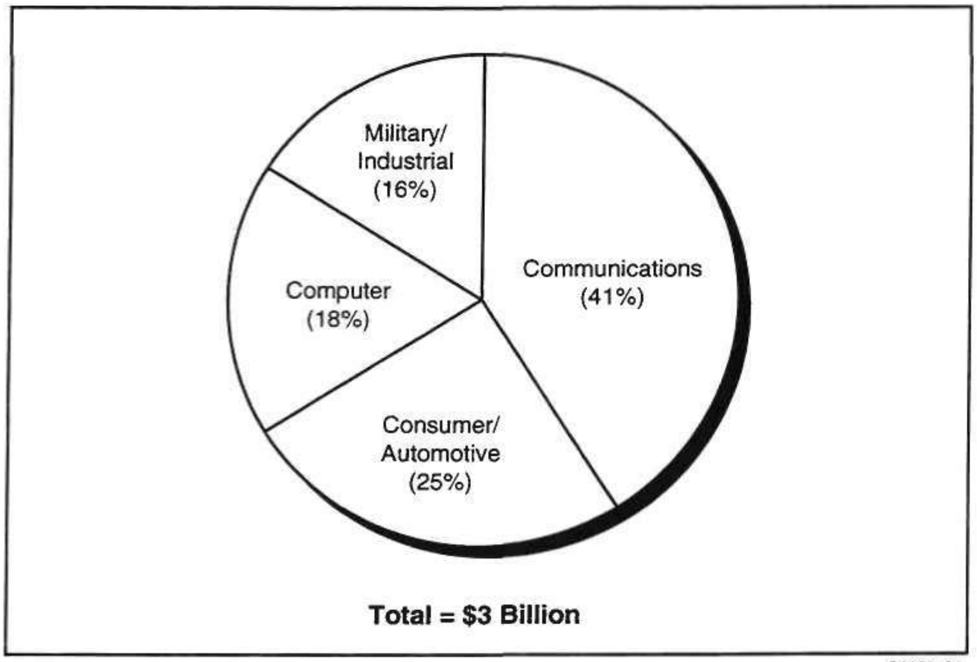
Figures 4-1 and 4-2 show the change in the DSP IC consumption by market during the five-year forecast period.

The discussion in this chapter will focus on the three major growth markets of DSP—computers, communications, and consumer.

Computer Market

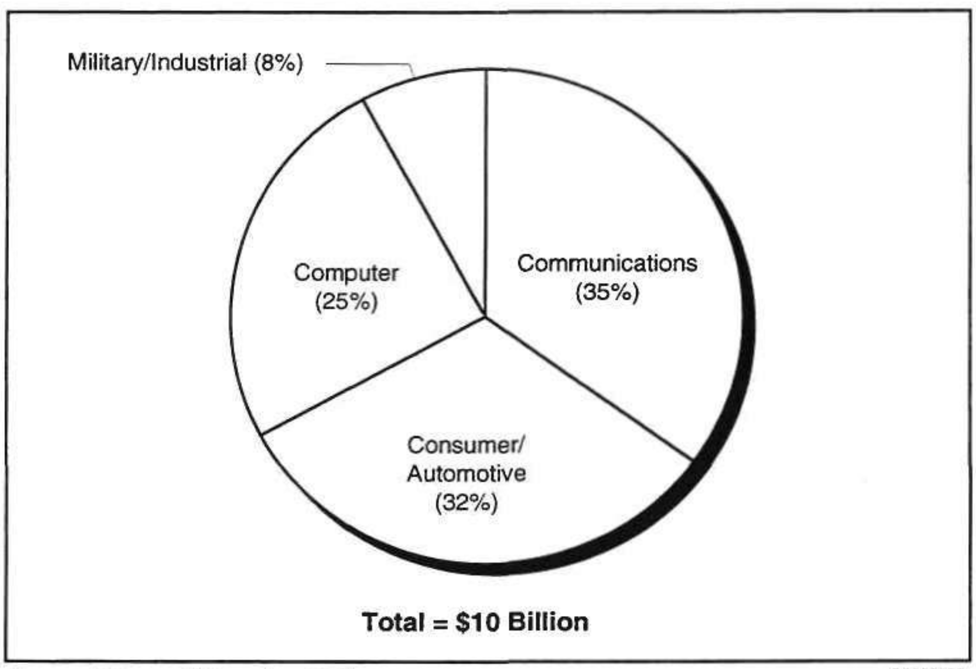
It may seem that digital computers have had little to do with "signal processing" in the past, being essentially number-processing devices. In fact, computers did have a number of signal processing functions in the peripherals devices. Modems and magnetic storage electronics are examples of digital/analog signal processing functions already found in computers. High-quality audio and video represent new capabilities, however, moving PCs beyond the realm of data processing and into a more interactive role with humans. This trend has been labeled "multimedia" and really represents the addition of much DSP power to the PC. Figure 4-3 shows the digital CPU existing in a digital domain insulated from the real world by a series of signal processing and interface peripherals.

Figure 4-1
1992 Consumption by Market



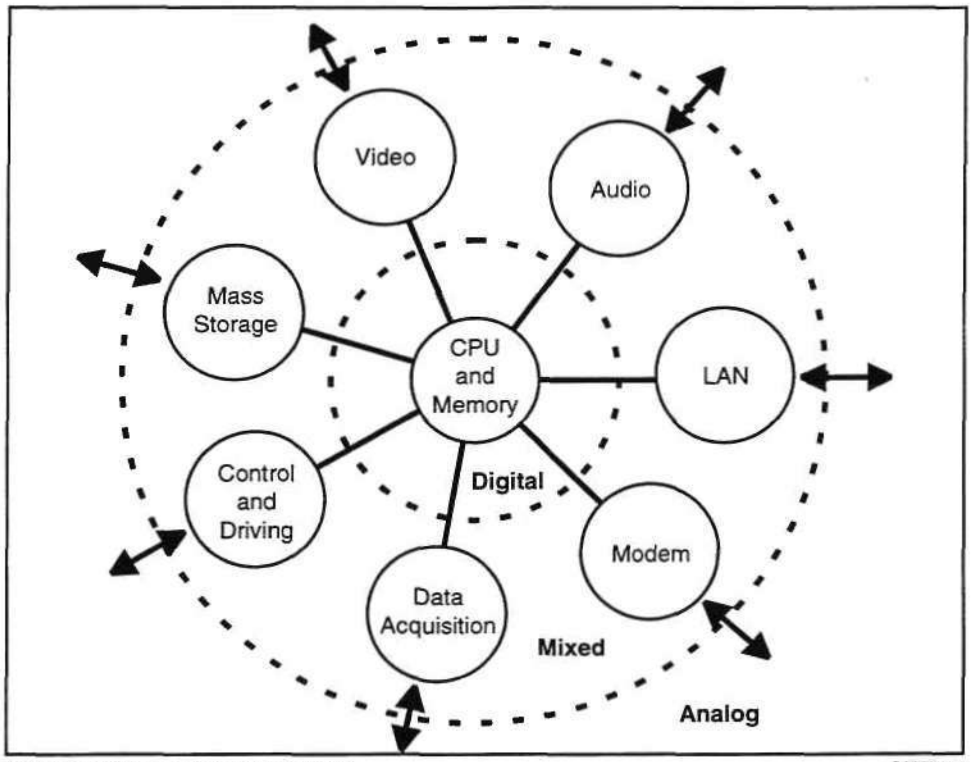
Source: Dataquest (December 1993)
G3006124

Figure 4-2
1997 Consumption by Market



Source: Dataquest (December 1993)
G3006125

Figure 4-3
DSP in Computers—Bridging the Signal and Number Domains



Source: Dataquest (December 1993) G3006126

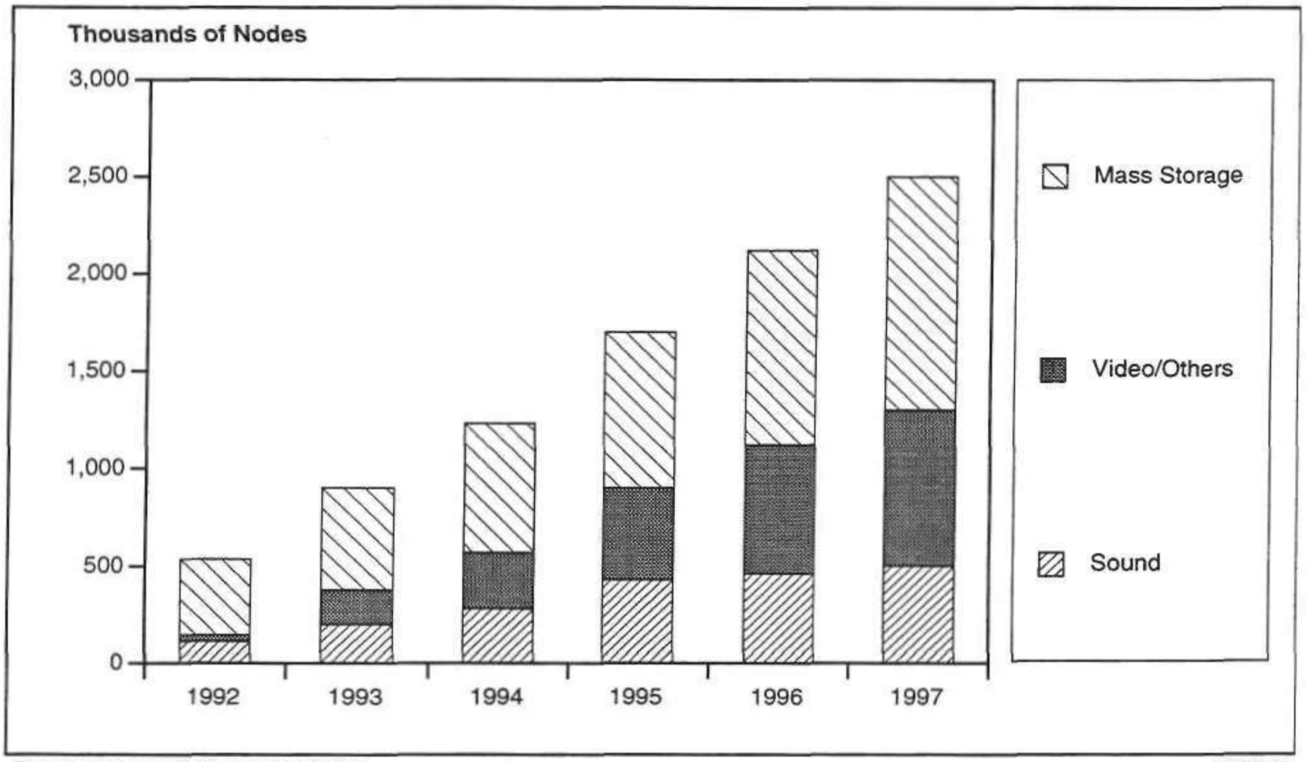
The figure shows some of the major applications for signal processing in a computer. Some applications for DSP are as follows:

- High-speed fax/modem
- Video compression (MPEG)
- Imaging
- Graphics
- Audio compression
- Disk drive electronics
- Data communications

DSP in Computers

The use of DSP IC functions in computer audio is expected to grow at a 35 percent CAGR, but the just-emerging video applications will grow at about a 90 percent CAGR during the next five years. The DSP ICs used in mass storage will continue growing at a low 26 percent rate. Figure 4-4 shows the forecast for DSP revenue in the computer market for these three major areas.

Figure 4-4
DSP in Computers, Forecast by Function



Source: Dataquest (December 1993)

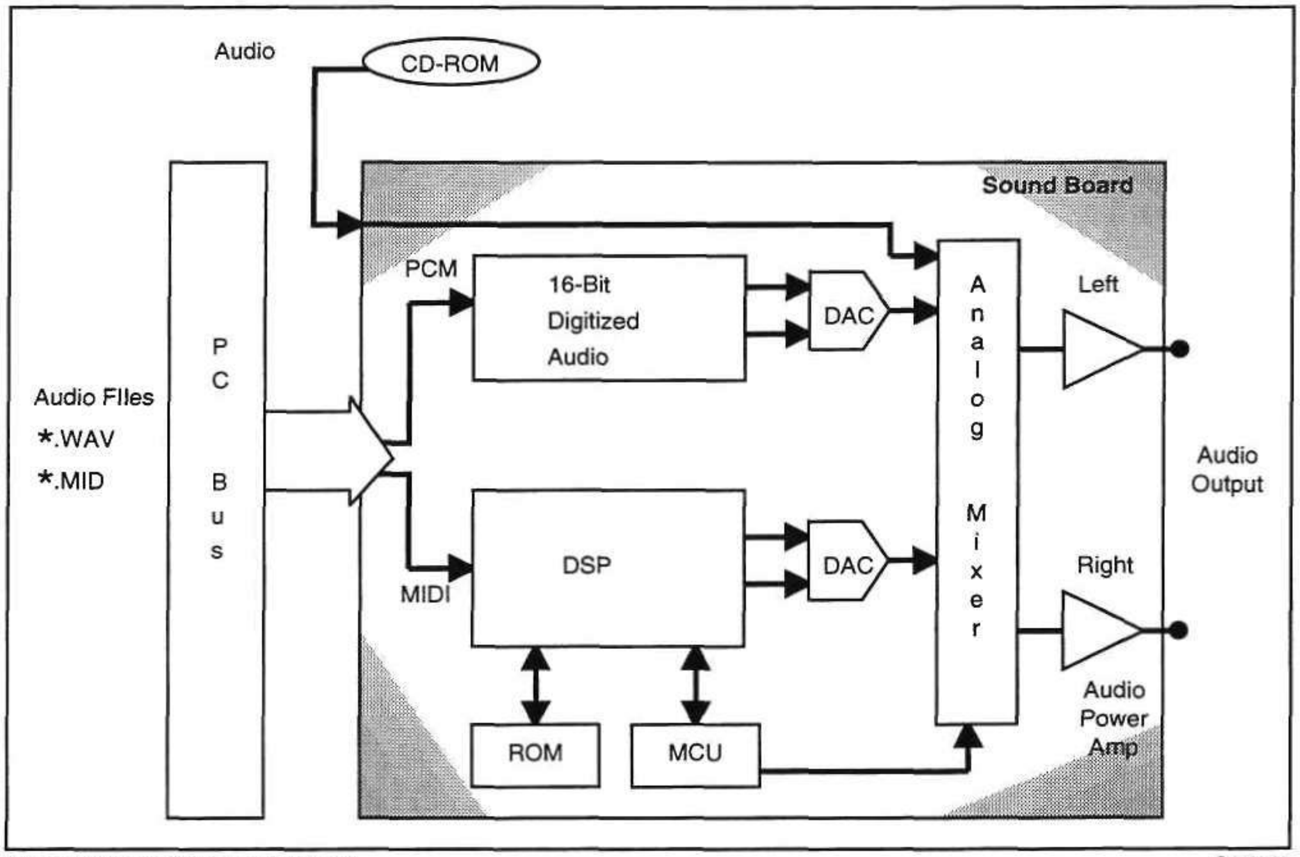
G3006127

Dataquest expects ICs used for DSP in the computer market to increase from only 2 percent of the computer IC revenue to 7 percent by 1997 as multimedia computing becomes more common.

Sound

Sound systems for the PC market escalated greatly in 1993 as multimedia computing took off. These systems use audio codecs for the analog sound inputs and outputs and a number of dedicated sound chips (such as the Yamaha OPL3) for sound synthesis. Both pDSP and dedicated DSP functions for wavetable lookup sound generation are found in the high-end sound systems. pDSPs offer advantages in terms of easy upgradability and the fact that the sound equivalent of "clip art" can be downloaded for special sound generation. Figure 4-5 shows a block diagram for a typical PC sound card using DSP.

Figure 4-5
PC Sound Card Block Diagram



Source: Dataquest (December 1993)

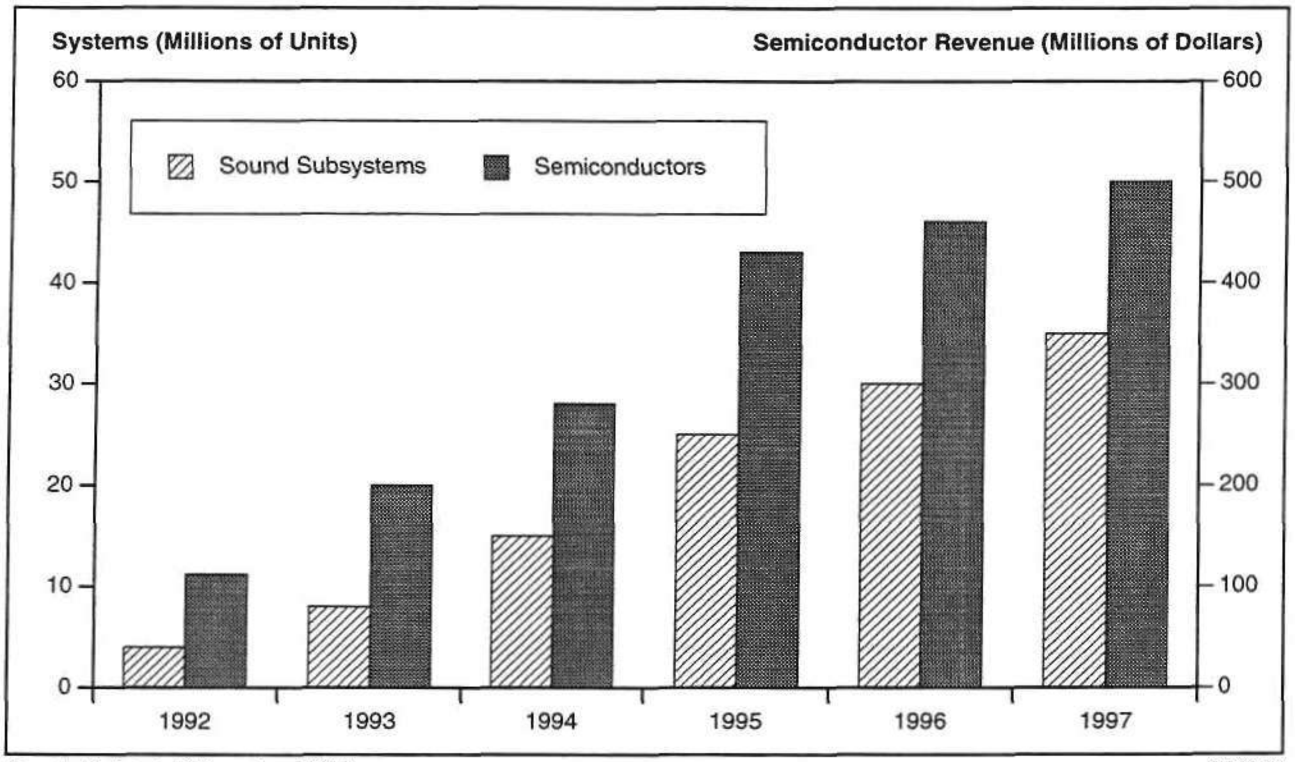
G3006128

Figure 4-6 shows the Dataquest forecast for sound boards (both stand-alone and as part of a package) and the corresponding semiconductor consumption related to it. The end-product unit forecast is a combination of sound boards and systems shipped with sound capabilities built in.

Disk Drive Electronics

The digital disk drive is very analog in nature. The signals on the magnetic media may be digitally "encoded," but they are read and written to by analog electronics; the head is positioned by analog servos and the spindle motor is driven by analog brushless DC motor controller. DSP has been penetrating these analog domains in recent years with DSP-based servo motor controls. DSP is entering the data path with partial response maximum likelihood (PRML) designs. PRML provides increased capacity, higher data rates, and greater error tolerance. PRML uses the sequence of bits to determine the state of the latest bit, replacing the analog peak detection circuit commonly used. Disk drive electronics are typical of the products that drive higher levels of integration into a few dedicated DSP chips.

Figure 4-6
PC Sound Board Market Forecast



Source: Dataquest (December 1993)
G3006129

Fax/Modem

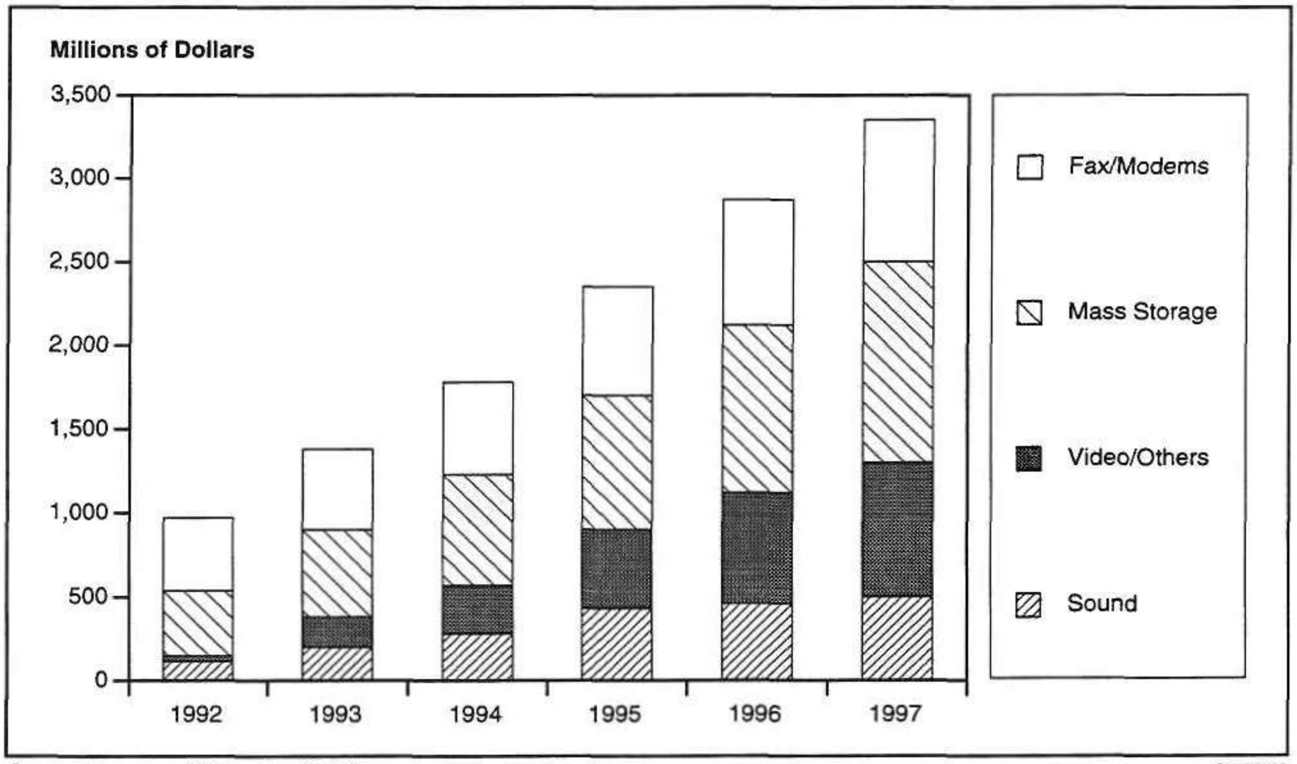
The forecast in Figure 4-4 does not include one of the major uses for DSP in computer and office equipment, the high-speed modem and fax/modem functions. For the purposes of categorization, modems are grouped within the telecommunications category. Figure 4-7 shows the forecast with the modem and fax/modem semiconductor forecast included.

Communications Market

The communications market was one of the early adopters of DSP because of the transmission and switching advantages. Despite being the largest market for DSP ICs, the communications market offers some of the most interesting new applications for DSP functions. The mix of old and new communications DSP applications is as follows:

- High-speed fax/modem
- Secure communications
- Echo cancellation
- T1
- ISDN
- Video teleconferencing
- Telephone answering devices
- Cellular phones
- Personal communications

Figure 4-7
DSP Revenue for Computer/Office Equipment

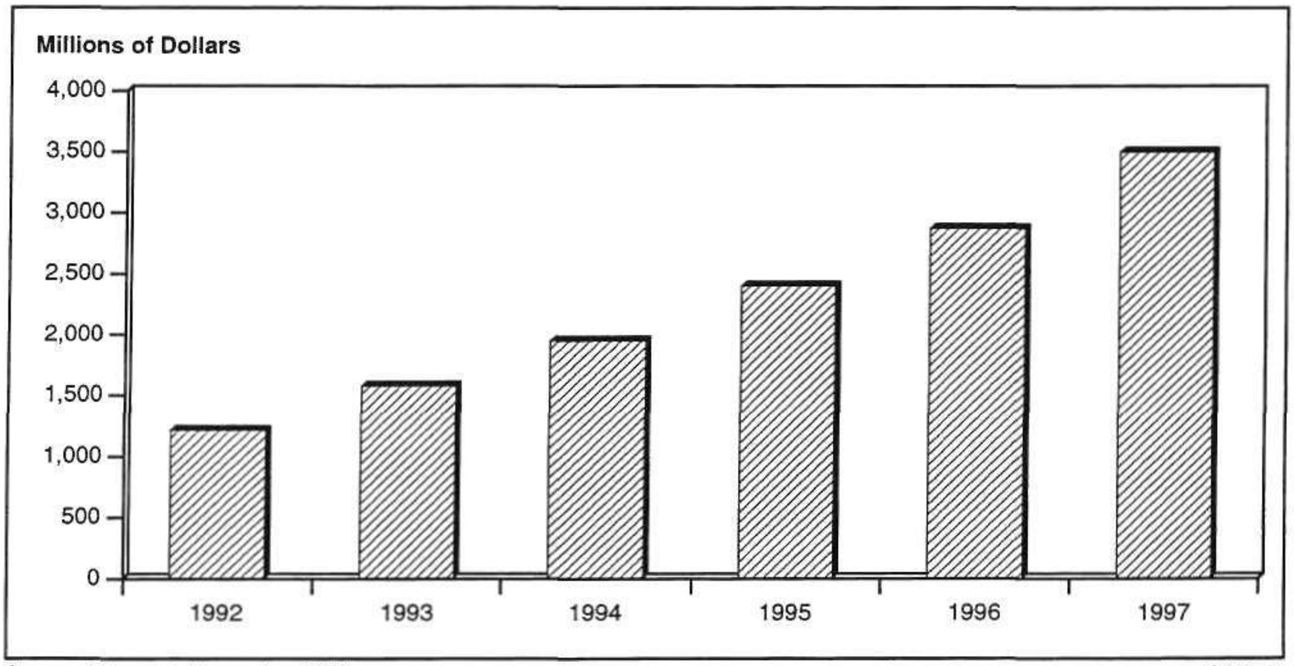


Source: Dataquest (December 1993) G3006130

Figure 4-8 shows Dataquest's forecast for DSP IC consumption within the communications market. The 23.5 percent CAGR for 1992 through 1997 is less than the growth forecast for computer and consumer applications, but communications has a much higher 1992 consumption with many more mature DSP segments. This growth rate is more than double the 11.6 percent CAGR forecast for all communications equipment. With this growth, the DSP-based segment of communications will go from 18 percent of the communications market consumption of ICs to almost 30 percent by 1997.

Although much of the public telephone transmission system is already digital, the growth area in telecom is in personal communications such as the emerging markets for digital cellular phones, digital cordless phones, and digital answering machines. Digital cellular phones have lower noise, are more secure, and use compression techniques to allow greater numbers of users.

Figure 4-8
DSP Semiconductor Forecast for Communications



Source: Dataquest (December 1993)

G3006131

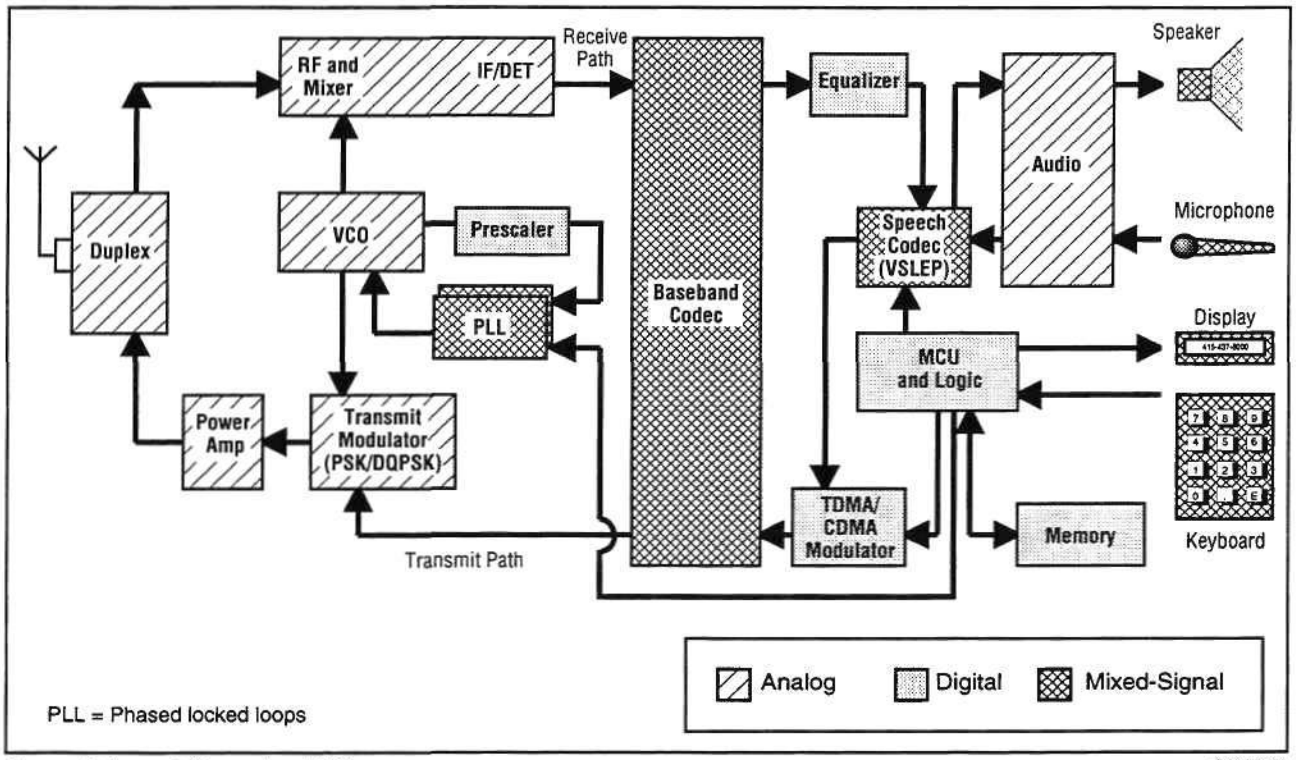
Figure 4-9 shows a block diagram for a digital cellular phone illustrating the digital, mixed-signal, and analog pieces of this "digital" product. Both analog and DSP are found within this product.

DSP is found in digital cordless phones such as CT-2 and Digital European Cordless Telecommunications (DECT), as well as in the digital cellular market. Although cordless phones may be less demanding in their DSP content than digital cellular phones, their growth in units will be much greater, giving a comparable effect to revenue growth. Figure 4-10 shows the forecast growth of digital cellular telephones, over the analog variety, from 1992 to 1997, while Figure 4-11 shows similar charts for digital cordless telephones.

Consumer Market

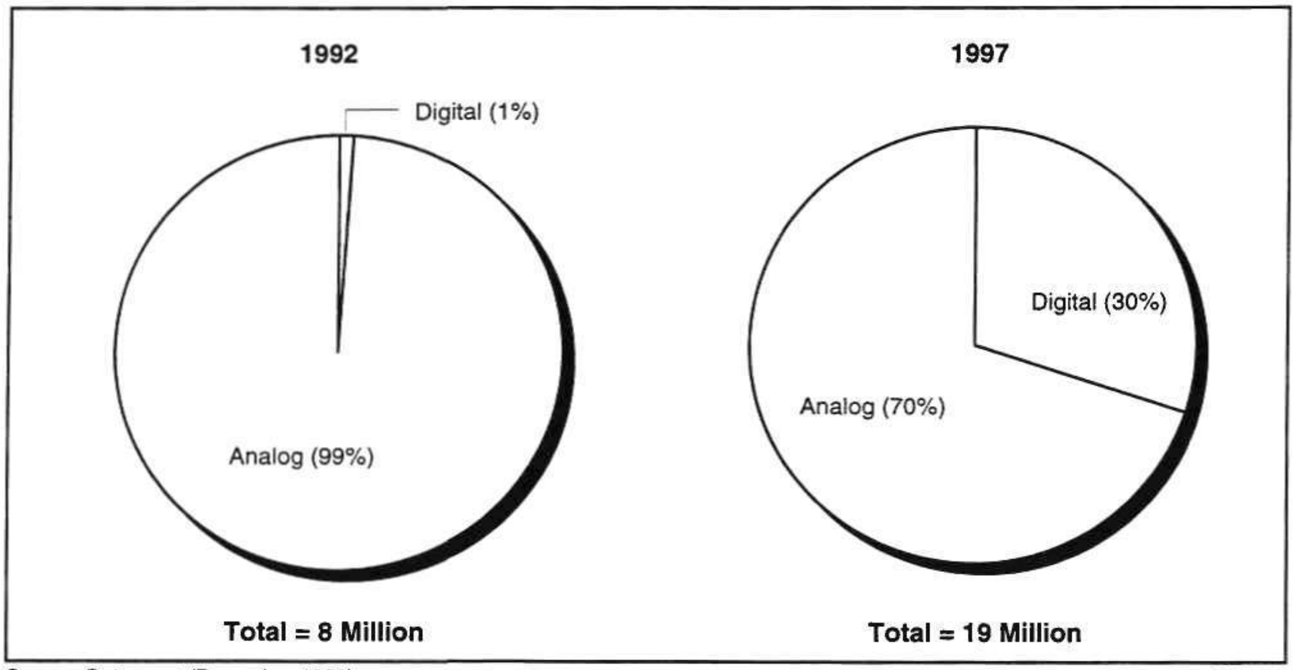
Consumer entertainment markets slowed in the early 1990s but are expected to be revitalized with DSP-based products. DSP has penetrated the consumer entertainment market in digital audio products, especially the CD, DAT, DCC, and MiniDisc formats for audio. Video applications are only now taking off in volume. Musical instruments have already made use of DSP techniques for music generation and synthesis. Other

Figure 4-9
Simplified Cellular Phone Block Diagram



Source: Dataquest (December 1993) G3006132

Figure 4-10
Cellular Telephone Consumption Forecast, Analog versus Digital (Units)



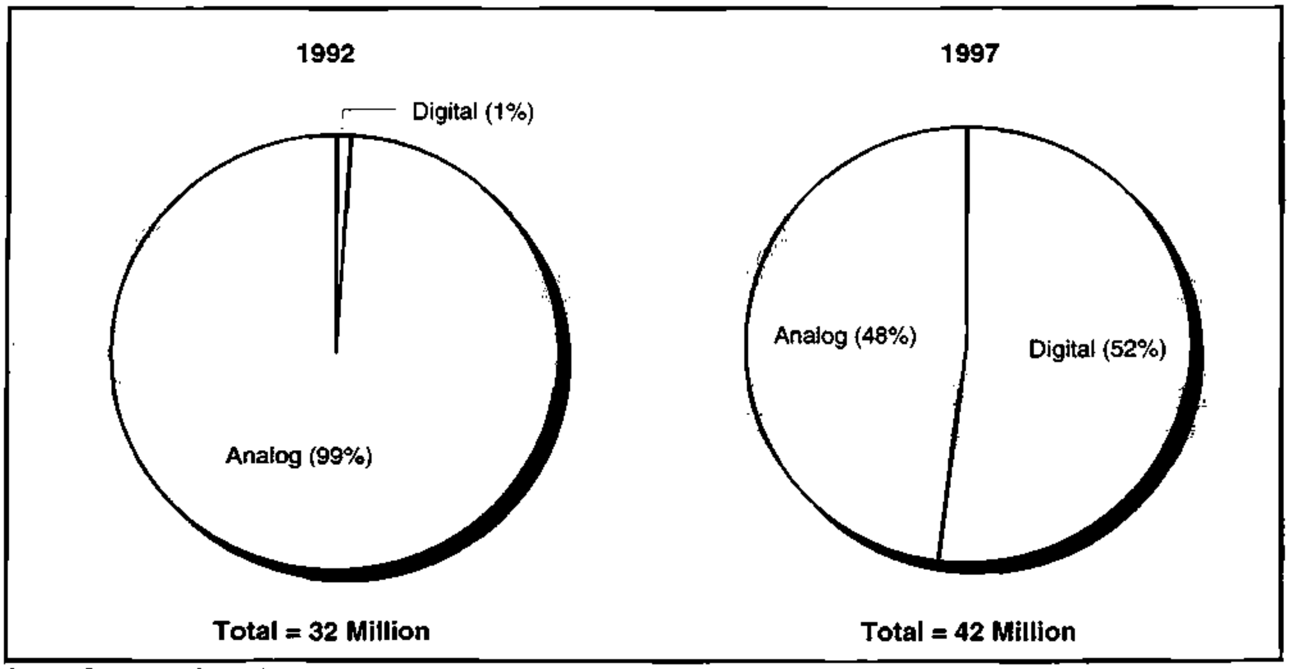
Source: Dataquest (December 1993) G3006133

applications would include automotive antilock braking, adaptive suspensions, and noise cancellation. Emerging consumer/automotive products that use DSP are as follows:

- HDTV
- Digital TV
- Digital audio
- Ghost cancellation
- Global positioning
- Voice recognition
- Automotive safety and comfort

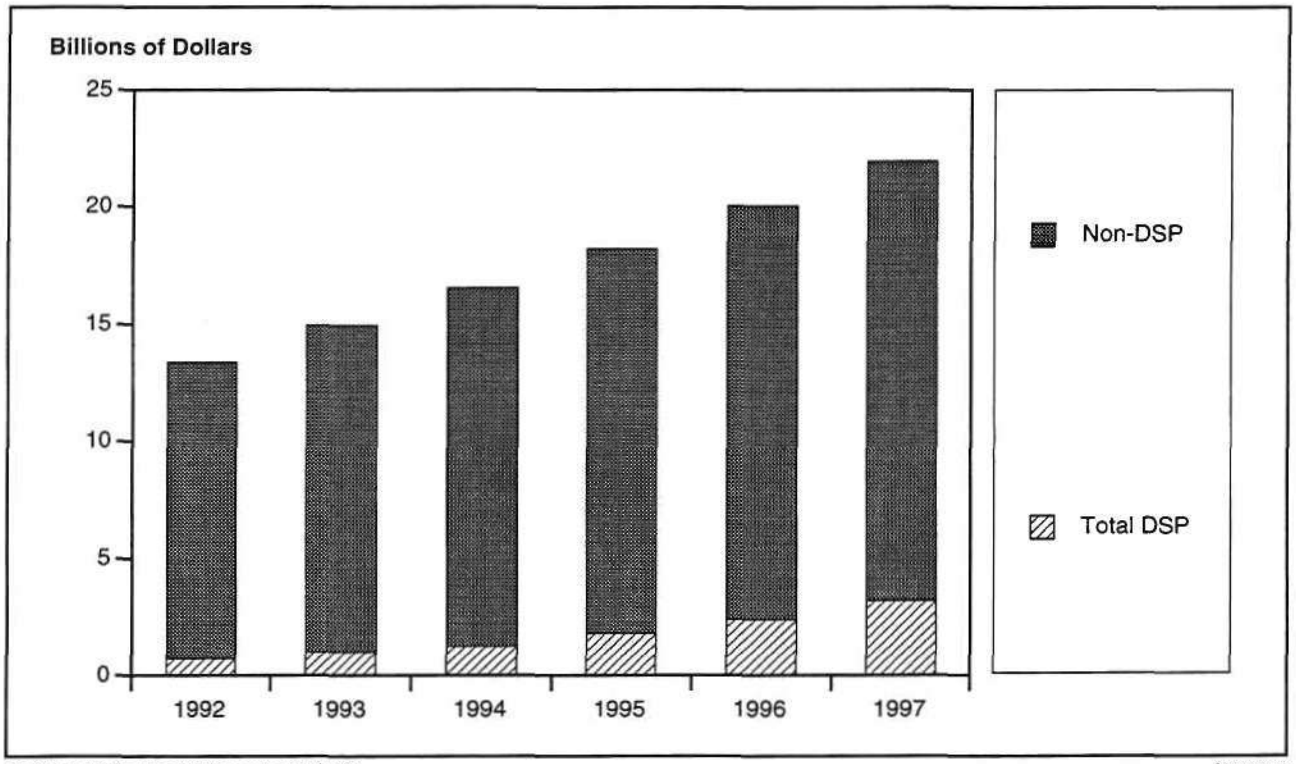
Figure 4-12 contrasts the size of the total IC consumption revenue for consumers with that of the DSP portion. DSP has penetrated the consumer market only slightly, but will grow substantially over the rest of the 1990s. DSP grows from 7.5 percent of consumer IC revenue in 1992 to almost 20 percent by 1997. The penetration into consumer electronics, outside of the audio applications, will be seen only in the highest-end products. DSP will not likely appear in the average radio, audio cassette player, or second TV set for some time.

Figure 4-11
Cordless Telephone Consumption Forecast, Analog versus Digital (Units)



Source: Dataquest (December 1993) G3006134

Figure 4-12
Consumer IC Revenue Forecast—Total and DSP



Source: Dataquest (December 1993)
G3006135

All ICs used for DSP in consumer products are expected to grow by 34 percent in the coming five years, with consumer audio DSP contributing a 22 percent CAGR and video DSP showing a 66 percent CAGR. Figure 4-13 shows the forecast revenue for audio and video applications over the 1992 to 1997 period.

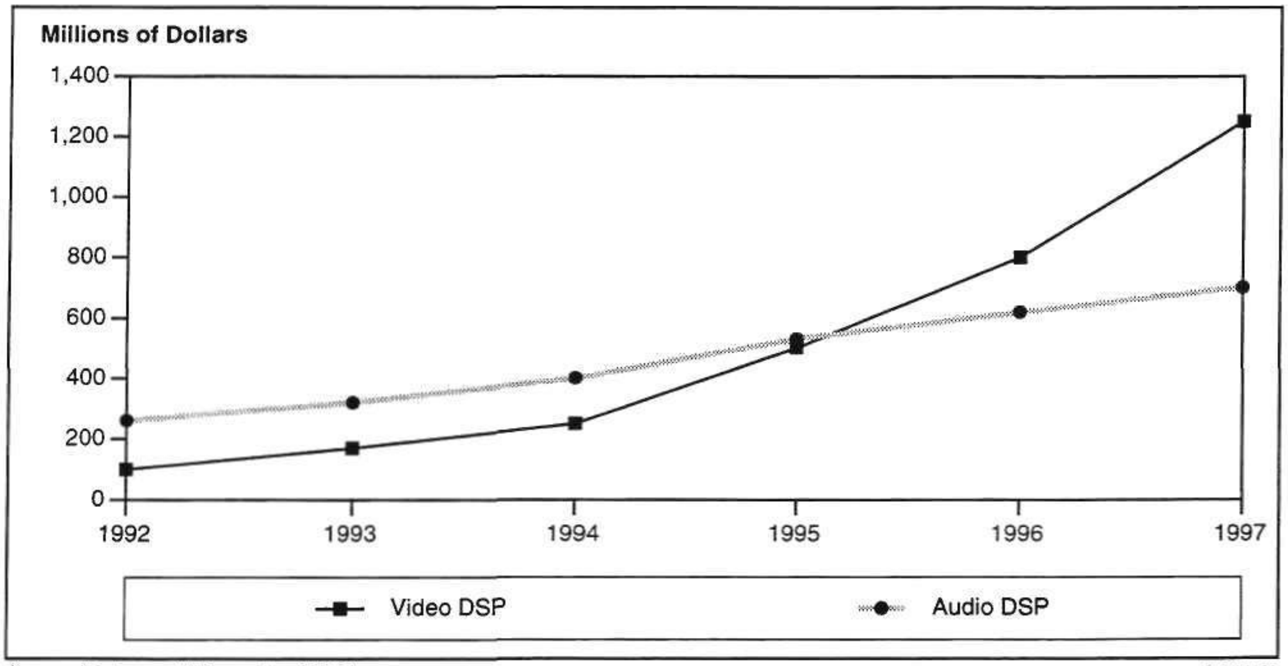
Market Summary

As we have seen in the preceding computer, communications, and consumer market overviews, audio and video are applications common among all three of these markets. As DSP brings common audio/video techniques to these three different markets, we start to see the much-talked-of "convergence" of computers, communications, and consumer products. Most of the audio and video applications listed in Table 4-2 are applicable to products in all of the electronics markets.

In addition to serving the common needs of many markets, these applications have a common set of functions such as compression, transmission, recognition, and noise cancellation. These common functions are best answered by common standards. Standards such as JPEG and MPEG will help to unify these previously unconnected markets.

Table 4-2 leaves a blank space for the video application comparable to music (which would have to be some type of visual art), a concept not highly developed at this time.

Figure 4-13
Revenue Forecast for DSP ICs by Type—Consumer Applications



Source: Dataquest (December 1993)
G3006136

Table 4-2
Comparison of Audio and Video Applications for DSP

Audio Applications for DSP	Video Applications for DSP
Recorded and transmitted audio	Recorded and transmitted video
Compression	Compression
Special effects	Special effects
MPEG audio	MPEG video (HDTV, among others)
Speech recognition	Image recognition/machine vision
Music/sound synthesis	
Voice communications	Video teleconferencing
Noise cancellation	Ghost cancellation

Source: Dataquest (December 1993)

Chapter 5

Companies, Products, and Competitive Issues

At this time, the major suppliers of semiconductors for DSP are quite different from the major suppliers of semiconductors for ASP. As Table 5-1 shows, the ASP supplier ranking is dominated by Japanese suppliers of consumer entertainment equipment, while the top five suppliers of semiconductors for DSP are North American suppliers more tuned to computer and communications markets. The opportunity presented by DSP has only been lightly tapped by the Japanese companies involved in consumer products. This has been changing, of course, and as DSP becomes more prevalent in home entertainment (beyond the CD and minidisc players) the Japanese suppliers will be found in the top ranks of DSP.

Table 5-1
Top Five Suppliers—Analog SP, Digital SP, and pDSP (Revenue Shown Is 1993 Estimate)

Top Five Suppliers to ASP ($9 Billion Market)	Top Five Suppliers to DSP ($4 Billion Market)	Top Five Suppliers of pDSPs ($700 Million Market)
Philips	Texas Instruments	Texas Instruments
Toshiba	Motorola	AT&T
Sanyo	AT&T	Motorola
Matsushita	Analog Devices	Analog Devices
Sony	NEC	NEC

Source: Dataquest (December 1993)

Table 5-2 lists suppliers of some of the ICs used in DSP. Not all of these suppliers offer pDSPs or MPRs, or ASICs or ASSPs with DSP cores. Many offer only supporting devices but they still supply into the broad DSP market.

One of the defining products for DSP is the pDSP. Table 5-3 lists the 1992 market share and rankings for the top eight suppliers of pDSPs. Eighty-five percent of the pDSP market is supplied by North American vendors; Japan has nearly 14 percent of the market.

Table 5-4 shows the consumption and production breakdown by region for pDSPs. A strong growth in most regional markets mainly benefited North American suppliers. Figure 5-1 shows this information in a graphical format.

Table 5-2
Semiconductor Suppliers to DSP, by Product Type

Company	pDSP	DSP Functions	MPRs	Data Converters	Mixed ASIC	Telecom	Mass Storage
AMD		X	X	X		X	
AMI		X					
AT&T Microelectronics	X				X	X	X
Actel Corporation	X						
Analog Devices	X	X		X	X		X
Burr-Brown				X			
Cirrus Logic Inc.			X	X		X	
Exar Corporation					X	X	X
Fujitsu	X	X	X	X	X	X	X
GEC Plessey Semiconductors		X	X	X	X	X	X
Harris Semiconductor		X		X	X	X	
Hitachi	X	X	X	X		X	X
Hughes		X					
IIT			X				
IMP							X
ITT		X					
Intel Corporation			X			X	
LSI Logic Corporation	X		X				
Matsushita Electronics Co.		X	X	X		X	X
Mietec					X	X	
Mitel Semiconductor						X	
Mitsubishi Electric			X	X		X	X
Motorola Semiconductor	X		X	X		X	X
NCR Microelectronics		X	X	X	X	X	X
NEC Corporation	X		X	X		X	X
National Semiconductor			X	X	X	X	X
Oki Semiconductor			X	X		X	
Philips Electronics		X	X	X		X	
Raytheon Semiconductor		X					
Rockwell International		X	X			X	
S3			X				
SGS-Thomson Microelectronics		X	X	X	X	X	X
Samsung Electronics			X	X		X	
Sanyo	X			X		X	
Sharp	X		X			X	
Siemens AG			X	X	X	X	
Sierra Semiconductor			X	X	X	X	X

(Continued)

Table 5-2 (Continued)
Semiconductor Suppliers to DSP, by Product Type

Company	pDSP	DSP Functions	MPRs	Data Converters	Mixed ASIC	Telecom	Mass Storage
Signal Processing Technologies		X		X			
Silicon Systems					X	X	X
Sony Corporation			X	X			X
Texas Instruments	X		X	X	X	X	X
Toshiba Corporation	X	X	X	X		X	
Weitek		X	X				
Winbond Electronics			X			X	
Yamaha				X			
Zoran	X	X					

Source: Dataquest (December 1993)

Table 5-3
Market Shares for Programmable DSP Suppliers

1992 Rank	1991 Rank	Company	1992 Market Share (%)	1992 Revenue ($M)	Percentage Change 1992/1991
1	1	Texas Instruments	38.5	171	20
2	3	AT&T	23.6	105	218
3	2	Motorola	14.2	63	58
4	6	Analog Devices	8.8	39	95
5	5	NEC	5.0	22	5
6	4	Fujitsu	4.7	21	-9
7	7	Toshiba	1.6	7	0
8	8	Sanyo	1.4	6	50
		Others	2.2	10	25
		Total	100.0	444	48

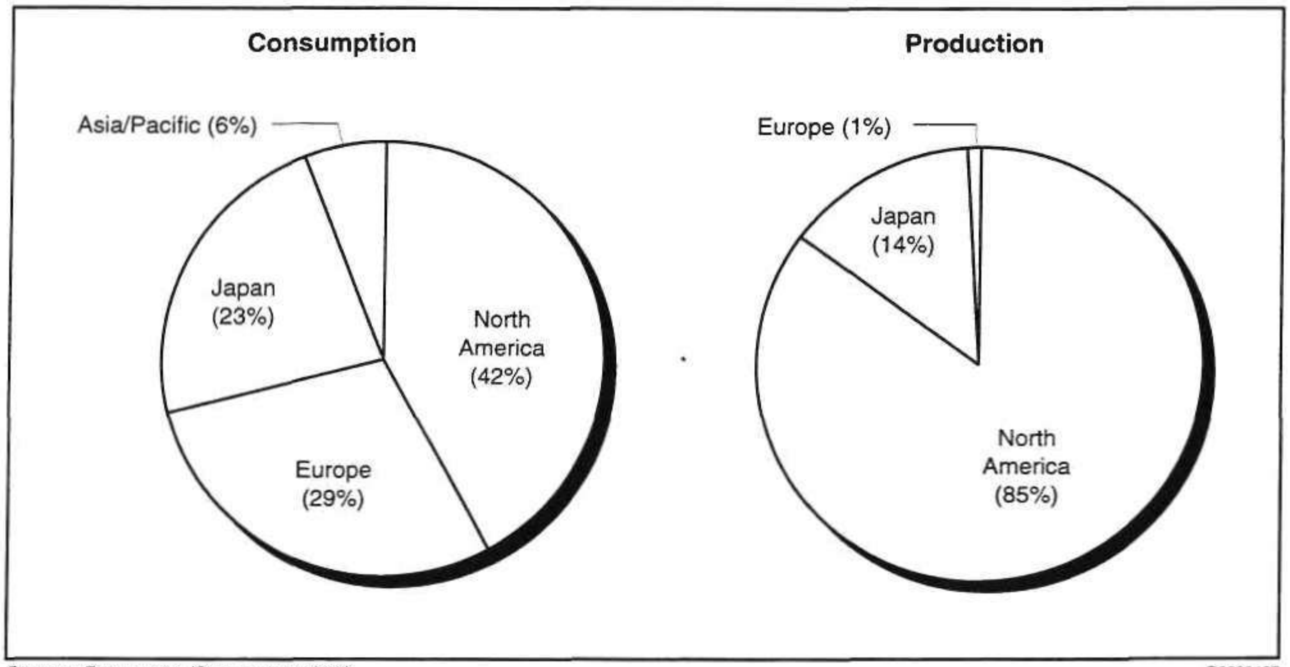
Source: Dataquest (December 1993)

Table 5-4
Comparison of 1992 Programmable DSP, Production and Consumption by Region

	Consumption			Production		
	($M)	Percentage of Total	1991-1992 Growth (%) ($M)	Percentage of Total	Percentage of Total	1991-1992 Growth (%)
Japan	102	23.0	5.2	61	13.7	-1.6
North America	184	41.4	54.6	379	85.4	59.9
Europe	130	29.3	85.7	4	0.9	NA
Asia/Pacific/ROW	28	6.3	115.4	0	0	NA
Total	444	100.0	48.5	444	100.0	48.5

N/A = Not applicable
Source: Dataquest (December 1993)

Figure 5-1
1992 pDSP Consumption and Production by Region



Source: Dataquest (December 1993)

The consumption and production pattern by region for pDSPs is very similar to that of data converters. Despite the fact that data converters are quite different products from very different suppliers, the regional patterns are similar because they are both fundamental to DSP. Table 5-5 compares these two product types by region.

The similarities point to the fact that pDSPs and general-purpose data converters penetrate the same higher-cost markets. Neither pDSPs nor individual data converters are found in the many cost-sensitive products, such as digital cordless telephones that use highly integrated dedicated solutions.

Table 5-5
Comparison of Programmable DSP and Data Converters, Production and Consumption by Region

	Consumption		Production	
	pDSP Percentage of Total	Data Converters Percentage of Total	pDSP Percentage of Total	Data Converters Percentage of Total
Japan	23	22	14	16
North America	42	43	85	78
Europe	29	21	1	5
Asia/Pacific/ROW	6	14	0	1
Total	100	100	100	100

Source: Dataquest (December 1993)

Appendix A
Selected DSP News of 1993

January

3DO Unveils Technology for New Consumer Electronics Standard
The 3DO Company demonstrated what it hopes would be a new standard in consumer electronics, the 3DO Interactive Multiplayer. The system was to be available in the fall and offer users interactive use of software and the ability to play music, video, and photo CDs. 3DO Interactive Multiplayers can animate up to 64 million pixels per second at peak, which helps images move smoothly without any jerkiness or interruption.

Fujitsu Develops 24-Bit Floating-Point DSP Chip
Fujitsu Ltd. announced the development of a 24-bit floating point DSP for high-end audio applications. Designed using a 0.8-micron process, the MB86223 is 25 percent faster than its predecessor, and can execute both floating- and fixed-point calculations, making possible development of audio equipment with a variety of sound effects.

February

TI and C-Cube to Jointly Develop Digital Compression Products
Texas Instruments and C-Cube Microsystems announced that they agreed to jointly develop ICs for audio and video compression. The agreement included technology and product development exchanges. Applications for the new ICs included digital CATV, HDTV, and CD-based consumer and multimedia products.

NEC to Sample Ship Audio DSP Chip
NEC Corporation was to begin sample shipping an audio DSP that makes possible advanced sound field control functions. The MicroPD6383GF integrates a 24-bit data bus, a 24-bit x 24-bit parallel multiplier, a 44-bit arithmetic logic unit, and a 44-bit accumulator to process audio signals. The new DSP supports audio equipment featuring surround, expander/compressor, and karaoke functions.

New Entrants to Development of Digital Mobile Phone Market
Sharp Corporation planned to enter the digital mobile phone market, in addition to Matsushita and Nokia of Finland. All three contracted with Kansai Digital Phone (KDP) to develop digital terminals.

HDTV Updated
The U.S. Federal Communications Commission was not hurrying its decision to announce an HDTV standard, and meetings were held in Washington, D.C. to discuss the current status of the next great step in broadcast television since color. The contenders were AT&T/Zenith and NBC/Sarnoff Labs, with entries from Philips in Europe and NHK of Japan

making things interesting. The studies were partly on behalf of the National Association of Broadcasters, which was concerned about quality and interference issues. Digital compression algorithms offered by General Instrument had already found support from TeleCommunications Inc., a large cable TV operator, which was to use them to expand channel-handling capacity tenfold on its systems. Hewlett-Packard announced its support for AT&T and Zenith, and TI announced its support of NBC and the David Sarnoff Labs.

TI's cDSP Becomes Available

TI announced availability of a 32-bit floating-point DSP core as part of its customizable DSP (cDSP) capability for systems that exceed 16-bit DSP requirements. The new 32-bit DSP was object code-compatible with TI's TMS320C30.

March

Sierra Announces Solutions for DECT Developed with National

Sierra Semiconductor announced second-generation silicon solutions supporting the DECT standard, resulting from a joint development effort with National Semiconductor. The complementary solutions interface at ARi1 (Advanced Radio Interface-1), which defines the signaling protocol between the radio transceiver and the digital processing portions of a DECT system.

Spectrum Teams with TI and IBM

Spectrum Signal Processing announced an agreement with TI and IBM to develop a suite of multimedia products for the PC using the MWave standard. Under the program, Spectrum and TI were to work together during the next two months to design, develop, and test the first in a family of boards using MWave. MWave-based products exploit the use of DSPs that provide a wide range of functionality, including integrated modems, fax, voice mail, audio, and MIDI. MWave products will do battle with dedicated single-function fax/modem and sound plug-in boards.

Toshiba and Matsushita Electric Tie Up with Sun Soft

Toshiba and Matsushita announced an agreement with Sun Soft for multimedia technology for outputting text data in synthesized sounds in Japanese on a workstation by the end of 1993. Used for phone-based data retrieval, the technology is likely to be seen on the "Solaris Live" workstation multimedia environment being developed by Sun Soft. Plans also call for development of audio/visual equipment control technology, which will enable VCRs and disc players to be controlled in an integrated manner.

ATR Establishes Voice Translation Lab

Advanced Telecommunications Research Institute International (ATR) established the ATR Voice Translation Communications Research Laboratory, which will work on a seven-year project to research and develop natural, interactive translation technology and natural voice processing technology to enable the immediate voice translation of any conversation. The $136.8 million project was to be funded 70 percent by the Japan Key Technology Center and 30 percent by private sources.

May

Motorola Introduces 40-MHz, Low-Voltage 24-Bit DSP56L002

Motorola's Microcontroller Technologies Group introduced its new DSP56L002 24-bit general-purpose DSP, which operates at 3.3V, making it optimum for battery-operated and portable applications. Initial target markets were telecom, computers, and consumer electronics such as portable digital audio products.

MCT Introduces Video Manager Plus

Media Computer Technologies Inc. (MCT), introduced VM+, an ASIC that supports full-motion video in NTSC, PAL, or CCIR-601 formats and accepts YUV or RGB digital video streams as well as audio. MCT said the true 24-bit architecture provides broadcast-quality video, compared to the 16-bit architectures that provide lesser-quality TV-grade video. MCT established an OEM relationship with the Hyundai and others, which it would not disclose.

Creative Technology Licenses QSound

Archer Communications Inc., the Canadian maker of the QSound technology, and Creative Technology, makers of the Sound Blaster, worked out a deal where Creative could incorporate QSound technology in chipsets and sound cards in at least three years. QSound is essentially a surround sound system used to enhance or "sweeten" the audio mix by placing sounds outside the normal listening area. Creative Technology expects to soon build the QSound technology into its SoundBlaster 16 audio cards.

Creative Technology to Acquire ShareVision

Creative Technology and ShareVision Technology Inc. announced that they had executed a letter of intent providing for Creative's acquisition of ShareVision for about $11 million in cash. ShareVision, a privately held company in San Jose, California, had developed and recently introduced a video conferencing product that allows Macintosh users to communicate using video, voice, graphics, and data anywhere in the world over a single standard telephone line. Plans call for eventually porting the product to the PC environment as well.

NHK Develops Digital TV System

The Japan Broadcasting Corporation (NHK) announced development of a new digital TV system called AW-CDM. The system divides images into 64 segments and achieves superior transmission quality with reduced interference while reducing bandwidth requirements.

Cirrus Logic Adds Telephone Emulation to Chipset

Cirrus Logic Inc. announced its CL-MD9624ECT telecom chip for personal and desktop PCs. Features included microphone input, audio drivers, and ADPCM compression. The two-chip solution was designed to enable manufacturers to build a complete data/fax/voice modem with telephone emulation. The digital signal microprocessor of the CL-MD9624ECT chipset was available in a 100-pin QFP or a 100-pin VQF.

Creative Technology Introduces Board with Speech Recognition

Creative Technology announced the SoundBlaster 16, which was to feature a bundled speech recognition program, VoiceAssist, which Creative said will allow the customization of any Windows application with voice commands, and provide API for application developers. The system supports up to 1,024 voice commands per application, with a maximum of 256 active words at a single time. VoiceAssist uses a speech recognition engine, VProCommand, developed by Voice Processing Corporation of Cambridge, Massachusetts.

SPEA Software AG Acquires Video Seven

Video Seven announced that it would become a wholly owned subsidiary of its principal technology provider and minority shareholder, SPEA Software AG. SPEA is a player in the high-end segment of the graphics accelerator market. SPEA plans to intensify the differentiation of the Video Seven product line with superior software. Video Seven has developed and marketed graphics products since 1983. Video Seven was to soon make its formal debut in the multimedia market with Media FX, a 16-bit audio board that used sampling technology.

NTT Mobile Develops Codec Technology for Digital Cordless Phones

NTT Mobile Communications Network Inc. developed LD-CELP, a half-rate voice codec technology for use with digital cordless telephones. The Japanese Ministry of Posts and Telecommunications (MPT) in April decided that digital cordless telephones would use a PCM method with a data transfer rate of 32 Kbps.

MTEL and Motorola Test New Integrated Cellular Telephone/Pager

Mobile Telecommunication Technologies Corporation announced that SkyTel Corporation, its principal subsidiary, and Motorola Inc. entered into an agreement to market-trial a device that combines Motorola's MicroTAC cellular phone with a numeric pager built in. Trial testing of the MicroTAC RSVP product was expected to commence in May in Chicago and Washington, D.C.

Zoran Introduces TV Ghost Canceler Chipset

Zoran Corporation announced a three-device chipset designed to eliminate TV picture "ghosts" because of reflections of the broadcast signal. "Ghost" cancellation depends on a multitap digital filter to provide the delay and magnitude to effectively cancel the "ghost" signal. At 648 taps total, this chipset has the highest tap count of any ghost-canceling solution offered. With this many taps, the chipset performs the equivalent of 18 billion operations per second.

IBM Announces MWave-Based "Audio Solution Board"

IBM announced that the Audio Solution Board was available to OEMs. The Audio Solution Board offered an integrated multimedia single-card solution with support for CD-ROM drives. Based on MWave DSP technology, the Audio Solution Board offered MCI-MPC and IBM's Multimedia Presentation Manager/2 (MMPM/2) compatibility. The 16-bit board offered eight-note polyphonic MIDI sample-based synthesis, wavefile record and playback at sampling rates up to 44.1 kHz, real-time 4:1 sound data compression, jacks for standard input/output devices, and a joystick port.

Sierra Semiconductor Adds QSound Feature to Family of Aria Chipsets

Sierra Semiconductor and Archer Communications Inc. announced that Sierra would license the QSound Virtual Audio technology for integration with its DSP-based family of Aria chipsets. Under the agreement, Sierra would sublicense QSound's Virtual Audio technology to Sierra's customers that are manufacturing boards based on the Aria chipset.

Video Seven Announces 16-Bit Audio Board

Video Seven introduced the Media FX, a 16-bit sound board that utilized the Soundscape chipset from Ensoniq (ICS part).

Tektronix and TV/COM International Announce Technology Partnership

Tektronix Microelectronics and TV/COM International announced a technology development agreement under which the companies would jointly develop solutions for low-cost digital receivers to be used in upcoming television compression systems. The ICs would be used in satellite broadcast applications including Direct Broadcast Satellites (DBS), Television Receive Only (TVRO), and professional and affiliate receive operations.

June

3DO Misses Summer Deadline but Says It Is Ready for Fall Launch

The 3DO Company announced that 302 software companies signed license agreements to develop software for the 3DO Interactive Multiplayer and said it will be ready for the 1993 Christmas season. Previously the company had said that products would be ready by summer. 3DO concluded a successful initial public offering, raising more than $48 million even without product. Panasonic planned a campaign for its REAL 3DO Interactive Multiplayer in the fall, featuring national TV spots and print advertising, a 10-city mall tour, in-store kiosks, and other promotional displays.

Pioneer Develops Multistandard Compressed Image Decoder Chipsets

Pioneer Electronic Corporation announced it developed the CD 1100 series of compressed image decoder chipsets that comply with the MPEG1, JPEG, and H.261 international standards and are capable of 25-Mbps decoding. CD 1101 is a spatial decoder, CD 1102 is a temporal decoder, and CD 1103 is a video formatter. CD 1103 is still under development. The new chipsets are to be used in such applications as CATV, packaged media (CD-ROM, among others), video cameras, videoconferencing, and video phones. Pioneer is also developing a version that will comply with the forthcoming MPEG2 standard. The chipsets were developed at the Pioneer Digital Design Centre Ltd. in the United Kingdom and will be manufactured in Japan.

Laser-Pacific and Philips Enter Agreement

Laser-Pacific Media and Philips Interactive Media of America (PIMA) announced that they entered into a long-term agreement calling for Laser-Pacific to provide MPEG digital compression services for PIMA and other CD-I developers and authors worldwide. The agreement was the first major result of Laser-Pacific's recently announced joint development effort with IBM Research to develop a digital compression application for the IBM POWER Visualization supercomputer system based on the international MPEG standards.

Sega Licenses Cinepak from SuperMac

SuperMac Technology Inc. announced that Sega of America Inc. would enhance its Sega CD video game platform with Cinepak for Sega, a custom version of SuperMac's advanced video compression technology, developed and licensed exclusively for Sega for use in all current and future Sega game systems. Sega's custom implementation of Cinepak will allow it to add high-fidelity, full-screen, full-motion video to upcoming interactive entertainment products. Cinepak is a video compression-decompression scheme that enables each video frame to occupy less disk space than usual, while retaining highly accurate colors and excellent image quality.

Sanyo and Thomson Announce Alliance and Plans for Imaging Chipsets

Sanyo Electric announced a wholly owned subsidiary devoted to multimedia, and its alliance with France's Thomson to make semiconductors for the new unit. Sanyo Marbic Media was to develop optical disks, CD-ROMs, and the MiniDisc-based software, mainly music and game programs. Sanyo produces 1.5 million music CDs per month on an OEM basis. The new company would take over this business, and planned to ship 2.5 million music CDs per month. Its work with Thomson was to focus first on ICs for G3-and-up (high-speed) fax machines, and video compression for applications such as CD-I-based karaoke, games, navigation systems, and multimedia computers. Product may appear as early as the first quarter of 1994.

MPC 2 Multimedia PC Standard Unveiled

The Multimedia Personal Computer (MPC) Marketing Council introduced the MPC Level 2 specification, which expands industry-standard minimum requirements for multimedia systems to 16-bit (or CD-quality) sound, a double-speed CD-ROM drive, and multisession Photo-CD capability. Initial gripes were with 8-bit sound and transfer rates of CD-ROM.

Kawasaki Steel Buys into Wireless Access

Kawasaki Steel purchased a 10 percent equity share of Wireless Access. Both companies agreed to jointly develop chips for wireless telecommunication devices. Each is to develop ASIC technology and jointly market ICs. Manufacturing is to be handled by Kawasaki. Wireless Access, just two years old and based in California, is involved in manufacturing ICs for telecom and PC cards.

Roland and Silicon Graphics Launch Virtual Reality Project

The Roland-developed RSS surround sound system was linked up with the Nihon Silicon Graphics' 64-bit RISC-equipped Indigo workstation and MIDI interface. The companies expected to have a prototype sound and image virtual reality system ready by October and planned to have an imaging system finished by 1994.

DSP Group Working with Microsoft and Compaq

DSP Group announced that it was working with Microsoft and Compaq to develop TrueSpeech for Windows, an application of the audio file compression technology developed by DSP Group.

NTSC Digital VCR Standards Being Worked Out

Matsushita, Sony, Philips, SGS Thomson S.A., Hitachi, Toshiba, Mitsubishi, Sharp, Sanyo, and JVC announced agreement on specifications for consumer digital VCRs for HDTV. The companies were to cooperate on developing specifications for recording on digital HDTV VCRs. The specifications were to be based on digital NTSC or SD specifications.

July

Motorola Introduces 16-Bit pDSP for Digital Cellular Applications

Motorola introduced the DSP56166, a 16-bit fixed-point pDSP IC designed specifically for U.S. and Japanese digital cellular voice processing. It has a clock speed of 60 MHz, an on-chip 14 bit delta-sigma codec (A/D and D/A conversion), PLL, and on-chip emulation.

August

Mitsubishi Introduces IC for Simulating Reverb

Mitsubishi announced its M65841SP device to be marketed to electronic musical instrument and surround sound manufacturers. The 0.8-micron line rule IC integrates five audio delay circuits with a frequency sampling rate of 250 kHz and contains an input-output low-pass filter, AD/DA converters, and a 40KB SRAM. The price was about $10 each. Mitsubishi said it would ship about 100,000 units a month by December.

Mitsubishi and AT&T Discuss HDTV Devices

Mitsubishi and AT&T announced that they were talking about joint development of ICs for HDTV in the United States. Mitsubishi had already developed the chips for the Japanese version of HDTV.

Star Semiconductor Announces SPROC-1200 Family of pDSPs

Star Semiconductor introduced a new family of pDSPs with two 24-bit fixed-point on-chip general-purpose processors. This device was software-compatible with the four-pDSP SPROC-1400 IC.

September

Sharp Introduces 24-Bit Array Processor

The LH9124L IC was a specialized 24-bit array DSP IC intended for ultrasound and tomography (such as CAT) applications. The architecture featured six on-board multiplier/accumulators and eight adders with 64-bit internal precision. Twenty-six built-in algorithms provided digital filtering, spectrum analysis, correlation, adaptive filtering, and compression functions.

Spectrum Signal Processing and Motorola Agree

Spectrum Signal Processing and Motorola announced an agreement on boards and software for DSP-based telecommunications boards.

October

Media Vision and Analog Devices Form Partnership

Media Vision and ADI formed an alliance to develop the next generation of semiconductors for PC multimedia applications. Media Vision was to have access to ADI's core DSP technology, which it was to use in its next generation of multimedia audio products.

C-Cube Announces VideoRISC Compression Architecture (VCA)

C-Cube Microsystems introduced the first two implementations of the VideoRISC Compression Architecture, the CLM4600 Broadcast MPEG2 Video encoder and the CLM4500 Consumer MPEG1 Video encoder. Both products allowed video compression into MPEG in real time. VCA was designed expressly for real-time compression and decompression and supported a wide variety of compression standards. These chipsets were based on a 32-bit video-specific RISC architecture.

Xicor Licenses PINE DSP Core from DSP Semiconductors

The low-voltage, low-power 16-bit fixed-point PINE DSP core was to be combined with Xicor's nonvolatile reprogrammable memory technology to DSP ICs aimed at the mobile computing and communications markets.

AT&T Licenses QSound's Virtual Audio Technology

QSound's Virtual Audio Technology was ported to the AT&T VCOS Multimedia Audio Library and the DSP3200 pDSP family. QSound is a multidimensional sound localization technology that provides an expanded sound field using only two-channel stereo audio systems.

Dolby Labs and Zoran Technology Alliance Results in New DSP

Zoran Corporation announced the ZR38000 fixed-point DSP family with an architecture designed around the decoding needs of the Dolby Laboratories' AC-3 digital surround sound algorithm. The first products using this DSP were to be Dolby Labs' professional theater decoders. In addition to the general-purpose ZR38000 DSP, a ZR38500 ASSP, optimized for six-channel Dolby AC-3 decoding, is to be found in DSP-based Dolby home theater decoders in 1994. A set of two-channel ASSP variations, the ZR 38501 and the ZR38511, were optimized for AC-3 or MPEG audio decoding, respectively.

Optivision Announces Real-Time MPEG Encoder

Optivision announced a real-time image and video compression board that used the C-Cube VideoRISC Compression Processor. The board, dubbed the Optivideo board, used one ISA slot and was intended for video authoring applications.

November

Microsoft Teams with Spectron Microsystems for DSP API

Microsoft and Spectron Microsystems teamed on the Microsoft DSP software architecture. This architecture was a combined host and DSP operating system to allow developers to take advantage of any pDSP in a PC. This DSP API was to allow multiple software developers to use the same hardware for DSP services. The Microsoft DSP API was to compete with MWave and VCOS.

Best Data Announces Third-Party MWave Board

Best Data Products announced a multiple task board using MWave chips from IBM. The board offered the functions of a CD-ROM interface, a fax/ modem, telephone answering machine, and a sound card. Future software upgrades are to allow for V.Fast, voice recognition, 3-D sound, video teleconferencing, and virtual reality interface.

For More Information...

Gary Grandbois, Senior Industry Analyst................................(408) 437-8251
Via fax..(408) 437-0292

Dataquest®
a company of The Dun & Bradstreet Corporation

Dataquest®

a company of The Dun & Bradstreet Corporation

Corporate Headquarters
Dataquest Incorporated
1290 Ridder Park Drive
San Jose, California 95131-2398
United States
Phone: 01-408-437-8000
Facsimile: 01-408-437-0292

Dataquest Incorporated
550 Cochituate Road
Framingham, Massachusetts 01701-9324
United States
Phone: 01-508-370-5555
Facsimile: 01-508-370-6262

Invitational Computer Conferences (ICC)
3990 Westerly Place, Suite 100
Newport Beach, California 92660
United States
Phone: (714) 476-9117
Facsimile: (714) 476-9969

Dataquest Japan Limited
Shinkawa Sanko Building
1-3-17, Shinkawa, Chuo-ku
Tokyo 104
Japan
Phone: 81-3-5566-0411
Facsimile: 81-3-5566-0425

Dataquest Korea
Trade Tower, Suite 3806
159 Samsung-dong
Kangnam-gu, Seoul 135-729
Korea
Phone: 011-82-2-551-1331
Facsimile: 011-82-2-551-1330

European Headquarters
Dataquest Europe Limited
Roussel House, Broadwater Park
Denham, Uxbridge
Middlesex UB9 5HP
England
Phone: 44-895-835050
Facsimile: 44-895-835260/1

Dataquest GmbH
Kronstadter Strasse 9
8000 Munich 80
Germany
Phone: 011-49-89-930-9090
Facsimile: 011-49-89-930-3277

Dataquest Europe SA
Tour Gallieni 2
36, Avenue du General de Gaulle
93175 Bagnolet Cedex
France
Phone: 011-33-1-48-97-3100
Facsimile: 011-33-1-48-97-3400

Representative Agencies in
Bangkok, Hong Kong,
Kronberg, North Sydney,
Singapore, Taipei, and Tel Aviv

NO1SEMIWW SEMIWWFR9302 BH: 1
Mr. Clark Fuhs
Dataquest Incorporated
1-1100
****
SJ - INTERNAL DISTRIBUTION
****

Dataquest®

Dataquest Perspective

Semiconductors

Semiconductors Worldwide

In This Issue

An Update on Mixed-Signal Design
Mixed-signal design may be one of the potential growth areas in the electronic design automation industry. In this *Dataquest Perspective,* Dataquest examines the mixed-signal and analog design market and reports on recent developments and trends in this area.
By Sharon Tan

(Reprinted with the permission of Dataquest's Electronic Design Automation Worldwide service.)

An Update on Mixed-Signal Design

As analog and digital functionalities become more closely intertwined, electronic design automation (EDA) tools supporting mixed-signal design are growing in popularity. Despite the fact that a standard analog hardware description language (HDL) does not exist, test methodologies have not been developed, and model availability and accuracy is somewhat limited, the analog design market continues to grow, reaching nearly 18 percent year-to-year growth in revenue for 1992.

Traditionally, design engineers have dealt with the analog and digital portions of their designs separately and have not treated the mixed-signal design problem as a unified whole. Only recently have vendors introduced products that enable true mixed-signal simulation, whether the simulation method involves coupling a digital simulator with a Spice-based analog simulator, or designing a mixed-signal simulator that operates in a single, unified environment. With the rapid growth in telecommunications, computers, and consumer electronics driving the demand for mixed-signal integrated circuits and printed circuit boards, the need for mixed-signal design tools could not be greater.

The Mixed-Signal Market

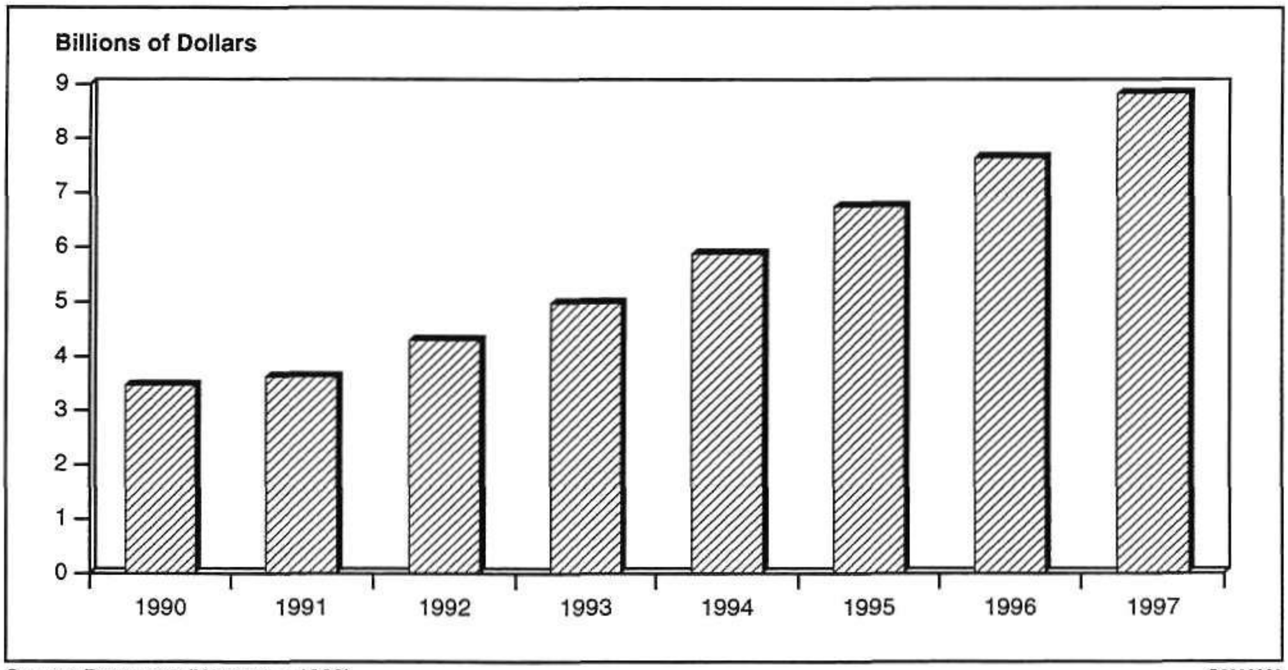
A mixed-signal design combines analog and digital functions on a single integrated circuit (IC) or printed circuit board (PCB). Although mixed-signal PCB designs comprise approximately 20 percent of board design starts, this article concentrates mostly on mixed-signal ASIC and full custom IC design. Mixing analog and digital functions on a single IC is a logical way to minimize the necessary PCB area, reduce pin count, minimize connections, and add such features as digital signal processing and audio

Dataquest®
a company of The Dun & Bradstreet Corporation

Program: Semiconductors Worldwide
Product Code: SEMI-WW-DP-9306
Publication Date: December 27, 1993

processing. The worldwide market for mixed-signal ICs reached $4.3 billion in 1992, comprising 42.6 percent of the $10.1 billion monolithic analog IC market. Figure 1 shows historical and forecast sales of mixed-signal ICs. Although revenue growth from 1991 to 1992 reached 18.7 percent, the market is expected to grow at a compound annual growth rate (CAGR) of 15.5 percent through 1997.

Figure 1
History and Five-Year Mixed-Signal IC Forecast



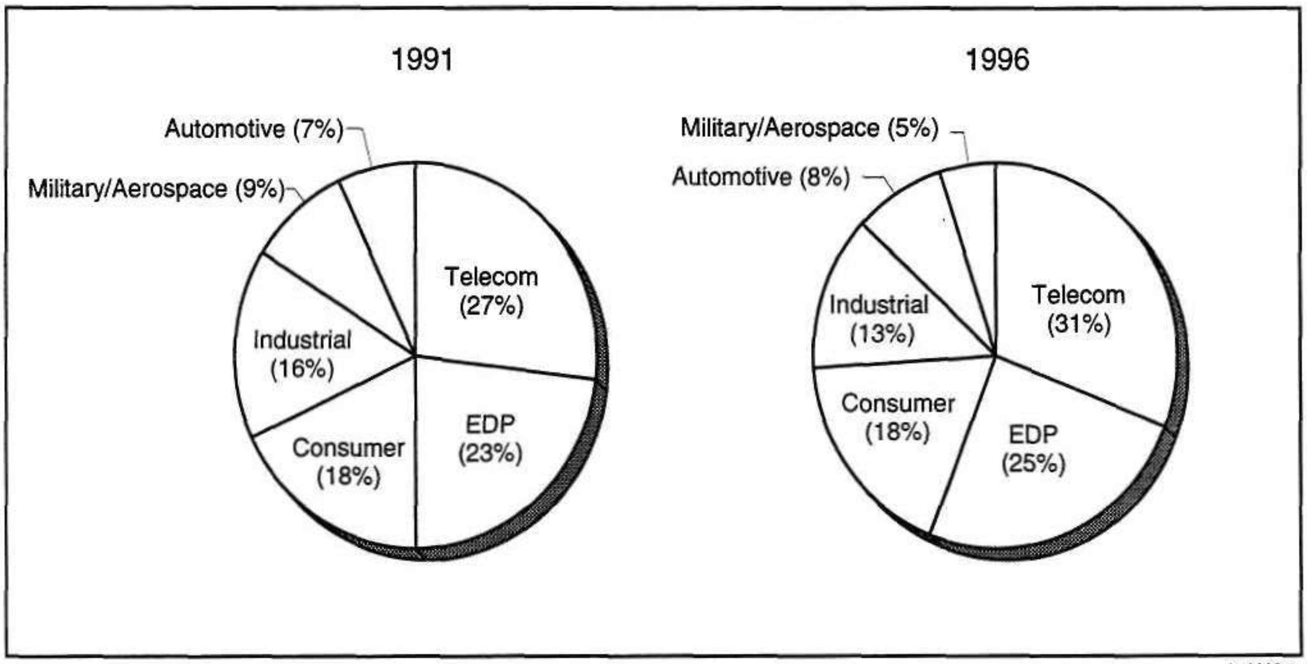
Source: Dataquest (November 1993) G3006063

Market Drivers

Dataquest divides mixed-signal semiconductor technology into six general application areas. These are telecommunications, electronic data processing (EDP), consumer, industrial, military/aerospace, and automotive. Revenue breakdown by these end market applications is shown in Figure 2. Typical products that employ mixed-signal circuitry include fax machines, modems, video processing equipment, speech processors, multimedia peripherals, power controllers, and computer storage devices.

The anticipated growth for mixed-signal circuitry is being driven primarily by the telecommunications, portable wireless communications, and EDP markets. Growth in the telecommunications market can be attributed to the expanding need for voice-processing/voice-messaging equipment, upgrading of analog line equipment in the central office market, and increasing use of new calling technologies such as predictive dialers.

Figure 2
Mixed-Signal Forecast, by Application Market, 1991 and 1996



Source: Dataquest (November 1993) G2002231

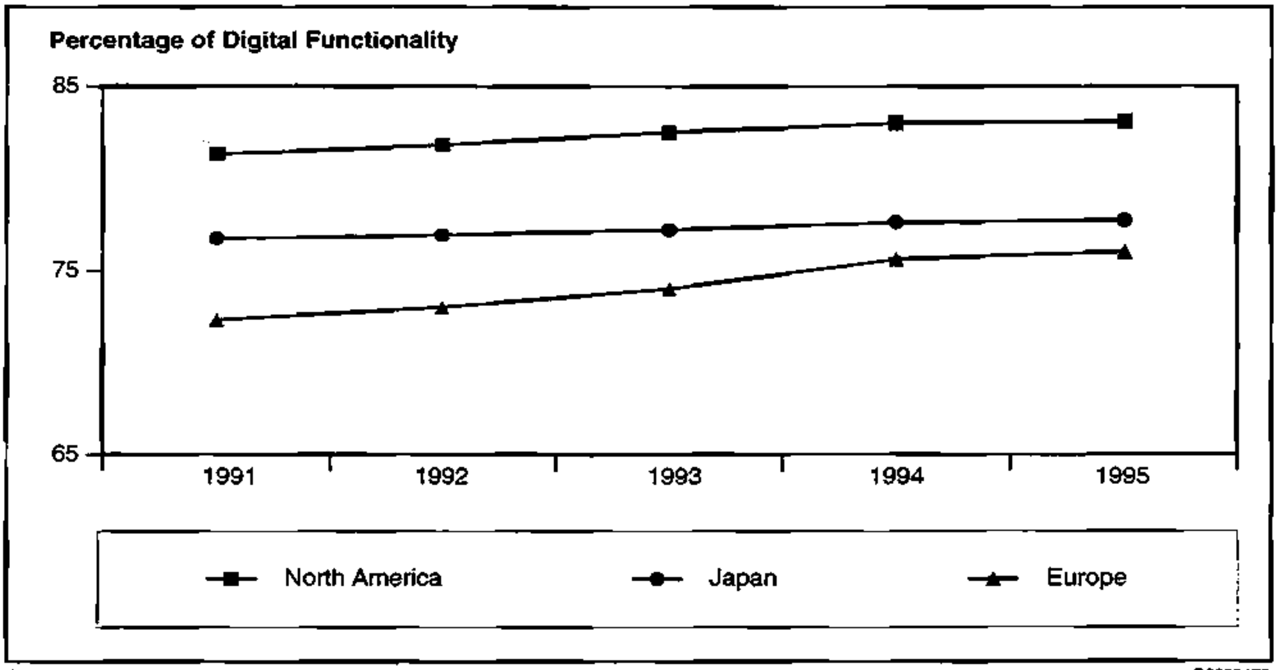
The electronic data processing market, in particular, mobile computing and storage needs, is also furthering the need for mixed-signal technology. Mobile computing, which requires the use of mixed-signal circuitry in miniaturized components, peripherals accessories, and disk drives, will have a 22 to 25 percent CAGR from 1992 to 1997. Growth in this market could also increase mixed-signal needs in communications peripherals for portable computing, including new modem and fax capabilities. Computers and multimedia products with enhanced human interfaces will also help drive mixed-signal sales.

Although retail consumer electronic sales have been sluggish, digital enhancements to entertainment and home appliances could spur strong sales for mixed-signal ICs. However, the demand for mixed-signal circuitry in the military applications market will be small, mainly because of the shrinking military budgets.

The Need for Mixed-Signal Design Tools

As shown in Figure 3, the percentage of analog content on a PCB is expected to continue to shrink, although not dramatically, through 1995. However, this picture does not reveal the whole story. Increasing circuit complexity, faster clock speeds, and tighter space requirements are driving the need for concurrent analysis of analog and digital functionality.

Figure 3
Percentage of Analog versus Digital Content for Printed Circuit Boards



Source: Dataquest (November 1993) G2002475

Market Impediments

While mixed-signal designs continue to proliferate the market, the availability of adequate design tools is becoming a major concern. In general, the mixed-signal design process is several steps behind the digital design process. The tools available to mixed-signal designers do not yet enable the productivity gains seen by the digital community. While simulation of digital designs is taking place at various levels of abstraction, many mixed-signal designs are still done at the transistor level using Spice or Spice-like simulators.

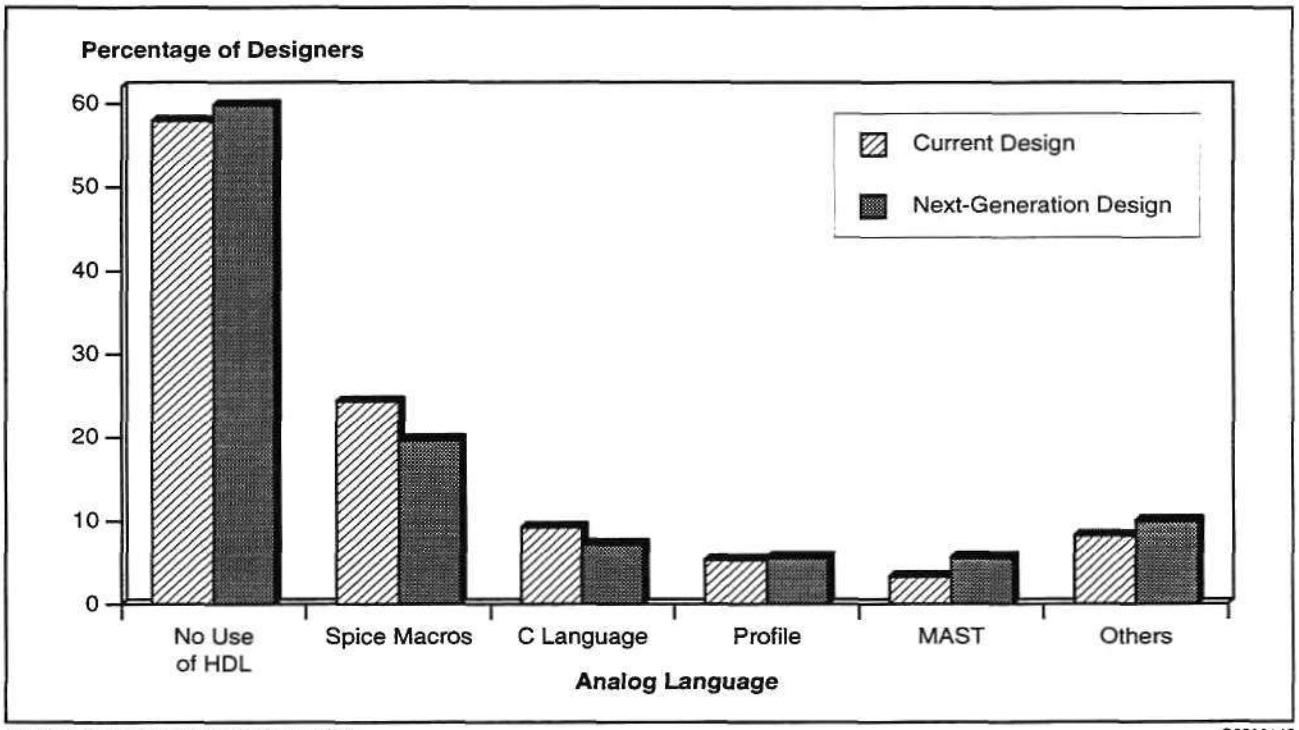
Mixed-Signal Design versus Digital Design

Mixed-signal tools lag digital design tools in the use of HDLs, synthesis capabilities, automatic place-and-route abilities, and test methodologies.

Hardware Description Languages

Widely accepted among digital designers is the use of high-level description languages to drive synthesis tools. Whereas hardware description languages such as VHSIC (Very High-Speed IC) hardware description languages (VHDLs) and Verilog have become commonplace among digital designers, the use of analog hardware description languages is limited. Nearly 60 percent of analog designers in North America and Europe do not use any HDL in their design implementations, *and* no clear analog HDL is being planned by the design community, as is shown in Figure 4.

Figure 4
Analog HDL Usage, Western World



Source: Dataquest (November 1993)

G3003145

Although Figure 4 indicates that the anticipated use of an analog HDL for next-generation designs is still small, the recently announced Analog VHDL International consortium could change this situation, although not in the near term. This consortium, in conjunction with the Institute of Electronics and Electrical Engineers, is trying to extend the VHDL standard to incorporate an analog HDL, thus accelerating the ability of EDA tool vendors to incorporate mixed-signal capabilities into their applications. In particular, the advent of a standard analog HDL might spur the development of analog models, one of the keys to mixed-signal simulation. The effects of these standardization efforts will probably not be felt in the near future, however. It is likely that a number of years will pass until a standard is completely hammered out, it becomes available to CAE vendors, and the tools get into the designer's hands.

Synthesis

Use of logic synthesis tools in the digital realm is popular among digital designers. The top-down design methodology was enabled by the emergence of logic synthesis technology, giving designers the ability to create gate-level structure from textual descriptions. To date, no analog synthesis tools are commercially available. It is expected that the first set of analog synthesis tools will be aimed at synthesizing fundamental analog blocks such as operational amplifiers or comparators. Full synthesis capability for analog circuits is still unknown.

Automatic Place-and-Route

Automatic place-and-route tools were among the first software tools available to digital designers, whose objective was to minimize chip area, interconnect lengths, and the number of pathways. Mixed-signal designers working with analog circuitry are faced with a different set of problems in place-and-route, namely crosstalk, coupling, impedance mismatches, and parasitics. While digital place-and-route helped to launch the growth of the digital ASIC design market, analog place-and-route tools, which must grapple with a wholly different set of design problems, have not enabled similar growth for the analog IC design market. Digital designers are realizing, however, that as feature sizes shrink and clock speeds increase beyond 33 MHz, electrical connections no longer operate as pathways that conduct signals from one device to another, and analog effects begin to creep into the digital layout problem. This realization might help to propel growth of analog place-and-route software, or at a minimum, automatic place-and-route tools that utilize analog analysis techniques.

Test Methodologies

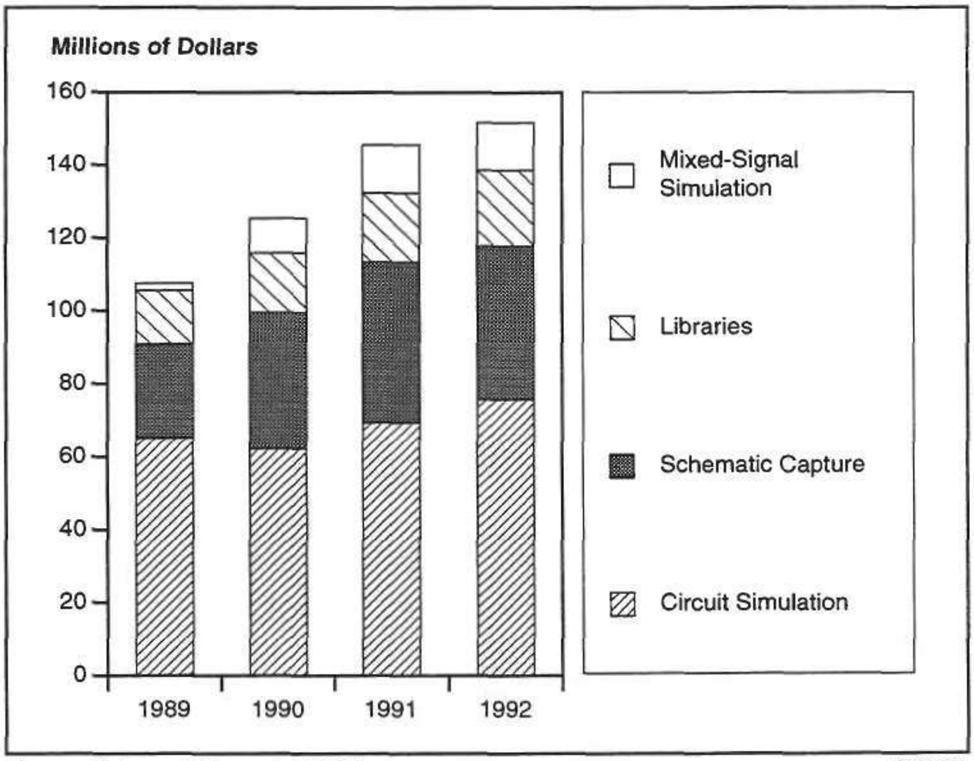
While numerous test methodologies, such as SCAN, BIST, and ATPG, exist for digital designers, analog circuits are usually tested by testing all of their specifications, an expensive and time-consuming task. While software such as Cadence's DANTES promotes test development and debug in conjunction with circuit design, effectively shortening test program development time, there still exists the need for most designers to test all specifications.

Analog Design Tools—An Overview

Analog design tools comprised $151.7 million, or nearly 20 percent of the $764.2 million worldwide electronic CAE market in 1992. Figure 5 shows the historical sales of analog design tools, segmented into different application areas. While revenue from digital design tools grew 9.1 percent from 1991 to 1992, revenue from analog design tools, which includes mixed-signal, only grew 4.2 percent. Much of the slow growth in analog tools can be attributed to lackluster sales of PCB analog tools, which fell 8.9 percent from 1991 to 1992. This contrasts to revenue from ASIC analog design tools, which grew 23.8 percent over that same period.

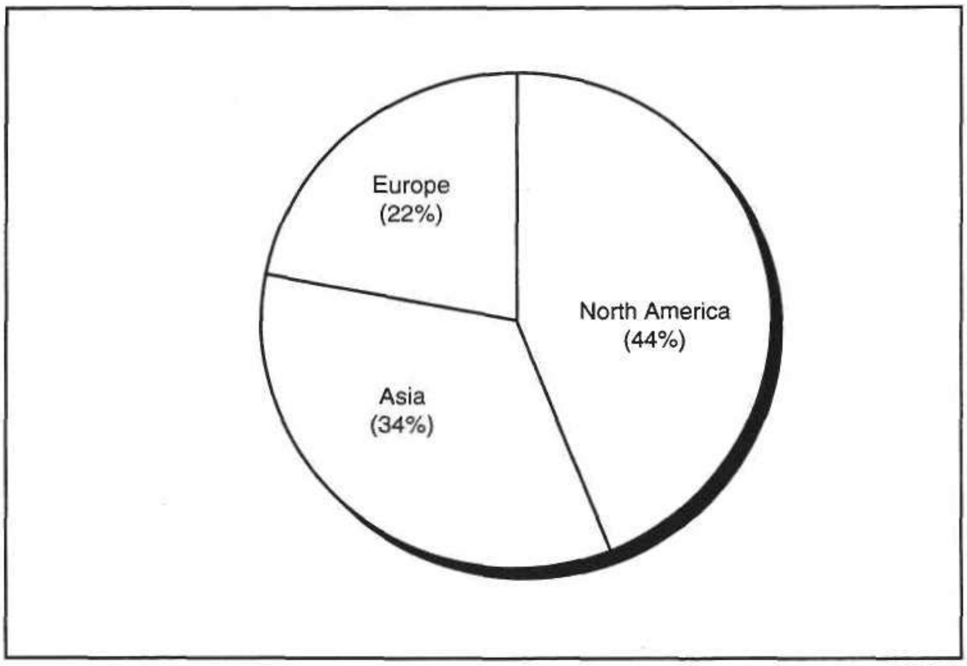
Figure 6 shows a breakdown of analog design tool revenue by region. North America consumed $67.1 million in analog tool sales in 1992, followed by Asia with $51.8 million in revenue and Europe with $32.8 million in revenue. Asia experienced negative growth in all areas, including a 9.1 percent drop in mixed-signal simulation tool sales in 1992. Europe reported a 7.7 percent decline in schematic capture revenue, while design verification tools grew 13.6 percent in 1992.

Figure 5
Historical Sales of Analog Design Tools



Source: Dataquest (November 1993)
G3006064

Figure 6
Breakdown of Analog Tool Revenue by Region, 1992

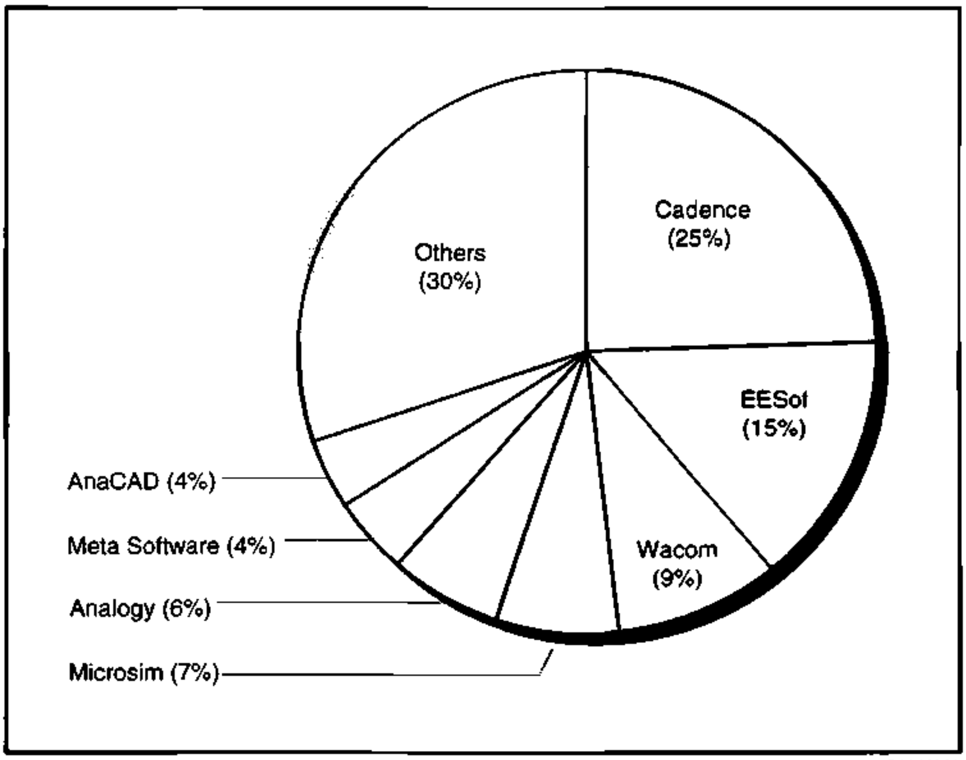


Source: Dataquest (November 1993)
G3006065

Mixed-Signal Design Tools—A Closer Look

Dataquest tracks mixed-signal design tools in two broad categories: design entry and design verification. Design entry tools, a $63 million market in 1992, consist of schematic capture software and analog libraries. Design verification tools, an $88.7 million market in 1992, include analog circuit simulation software, employed by analog and mixed-signal designers, and mixed-signal simulation software, used mainly by mixed-signal engineers. Market share of the top 7 analog tool vendors is shown in Figure 7, and a list of the top vendors and their respective sources of analog revenue is given in Table 1. Cadence tops the list with 24.5 percent share of the analog design market.

Figure 7
Market Share of Leading Analog Tool Vendors



Source: Dataquest (November 1993) G3006066

Design Entry Tools

Analog design entry tools include software used for analog and mixed-signal ASIC and board-level designs. This category reported $63 million in sales in both 1991 and 1992, with $42 million derived from schematic capture revenue and $21 million from analog library tool sales in 1992. Cadence and EEsof dominate the analog library market, whereas Cadence and Wacom combined make up nearly 60 percent of the analog schematic entry market.

Table 1
1992 Analog Design Revenue of Top Vendors

Vendor	Analog Design Revenue ($M)	Revenue Source: Design Entry	Revenue Source: Design Verification
Cadence	37.2	19.8	17.4
EEsof	22.0	11.0	11.0
Wacom	13.9	11.6	2.3
MicroSim	10.5	1.0	9.5
Analogy	9.6	1.1	8.5
Meta-Software	6.6	2.0	4.6

Source: Dataquest (October 1993)

Design Verification

Dataquest divides design verification tools into the categories of analog circuit simulation and mixed-signal simulation. Simulation software from both categories are used in mixed-signal design.

Circuit Simulation Software

Circuit simulators totaled $75.6 million in revenue during 1992. This subapplication encompasses most of the Spice-based simulators and the growing area of specialty simulators that are geared toward specific applications, such as switched-capacitor circuits. Table 2 shows the top players and their respective analog simulation offerings.

Table 2
Circuit Simulation Vendors and Product Offerings

Vendor	Circuit Simulation Products
AnaCAD	Eldo
Analogy	Saber
Cadence	Cadence Spice, Spectre
Contec Microelectronics	ContecSPICE
EEsof	OmniSys
Mentor Graphics	AccuSim
Meta-Software	HSpice
MicroSim	PSpice
Viewlogic	ViewSpice

Source: Dataquest (October 1993)

Mixed-Signal Simulation Software

The mixed-signal simulation market, which totaled $13.1 million in sales in 1992, remained nearly constant from 1991 to 1992, in sharp contrast to the 40.0 percent growth in revenue from 1990 to 1991. Low sales in this area might be attributed to the fact that mixed-signal design tools still do not enable the needed productivity gains. Some end users may be piecing together their own mixed-signal simulators, using internally developed versions of Spice with one of the digital simulators available on the market. It is not uncommon for mixed-signal designers to break a design specification into analog and digital blocks, design and implement each part independently, and then feed the results into a mixed-level simulator to address interface problems.

Mixed-signal simulators are of two types: "glued" or coupled simulators and native simulators. Glued simulators integrate a standalone digital simulator with a standalone analog simulator through a common interface or simulation backplane. In this scenario, the digital and analog simulators are usually from different vendors. Although this simulation method is popular among vendors, drawbacks include the significant amount of memory and time that it can take to run a simulation. In this scheme, the digital simulator is usually faster than the analog simulator and must backtrack and resimulate or wait for the analog simulator to catch up. Data must be exchanged without error and within a reasonable amount of time.

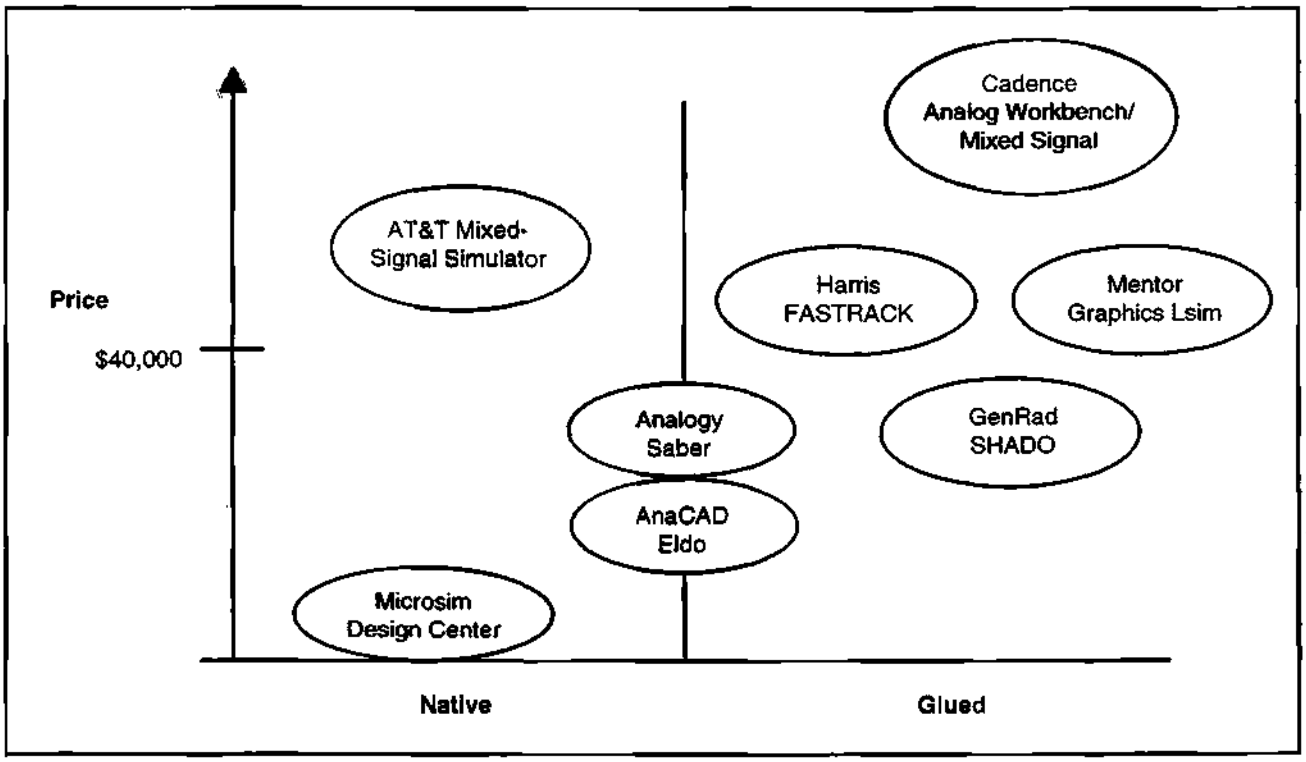
Native simulation incorporates analog and digital algorithms into a single simulation environment. Although this method enables the use of one common language to describe analog and digital circuitry and the ability to easily feed back information from the analog portion of the circuit to the digital portion and vice versa, there are drawbacks. Native simulators do not give designers the same flexibility as glued simulators. Many of them lack the full functionality and comprehensive model libraries that can be found with glued simulators. Figure 8 shows how some of the current vendors have positioned their products within the market.

The Future for Mixed-Signal Design Tools

Analog design tools are expected to be among the fastest growing areas for electronic CAE. While Dataquest anticipates electronic CAE to grow at a 12.7 percent CAGR from 1992 to 1997, analog design is forecast to grow at a 14.3 percent CAGR over that same period. Figure 9 contains a forecast of analog tool sales by subapplication. Mixed-signal simulation software is expected to outpace the growth of other tools, with a 21.5 percent CAGR through 1997.

Much of the increased demand for analog design tools, in particular, mixed-signal simulation tools, will be driven by growth in end-market applications such as portable computers, mobile communications, and voice processing equipment.

Figure 8
Mixed-Signal Simulation Scheme



Source: Dataquest (November 1993) G3006067

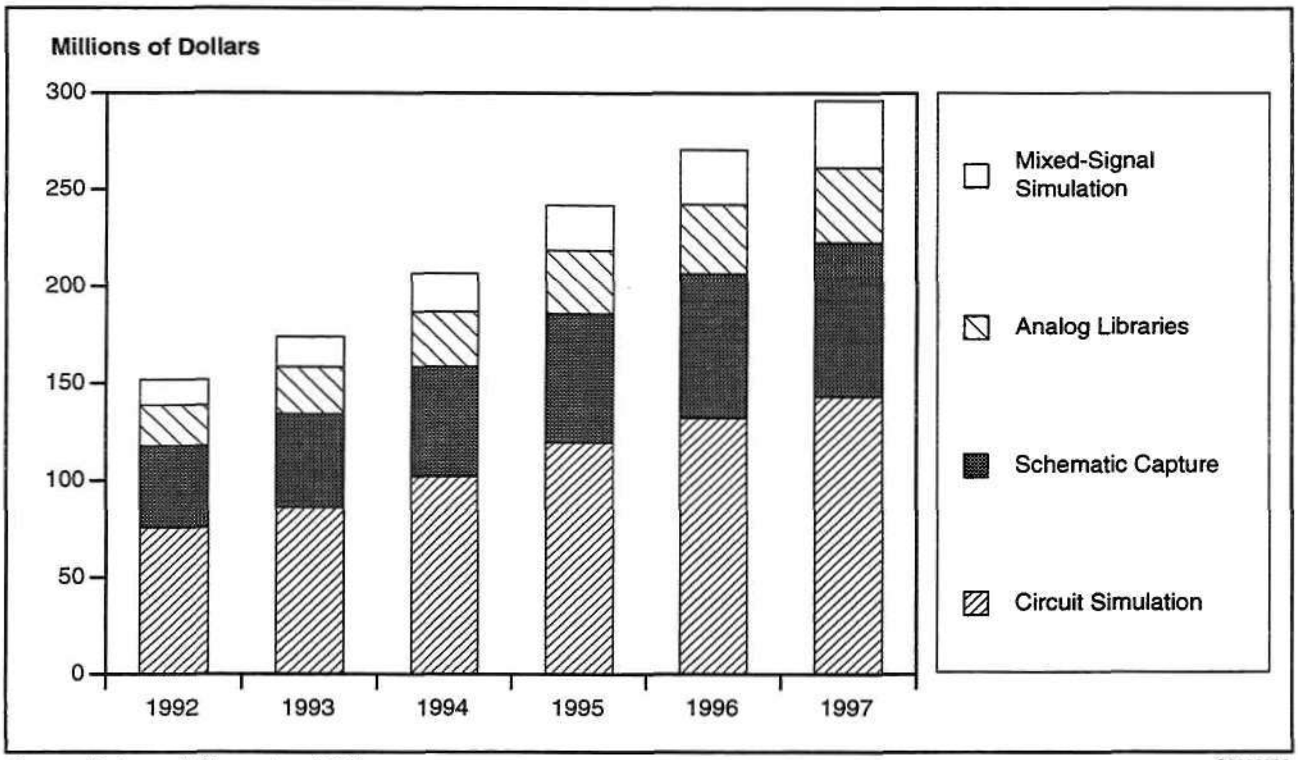
Dataquest Perspective

As mixed-signal circuitry becomes more commonplace in telecommunications equipment, computers, and consumer electronics, the need for analog and mixed-signal design software will continue to grow, outpacing growth of other electronic CAE tools. With this rapid proliferation of mixed-signal designs, the need for more effective, easy-to-use analog design tools could not be greater. EDA vendors can capitalize on the anticipated growth in mixed-signal design by addressing the following areas:

- True mixed-mode simulation than faster simulation speeds
- Extensive and accurate modeling capabilities
- Standardization of an analog HDL enabling top-down analog design and higher levels of abstraction
- Analog test methodologies addressing synthesis-for-test and better models

It is clear that mixed-signal and analog design tools do not yet enable the productivity gains seen by digital designers. The demand for such software will be even greater in the future, and there is still plenty of room for EDA vendors to develop application to meet these needs.

Figure 9
Forecast Analog Design Tool Sales



Source: Dataquest (November 1993)

G3006068

NOISEMIWW SEMIWWDP9306 BH: 1 N: 1
Mr. Clark Fuhs
Dataquest Incorporated
1-1100
****
SJ - INTERNAL DISTRIBUTION
****

For More Information...

Gary Grandbois, Senior Industry Analyst .... (408) 437-8251
Via fax .... (408) 437-0292

Dataquest Perspective

Semiconductors

Microcomponents Worldwide

In This Issue

Quarterly 80x86 Market Update

Several significant new products have been announced since our last quarterly update, including Intel's Pentium processor, Advanced Micro Devices' new line of 486s, and Cyrix's new 486SX pin-compatibles. This article will provide a brief analysis of the significance of these announcements, and summarize other noteworthy events as well as expectations for next quarter. As always, we will cover our standard topics of analysis for the 80x86 microprocessor market, including 80x86 shipment trends, 80x86 pricing trends, and 80x86 market share.

By Ken Lowe

Quarterly 80x86 Market Update

Current Events and Issues

The first quarter of 1993 saw continued growth of the 32-bit 80x86 microprocessors, reaching a combined total of nearly 10.5 million units. Price wars continued unabated in the PC industry and the emergence of a new market for hand-held electronic systems seems just around the corner, promising enormous volumes. Key events occurring in the marketplace are as follows:

- Industry legal battles being waged on multiple fronts
- Intel formally introduces the Pentium processor
- AMD rolls out its new line of 486 processors
- Cyrix announces its new 486SX pin-compatible processors
- RISC processor industry starts making its move

Our analysis of these and other related events affecting the 80x86 microprocessor market is in the sections that follow.

Industry Legal Battles Waged on Multiple Fronts

Somewhat unrelated to the fact that Intel is the No. 1 semiconductor vendor in the world and is showing outstanding financial performance, its legal department is striking out in all directions. This last quarter saw no less than six separate actions directly involving four companies, under

Dataquest®
a company of The Dun & Bradstreet Corporation

Program: Microcomponents Worldwide
Product Code: MCRO-WW-DP-9303
Publication Date: May 31, 1993

three basic legal battlefronts. Intel's legal actions are an embodiment of its core strategy: invest heavily in R&D of microcomponent building blocks to create a profitable differential advantage, and take strong legal action as necessary to protect that investment (primarily intellectual property). The current battlefronts are summarized in the following paragraphs.

Intel versus AMD: "Use That 486 Microcode at Your Own Risk"

Changing the current momentum of the most heated legal battle in the industry, Judge Ingram of the California state superior court in April granted AMD's motion for a new trial (for microcode rights) based on newly discovered evidence: a press release that Intel allegedly withheld from AMD. Intel in turn claims that this claim of nondisclosure is factually erroneous, that AMD has had this press release statement in its files. As a result, Intel is requesting the judge to certify his opinion and allow an immediate appeal to the ninth circuit court (a higher court of appeal) before beginning a new trial. Furthermore, it seems that, in spite of the fact that Ingram did not grant AMD a license to Intel's microcode in his new trial opinion, AMD has decided to ship a 486 with Intel microcode, for which Intel has reiterated its complaint to the courts, which includes the following allegations:

- No processor microcode license (similar to 287 case)
- No ICE microcode license (claiming AMD copied the microcode used in the ICE)
- No right to import (separate from copyright statutes)
- No foundry rights (no right to have microcode copied outside)
- 1995 termination of rights (including any alleged rights to copy microcode)
- No license for other programs including the Overall Control Program and Floating Point Control Programs

To make matters worse, Intel has filed an additional complaint against AMD for its "Independence Day" 486 version, which does not use copied Intel microcode, but used it during development, thus making it "unclean." Intel alleges that AMD's copying of Intel microcode to aid in disassembly and produce intermediate versions of 486s violates a court ruling that prevents copying and disassembly of computer programs for reverse engineering when alternative methods of reverse engineering exist (which Cyrix demonstrated in its 486 development). Essentially this implies that AMD's 486s are legally tainted, and Intel most likely will be seeking damages and injunctions against AMD shipping any of its current 486s.

Intel versus Cyrix, et al.: "We Patented the Chip and the System Usage!"

Intel's patent 4,972,338 is referred to as the Crawford patent, and includes numerous claims to a 32-bit x86 architecture using a paging memory scheme, with separate claims for chip-level and system-level implementation. The system-level claim covers the use of x86 microprocessors, memory devices, and software programs that invoke the memory paging features, which include Windows and certain other DOS programs. Though Cyrix's foundry, SGS-Thomson, covers the sale of chips using this patent (the subject of a separate legal battle), Intel claims that system manufacturers must also hold a patent cross-license or pay it a fee (set by Intel at 1 percent of the system price, which means $10 to $20 per system). Addressing the only legal loophole available, Intel asserts that, because x86 processors have valid use outside of applications using memory paging (laser printers and communications switches, among others), the chip level patent (covered by SGS-Thomson) does not automatically extend to system usage.

To head off Intel's legal pursuit of PC system vendors, Cyrix filed a request for a preliminary injunction against Intel. However, this request was denied (by a Texas court), allowing Intel to begin its enforcement. Two weeks later, Intel chose its first target, a relatively small Taiwanese company named Twinhead Computers (which happens to sell a notebook computer with a Cyrix processor that is bundled with Windows). Intel filed a complaint with the U.S. International Trade Commission, claiming that Twinhead is importing a PC system in violation of the Crawford patent. Twinhead issued a statement indicating that it has been unwittingly dragged into the middle of what should be an Intel-versus-Cyrix litigation battle. In spite of the court's denial of its request for an injunction, Cyrix believes that Intel's case is meritless and is working with Twinhead and other customers on counterinfringement strategies, including importing the systems without the CPU installed.

Intel versus ULSI: "We Have Bigger Fish to Fry"

In a quiet finish to a quiet battle over intellectual property related to math coprocessors, Intel and ULSI announced that they have reached a settlement out of court without disclosure of any details. This would seem to indicate that, without much to gain, it is better to open the docket for more crucial cases.

Intel Rolls Out the Pentium Processor

In a staged sequence of introduction events, Intel finally took the wraps off the Pentium processor, allowing the public to first digest its technical performance, then its price positioning. The net result of what we know is as follows:

- Pentium processors will offer a performance level of about 65 SPECint92 and 57 SPECflt92, matching today's mainstream workstations (see Table 1 for technical details).

Pentium processors are priced at $878 and $965 for 60- and 66-MHz versions respectively. However, less than 10 vendors have any allocation of parts to purchase.

Table 1
Pentium Technical Specifications

	Description
Technology	
Process	BiCMOS
Lithography	0.8 micron
Metal Layers	Three
Number of Transistors	3.1 million
Cache Memory Cell	Six-transistor SRAM
Die Size	640 x 640 mils per side
Performance	
Clock	60 and 66 MHz
SPECint92	64.5 at 66 MHz
SPECflt92	56.9 at 66 MHz
Power Consumption	13W at 60 MHz
Architecture	
Wordwidth	32-bit integer unit
Data Path at the Pins	64-bit data path
Internal Data Paths	Up to 256 bits
Cache Size	8KB instruction/8KB data
Integer Unit	Dual five-stage execution units
Floating Point	Eight-stage pipeline

Source: Intel Corporation

- Systems have been introduced by Compaq, AST, Zenith Data Systems, ALR, NCR, and NEC with prices for single-processor desktop systems ranging from $3,000 to $9,000.
- Only about 200,000 units will be available throughout this year, so Pentium's impact on the PC landscape will be minor until at least mid-1994.

Although this announcement may be deemed late by some, it could hardly have been made any earlier. Intel is still reaping the rewards of a nearly sole-source position in the 486 market, and it is running flat out trying to keep up with today's demand. It makes no sense to pull in the ramp for the Pentium and risk prematurely ending the life of the extremely profitable 486.

Intel's impressive performance benchmarks are competitive with today's RISC workstation processors, but it is highly unlikely that any major workstation manufacturers will be designing in an x86-based architecture anytime soon. The primary short-term benefit of this higher performance will be that software written for PCs simply will run faster. According to Intel, a 66-MHz Pentium-based machine will run such popular applications as Word, WordPerfect, Excel, and dBASE IV 1.6 times faster than a system based upon an Intel 486DX2-66. Such a performance boost should be well accepted by the typical power user and for x86-based file server applications. However, before the 486 line of processors is overtaken in volume by the Pentium processor, new CPU power-hungry applications such as full-motion video, 3-D modeling of solids, speech recognition, and imaging will have to become mainstream business applications.

Packing 3.1 million transistors into a single chip running at 66 MHz provides an incredible opportunity to boost processing power, and also gives a tremendous challenge to dissipate all of the heat generated by those 3.1 million transistors. System thermal management will be a key component for PC designers designing systems based on the Pentium. Although Intel claims that the Pentium's 13W power dissipation at 60 MHz is half that of Digital Equipment Corporation's Alpha processor, the Alpha is being used in technical workstations whose designers have more experience in dealing with high-speed, high-power microprocessors. The typical PC OEM has not been forced to deal with such issues, and those that can more quickly adapt to this new environment will have the best chance of success.

Intel once again appears to be well positioned to milk the high profit out of an existing microprocessor while successfully positioning itself for the future. When 486 clone devices begin to enter the market in earnest, Intel will once again have the luxury to retreat from the price wars and transition its microprocessor production to the next-generation processor. In fact, it is to Intel's benefit when these clone manufacturers do enter the market. Intel can expedite its transition without worrying that customers for the older-generation product will be left without a supplier.

AMD Announces Its New Family of 486 Processors

On the heels of the positive momentum resulting from Judge Ingram's granting of a retrial (against Intel for microcode rights), AMD began shipments of its first 486 products. Initial members of the Am486 family include 33-MHz and 40-MHz single-clocked versions, and a clock-doubled 50-MHz device. Each of these initial parts is a pin-compatible replacement for its Intel counterpart (with the exception of the 40-MHz speed). In the same announcement, AMD revealed that it already is sampling a low-voltage version of the 33-MHz device and that plans include higher-performance and lower-power versions.

The major versions, with their prices, are as follows:

- Am486DX-33 and -40, both available now, priced at $306 (1,000 quantity)
- Am486DX2-50, available in June, priced at $417 (1,000 quantity)

Each of these initial Am486 products incorporates Intel microcode, though AMD has stated that it will continue to develop its "clean-room" microcode to achieve technological independence. AMD plans to announce the new AMD microcode versions on July 4, referred to as the "Independence Day" microcode.

Dataquest believes that these new products are a good starting point for AMD's new 486 product line. However, it must move quickly and accurately during the next 12 months to catch up to Intel's performance lead. Though AMD has a sufficient customer base to move as many 486s as it can produce this year (estimated at 500,000 to 600,000 units), it is offering little more than "me-too" products at "me-too" prices. Because there is a lot of pricing room to move in, we anticipate a parity pricing strategy until the first half of 1994, when manufacturing capacity and costs will allow AMD to push down hard on pricing to begin regaining market share. We also expect higher-performance versions to be available in the first half of next year, at least a DX2-66-MHz version and perhaps a DX2-80-MHz version.

Cyrix Announces Its New Line of 486SX Pin-Compatibles

On May 24, Cyrix announced a new family of 486SX pin-compatibles featuring higher clock rates (up to 50 MHz), 2KB on-chip cache with write-back, static core design, and built-in SMM power management features. These processors are targeted toward both desktop and notebook systems and will raise the bar for 486SX performance levels. Furthermore, the new Cyrix family works with a companion low-cost math coprocessor that adds $20 to the CPU cost when purchased as a set. Six specific models were included in the announcement, priced as follows:

- Cx486S-33 and -40: 486SX pin-compatible devices with 33- and 40-MHz clock speeds and 5V operation. Prices are $139 and $179, respectively (1,000 quantity).
- Cx486S-V25 and -V33: 486SX pin-compatible devices with 25- and 33-MHz clock speeds and 3V operation. Prices are $139 and $159, respectively (1,000 quantity).
- Cx486S2-40 and -50: 486SX pin-compatible devices with clock-doubled speeds of 40- and 50-MHz, respectively (20- and 25-MHz external, respectively), and 5V operation. Prices are $179 and $199, respectively (1,000 quantity).

Cyrix continues to demonstrate its technical proficiency by developing and introducing new versions of 486SX-compatibles at a rapid pace. However, the proof of its formula will be the volume of business it can extract from the market. Total unit shipments to date are estimated at slightly less than 1 million units (including Texas Instruments' volume). Dataquest believes that these new products provide a strong addition to Cyrix's line and position it for further growth.

Cyrix's business plan calls for a central focus on chip sales to system OEMs. However, Cyrix is piecing together an aggressive program to go after the retail upgrade market, as well as leveraging additional volume through partnering arrangements, currently with TI. Its long-term outlook is less certain, though it plans to introduce many high-performance processors, including full 486DX-compatibles with 8Kb cache and FPU, and even a Pentium competitor. It will begin to face competition head-on where fewer product-line holes are available to capitalize on.

RISC Processor Industry Starts Making Its Move

The open-system RISC microprocessor alliances are becoming more aggressive in their pursuit of mainstream x86 microprocessor-based personal computers. With introduction of Windows NT just around the corner, many of the alliances, such as MIPS and Alpha, see the opportunity at hand to begin the long task of market penetration. By far the strongest opponent, PowerPC by Motorola and IBM is stepping up its presence in the market by unveiling the first-generation chips and pitching openness and an operating system support model that includes Windows NT and many others. The SPARC camp is headed in the opposite direction, with its operating system (SunSoft's Solaris) being ported to the x86 and PowerPC architectures and consolidation occurring among its vendors.

MIPS Family Adds New Processors and Chip Sets

MIPS Technologies Inc., in conjunction with NEC, announced a dramatic new addition to its R4000 series of microprocessors. The R4200, targeted toward portable systems and advanced desktops running under the Windows NT operating system, features a 64-bit architecture, 80-MHz clock-doubled speed (40-MHz externally), and 24Kb of on-chip cache. However, the big punch comes from reported combination of performance/power/price delivered by the R4200: 55 SPECint92 performance, with less than 1.5W power consumption, for a target volume price of $55 (anticipated for year-end volumes). Furthermore, NEC, ACER Labs, and other vendors are introducing chip sets to work with the R4000 series to create cost-effective, high-performance system designs. The only question is how long it will take for Windows NT to level the playing field and allow non-X86 architectures to sell into the mainstream PC market.

First Versions of PowerPC Chip Unveiled

IBM and Motorola both formally and independently rolled out new versions of their PowerPC family, targeted at performance desktop systems. Motorola announced its version of the PowerPC 601 first, two weeks before IBM's announcement, pricing the basic 50-MHz chip at $280, and said it would also make a more powerful 66-MHz version that would sell for $374 (at quantities of 20,000 units or more). The first computers using the new MPC601 chip are expected to come to market late this year or early in 1994, with both IBM and Apple expected to announced PowerPC-based PCs with prices starting at less than $3,000. Again, the playing field must become level before any team can enter and compete.

Consolidation of Vendors in SPARC Camp

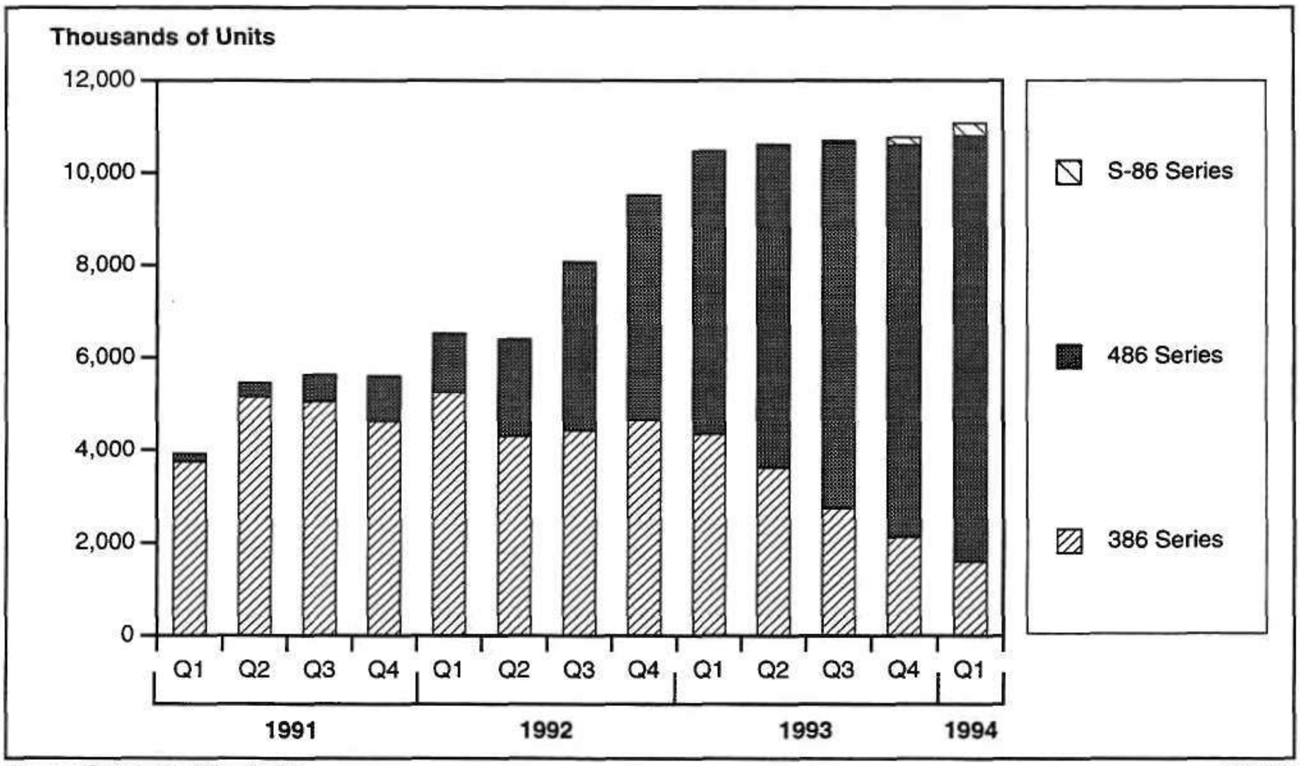
Cypress Semiconductor announced that it has sold its Ross Technology subsidiary to Fujitsu Ltd., another SPARC microprocessor vendor that has fallen from the top of Sun's list. Ross originally was formed to produce derivative architectures of Sun's SPARC CPU, and for a short time became

Sun's main supplier of the SPARC microprocessor. While Ross was designing its own version of a next-generation SPARC processor, Sun was doing its own in conjunction with TI. The Sun design, although initially not hitting its speed targets, came out first and was designed into the SPARCstation 10. Ross was not interested in participating with Sun as a silicon foundry and continued its own SPARC development effort. After considerable time, effort, and dollars were spent by Ross, Sun would make no commitment to use the Ross-designed SPARC. Although there were claims of at least 15 design wins for the HyperSPARC, the market for this architecture outside of Sun is not large enough to support a company the size of Ross. Ross' losses were said to be $4 million last quarter.

80x86 Shipment Trends

Unit shipments for 32-bit 80x86 microprocessors showed strong overall growth during the first quarter of 1993, again reaching a new record level of 10.5 million units (see Figure 1). Dataquest believes that this overall growth will slow and become nearly flat during the next three quarters because of the current "bubble" in upgrade demand, which has driven most of the current unit growth. Further dramatic pricing changes at the system level also are not anticipated in the near future, allowing demand to stabilize based on current economics.

Figure 1
32-Bit x86 Unit Volume, by Product Type



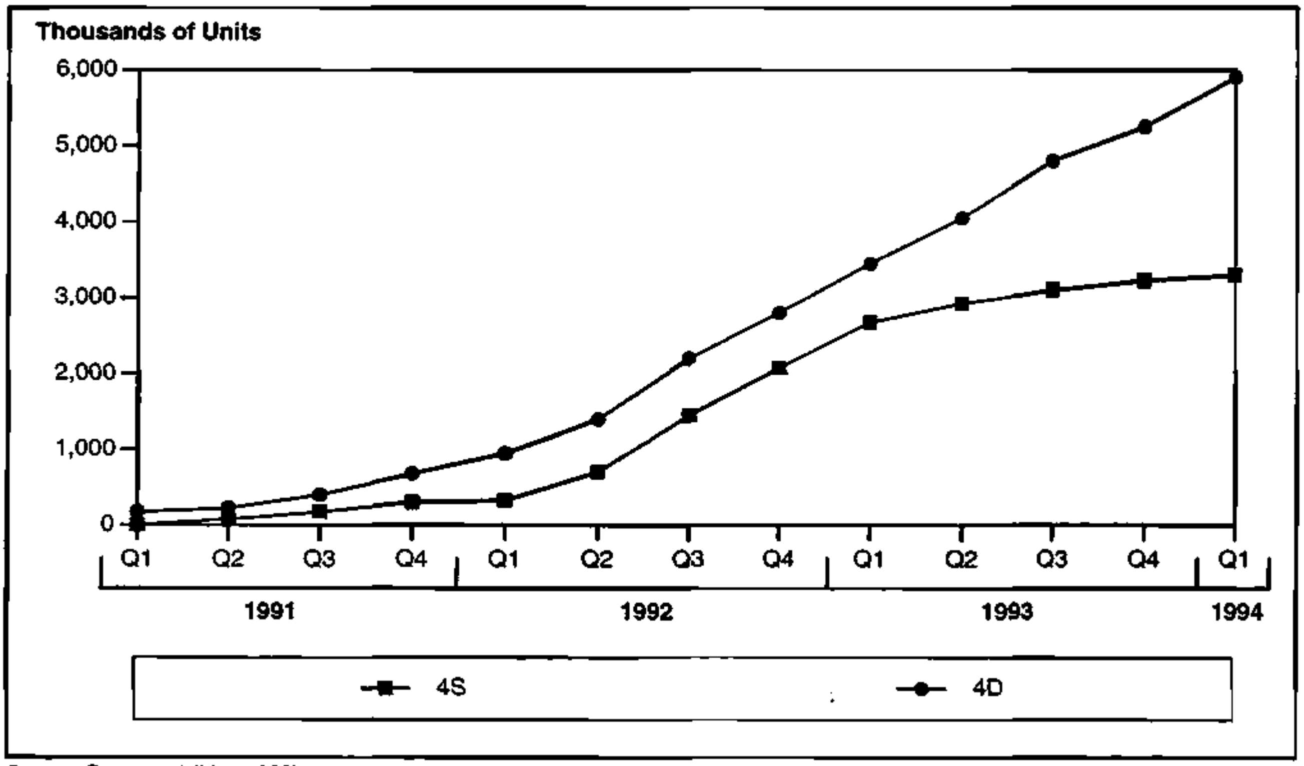
Source: Dataquest (May 1993)

G3000137

All of the new growth during the first quarter came from the 486 series, which showed robust 24 percent growth in one quarter, from 4.9 million units to 6.1 million units (see Figure 2). Most of the processors in this series are still under minor allocation from Intel, but will receive a boost in supply from Cyrix's new 486SX-compatible family as well as AMD's new 486DX-compatible family. The 486DX segment is now being driven by the DX2 version, the highest-growth processor in the family. We expect even higher growth rates for the DX2 in the second half of this year, at the expense of the standard DXs, which have nearly peaked in volume. Pentium forecasts have been adjusted downward to about 200,000 units this year to reflect Intel's limited supply.

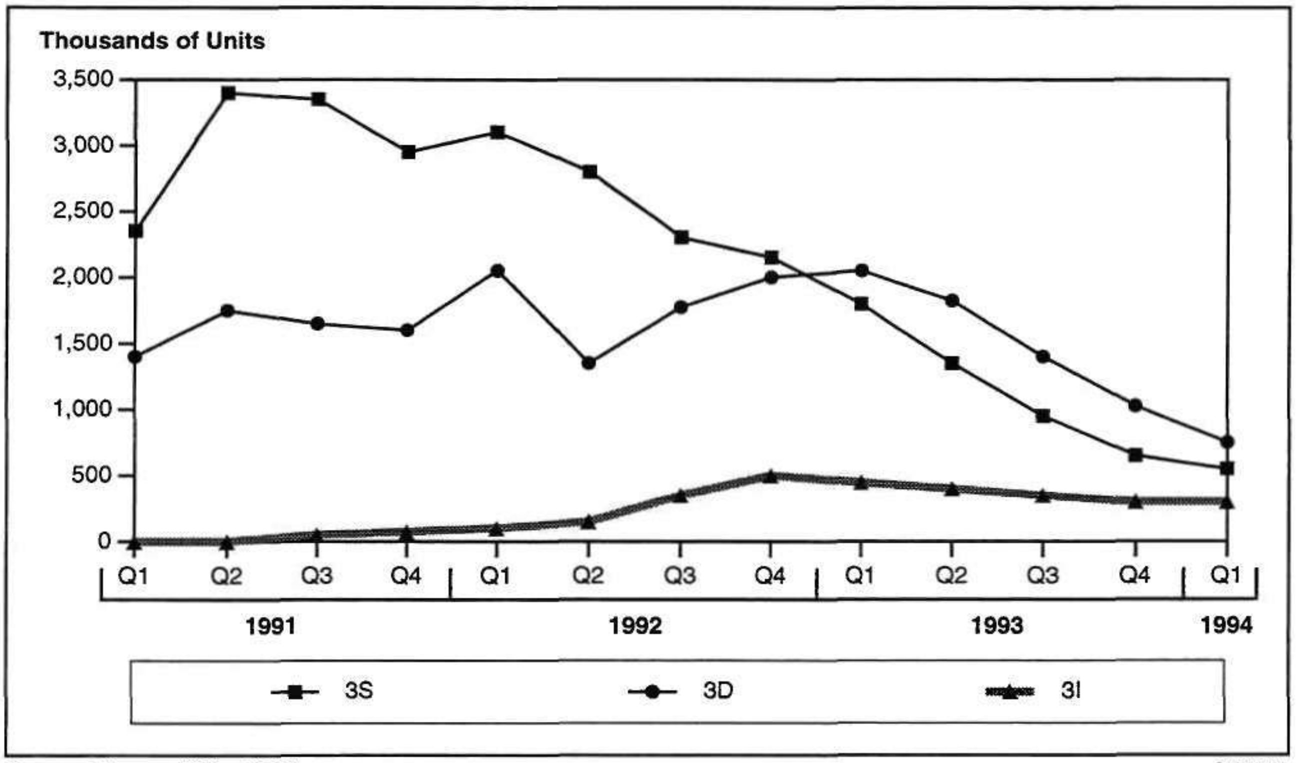
Following three consecutive quarters of mild growth, 386 unit volumes have finally begun to drop, signaling the start of what may be a rather fast decline over the next two years (see Figure 3). Remaining strong was the 386DX (primarily the 40-MHz version), which maintained its overall volume level because of its competitive position with the 486SX as well as a growing base of demand in the less sensitive countries of the Asia/Pacific region and rest-of-world regions. The 386SX, on the other hand, is headed steadily downward and is soon to be followed by the 386i (currently 386SL), which will then be revived starting in 1994 by hand-held electronic devices.

Figure 2
486 Family Quarterly Shipment Trends



Source: Dataquest (May 1993) G3000139

Figure 3
386 Family Quarterly Shipment Trends



Source: Dataquest (May 1993)

G3000138

80x86 Pricing Trends

From a pricing standpoint, 1993 has begun rather mildly, with most current microprocessor families following a steady, slow fall in pricing. As shown in Table 2, each x86 series is on a steady path downward (though as a whole, the overall average selling price (ASP) for 80x86-class microprocessors (not shown here) is increasing because of the mix moving toward 486s).

ASP Calculation Methodology

The prices shown in Table 2 are Dataquest's estimate of the industry ASPs for each product type, estimated as follows:

- Version-specific ASPs (for each speed grade or configuration offered in a vendor's product line) is based on its nominal (1,000 quantity) list prices, discounted according to estimated volume pricing.
- Vendor ASPs for a given product type are a weighted average of the ASP calculated for each version offered by that vendor.
- Industry ASPs for a given product type are derived from a consolidation of the vendor ASPs (by product type) for each vendor, factored in according to market share.

Table 2
80x86 Pricing Model (Dollars)

Price	1991		1992				1993			
Type	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
3S	77	75	64	55	44	41	40	36	34	33
3I	130	122	118	93	63	54	45	42	41	39
3D	153	142	116	74	65	54	51	47	44	41
4S	222	203	190	151	103	97	93	91	84	79
4D	410	396	390	388	388	377	357	343	311	253
S-86	-	-	-	-	-	-	-	814	814	773

Source: Dataquest (May 1993)

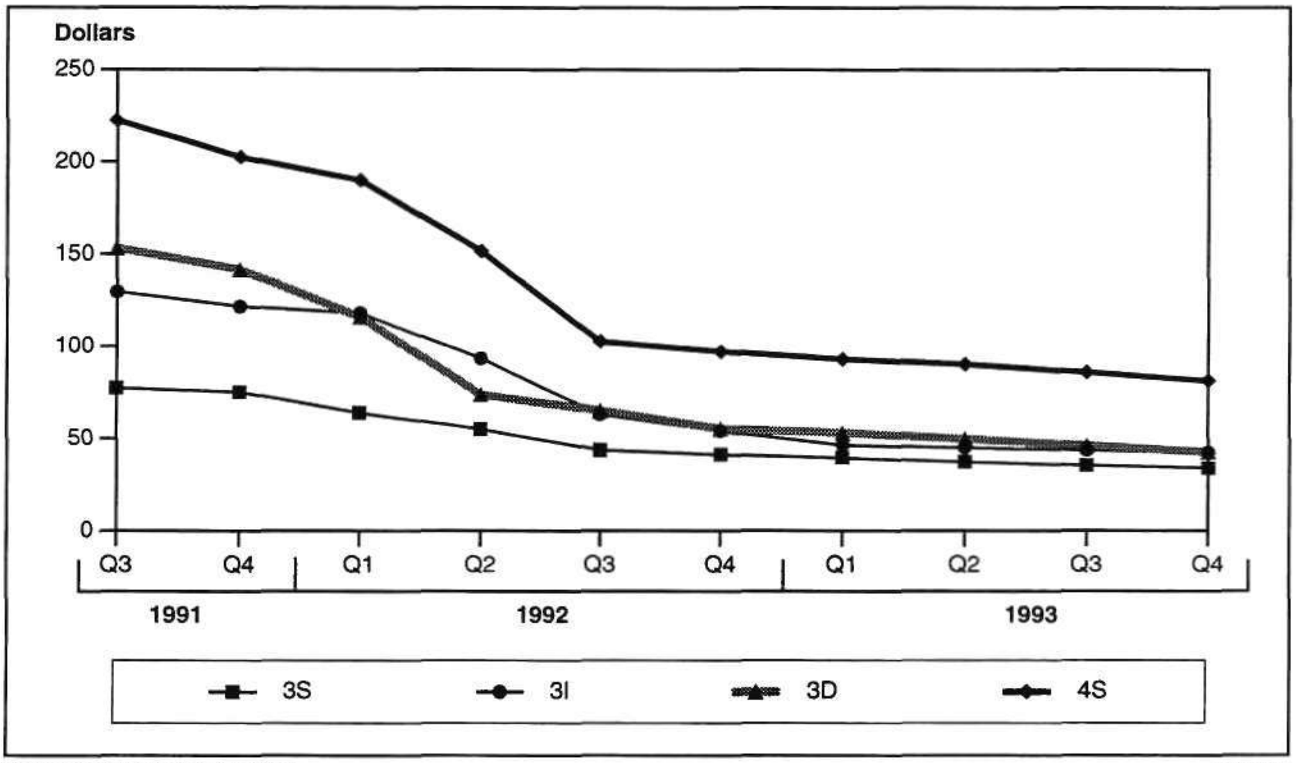
Figure 4 shows the trends for the "entry-level" competition, comprising the 386 series and the 4S (486SX-like) subset of the 486 series. The first point of interest is the relative stability of the 386 family, which has assumed a $30 to $50 price band with a relatively slow downward slope because of the lack of price elasticity in current demand. On the low side, AMD is offering 386SXs in the high $20s to certain customers, providing the lowest entry point for a 32-bit x86 system. The 486SX is shown to be dropping steadily over the next four quarters as Intel's capacity to deliver increases and Cyrix's gets aggressive with its new 486SX pin-compatibles.

The 486DX series are near the knee of their price reduction curve, placing the ASP for the entire line below $300 by the fourth quarter of this year (see Figure 5). AMD has entered the market with a new line of 486DXs with a parity pricing strategy (at least currently, while supply-constrained) that we expect to slide down rather quickly during 1994 to regain lost market share. We expect Intel's pricing strategy to be to let the standard 486DX line move down slowly while its DX2 versions will move downward aggressively to maintain a value position relative to competitive offerings (much like its 486SX positioning against AMD's 386DX). We expect more aggressive versions of the Pentium processor, which will not be a factor in the next 12 months, to place downward price pressure on the 486DX series by mid-1994. Based on these assumptions, it will become difficult for Intel's competitors to enjoy premium pricing positions of their new 486 products long enough to recoup the R&D investment prior to the onslaught of margin-sensitive pricing wars.

80x86 Market Share Trends

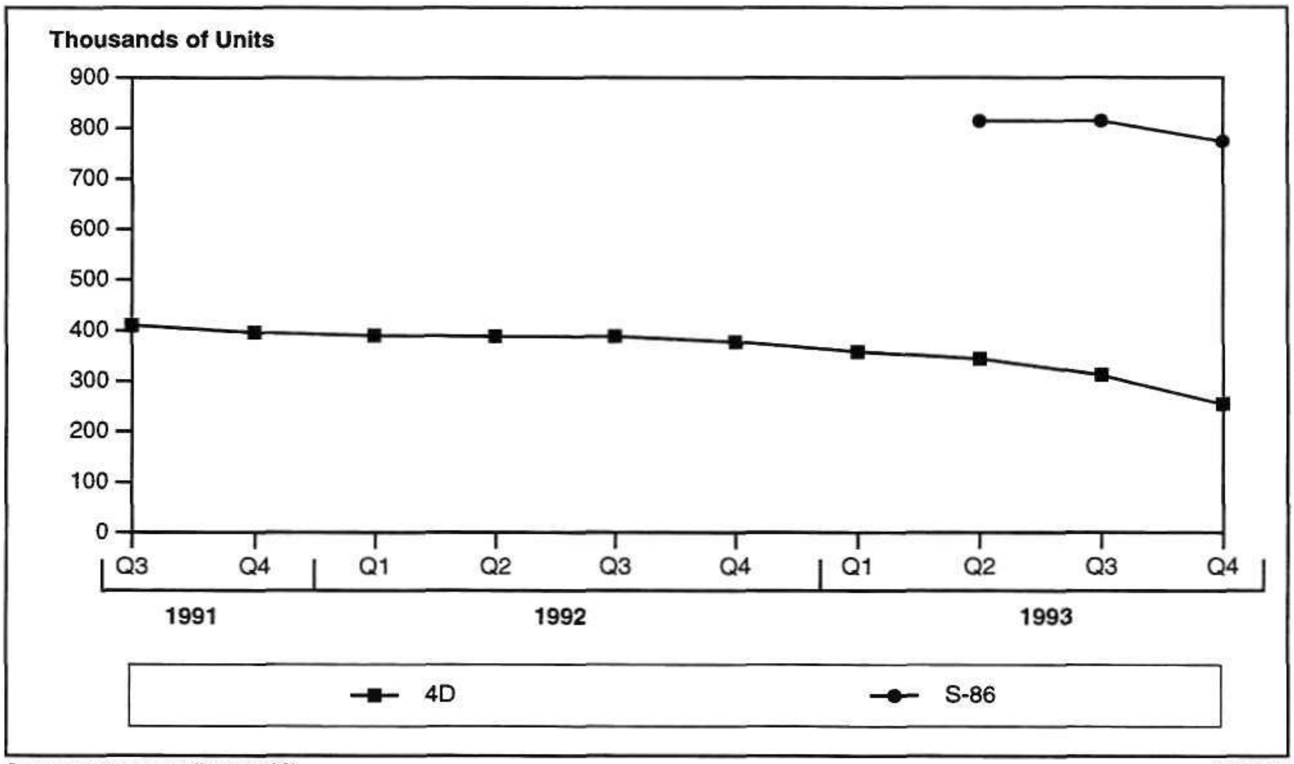
As shown in Figure 6, Intel has begun its ascent, regaining some of the substantial market share it lost to AMD's successful 386 entry. We expect Intel to continue to recover market share over the next several quarters as the market moves to the 486 and Intel shifts to a market-share-protection strategy from a profit-margin-only strategy. Also being counted in increasing quantities is the team of Cyrix and TI, now accounting for about 3 percent of the total market, having shipped about 1 million units since their introductions one year ago. We anticipate that AMD will continue to have

Figure 4
Entry-Level x86 Quarterly Price Trends



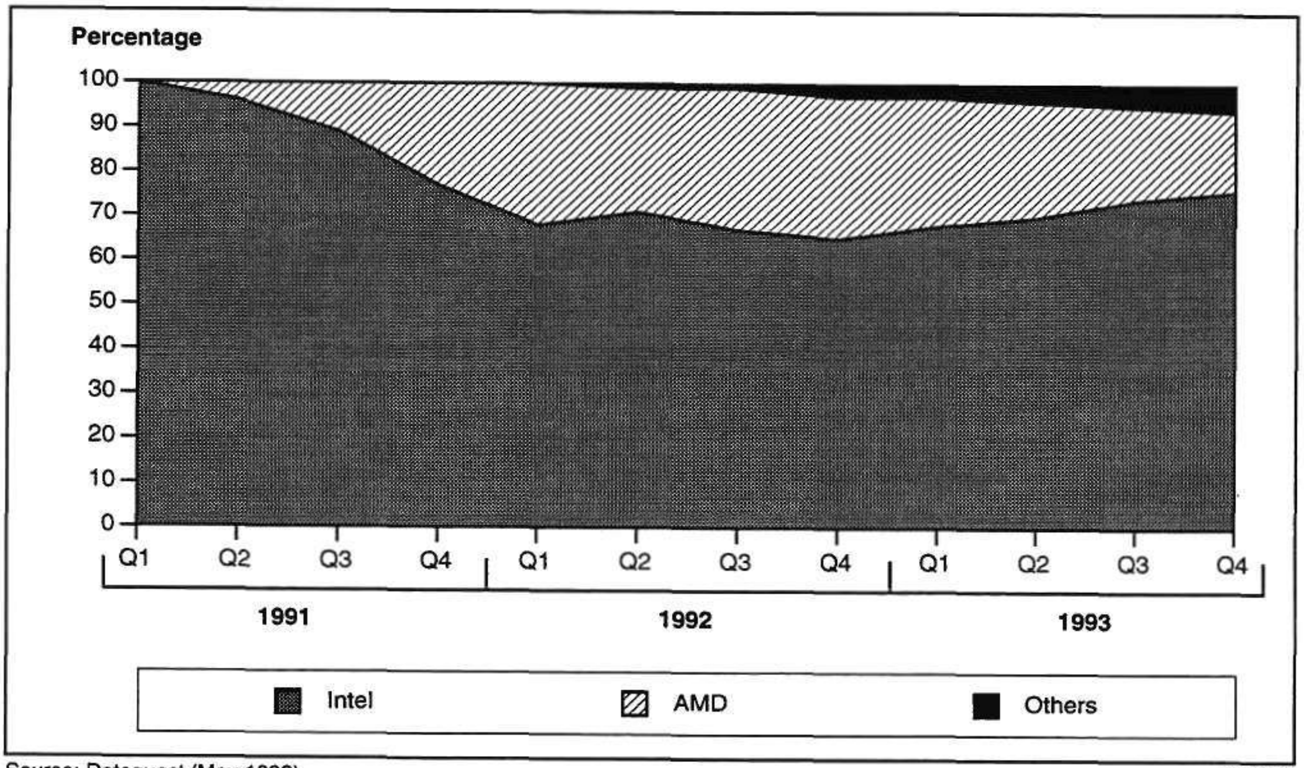
Source: Dataquest (May 1993)
G3000141

Figure 5
High-Performance x86 Price Trends



Source: Dataquest (May 1993)
G3002228

Figure 6
32-Bit x86 Market Share Trends (Unit Shipments)



Source: Dataquest (May 1993)

G3000143

its market share squeezed during the next three quarters because its 386 volumes most certainly will fall faster than its 486 sales can ramp (estimated at 500,000 units this year).

One key factor that affects market entry is the number of PC vendors to which these processors may be sold. To be sure, the PC market has more vendors (500 to 700 participated in the Intel-Inside campaign) than Intel can effectively service. Thus we believe that part of Intel's marketing strategy is to tighten its relationship with the top 25 or so PC vendors, help strengthen its position in the market (including enabling it to go after the "low-end" PC segment), and effectively eliminate the hundreds of no-name vendors that move the bulk of non-Intel processors. As the field of PC vendors consolidates, barriers to entry for potential x86 competitors will increase.

Dataquest Perspective

We expect the next quarter's events to be as exciting as the last, with additional 486 announcements from all vendors, feedback coming in from real Pentium-based systems hitting the streets, the movement of AMD 486s into early volume, and the continuance of a number of critical legal battles. The market will begin to move more rapidly to the 486, and only hand-held electronic devices will represent a growth area for highly integrated 386s. Though we have seen delays in market entry from potential new vendors, we still expect to see announcements prior to year-end from Nexgen (a P5 competitor), UMC (a 486SX competitor) and IIT (a 486DX competitor).

By Ken Lowe

For More Information...

Ken Lowe, Senior Industry Analyst .... (408) 437-8366
Via fax .... (408) 437-0292

Dataquest Perspective

Semiconductors

Semiconductors Worldwide

In This Issue

Strategic Alliances—First and Second Quarters 1993
This article offers an overview of worldwide alliances between companies in the electronics industry for January through June 1993. It characterizes the alliances by company and region, as well as by alliance and product type.
By Mary A. Olsson

Strategic Alliances—First and Second Quarters 1993

This article provides an overview of worldwide alliances between companies in the electronics industry during the first half of 1993. It will characterize those alliances by company and region, and by alliance type as well as by product type.

Strategic alliances between companies can provide significant opportunities in the growth and direction of products, technologies, companies, and regions. Opportunities or benefits of strategic alliances include the following:

- Access to new markets
- Access to foreign markets
- Increased financial leverage
- Access to innovative technology
- Access to manufacturing processes
- Access to technology commercialization
- Strong regional ties during economic downturns

The strategic alliance data in Table 1 and Figures 1 through 3 is incomplete in that it covers only those alliances announced or released into the public domain. A significant amount of alliances made between companies are not disclosed for purposes of confidentiality, protection of technology, and other proprietary reasons. Dataquest classifies strategic alliances into the following major categories used in Table 1 and Figure 1:

- LA: Licensing agreement
- SS: Second source agreement

Dataquest®
a company of The Dun & Bradstreet Corporation

Program: Semiconductors Worldwide
Product Code: SEMI-WW-DP-9305
Publication Date: August 30, 1993

- SA: Sales agency agreement
- FA: Fab agreement
- AT: Assembly and testing agreement
- TE: Technology exchange
- JV: Joint venture
- JD: Joint development
- IV: Investment
- CO: Coordination of standard
- PC: Procurement agreement
- OT: Other types

The following paragraphs provide details on the categories.

LA: License agreements are defined as legal permission to use a company's patents or proprietary technology for a fee or royalty payment. This could also include a cross-licensing agreement where the companies involved have legal permission to another company's patents or proprietary technology.

SS: Second source agreements allow companies the ability to manufacture a product designed and developed by another company as a second source of supply for customers.

SA: Sales agency agreements provide companies with exclusive or nonexclusive rights to sell the partner's original products to which value is added, in specified markets.

FA: Fab agreements involve the use of another company's fabrication facilities to manufacture a product.

AT: Assembly and test agreements involve a company's manufactured components and parts shipped to another company for assembly and test.

TE: Technology exchange involves an exchange of proprietary technologies that may or may not involve a transfer of money.

JV: Joint ventures involve two or more companies that jointly form a company to develop, manufacture, or market new products.

JD: Joint development agreements are between two or more companies that decide to combine forces and capabilities to develop new products or technology.

IV: Investment alliances are made between regional companies or foreign companies in other companies for the purposes of gaining access to technology or acquisition of small start-ups or innovative companies.

CO: Coordination of standards are agreements on common or compatible technical standards that would link devices and systems and users of different components, systems, or tools.

PC: Procurement agreements are commitments by companies to purchase certain quantities of specific goods or services over a contracted time.

OT: Other types of agreements could include visitation and research participation where researchers visit, observe, and participate in the R&D activities of the allied company. An original equipment manufacturing agreement might involve the manufacturing of a product for another company that will label it with its name or logo and will also handle all of the business aspects of that product, such as marketing and service of the product. Service agreements are those provisions of follow-up service of the product in foreign markets.

Figure 2 shows the total number of alliances between regional companies, while Figure 3 categorizes all of the alliances for 1993 by type. Multiproduct alliances are combinations of one or more product areas. Other devices include video, disk drives, decoder chips, analog, discrete, and optoelectronic. Other product types include multichip modules, motherboards, SIMMs, multimedia technology, fabrication and foundry services, and other process technology agreements.

Dataquest Perspective

Highlights of the first half of the year agreements include the following:

- License and joint development agreements were the fastest-growing areas. Of the accountable 17 JD agreements, most were made between companies in the United States across all product areas. Of the 31 LA agreements, most were made by companies in the United States, with focus predominantly in the areas of video compression and telecommunications applications.
- Joint venture activity led by the U.S. companies in the area of telecommunications has already surpassed the total worldwide 1992 JV activity.
- In the area of semiconductor components, the most notable change is that agreements involving microcomponents have surpassed those of memory products.
- Systems and equipment agreements have surpassed 1992 totals, and those types of agreements are growing at a faster pace than are component agreements. During the first half of 1993, the most active companies in numbers of agreements for systems and equipment were Apple Computer, AT&T, The Bull Group, Motorola, and NCR.

Table 1
1993 Strategic Alliances

Company A	Region	Product	Company B	Region	Product	Type	Month	Year
Hewlett-Packard	United States	System service/support	Wyse Technology	United States	PCs/UNIX/Wyse kits	OT	January	1993
Motorola	United States	Trunked radio infrastructure	Racotek Inc.	United States	Wireless mobile data communications	IV	January	1993
Hewlett-Packard	United States	0.35µm CMOS process	AMD	United States	0.35µm CMOS process	TE	January	1993
VLSI Technology Inc.	United States	Logic design	Hitachi	Japan	Fab and manufacturing	FA, LA, JD	January	1993
Toshiba	Japan	5V NAND Flash	Samsung	Korea	Cross license and manufacturing	LA, SS	January	1993
Crosspoint Solutions	United States	FPGA architecture	Hitachi	Japan	Musashi FAB/foundry	FA, SA	January	1993
National Semiconductor	United States	6-inch fab 19.9 percent share	Defense Software & Systems Inc.	Israel	80.1 percent share of fab	JV	January	1993
Texas Instruments	United States	Programmable video DSPs	C-Cube Microsystems	United States	Decoder chips	JD	February	1993
AMD	United States	Flash technology	Siemens	Europe	Microcontroller and foundry	FA, TE	February	1993
General DataComm Inc.	United States	Public network switch equipment	NetComm Ltd.	Europe	ATM technology	JD	February	1993
Hoechst AG	Europe	Joint manufacture marketing	American Superconductor Corporation	United States	Superconductor wires	JD, IV	February	1993
Pyramid Tech	United States	MIPS-based server	ICL plc	Europe	SPARC/super SPARC processors	LA	February	1993
ARM	United States	ARM RISC CPU	Sharp	Japan		SS	February	1993
Thomson	Europe	Consumer	Compression Labs Inc.	United States	Video	JD, IV	February	1993
Texas Instruments	United States	3V logic CMOS/BICMOS	Philips	Europe	3V logic	JD, SS	February	1993
LTX Corporation	United States	Test equipment hardware/software	Ando Electronic Co. Ltd.	Japan	Royalty and distribution agreement	JD	February	1993
LSI Logic Corporation	United States	Layout and delay calculation capabilities	Synapsys Inc.	United States	Synthesis, test, and simulation tools	JD	February	1993
AT&T	United States	Fast SRAMs/logic	NEC	Japan	Fast SRAMs/logic	TE	February	1993

(Continued)

Table 1 (Continued)
1993 Strategic Alliances

Company A	Region	Product	Company B	Region	Product	Type	Month	Year
Intel	United States	486 chip set	VLSI Technology Inc.	United States	Development and manufacturing	JD	February	1993
IBM	United States	Computers, services, software	Tata Information Systems LTD	India	Products and services	JV	February	1993
Texas Instruments	United States	16Mb DRAM facility	Acer	Taiwan	PCs	JD, IV	February	1993
Macronix	Taiwan	16Mb flash/FAB/patent	NKK	Japan	Fab, investment, distribution	JD, IV, SA	February	1993
Texas Instruments	United States	FIFO clock architecture	IDT	United States	FIFOs	JD, SS	February	1993
Motorola Semiconductor	United States	Small-signal transistors/ diodes	Philips Semiconductor International	Europe	Assembly and test	JD	February	1993
Northern Telecom	Canada	DMS SuperNode switch system	Tandem Computers Inc.	United States	Service control/service creation environment	JD	February	1993
Apple	United States	Newton	Cirrus Logic Inc.	United States	Chipsets and silicon for Newton	LA	March	1993
Apple	United States	Newton	Motorola	United States	Hand-held wireless communications	LA	March	1993
Apple	United States	Newton	Kyushu Matsushita Electric	Japan	Newton operating system	LA	March	1993
Apple	United States	Newton	LSI Logic Corporation	United States	1.0µm interface ASIC/ ARM CPU	LA	March	1993
Digital Equipment Corporation	United States	Alpha AXP chips	Mitsubishi Electric Corporation	Japan	0.5µm Saijo factory	LA, SS	March	1993
Intel	United States	X86 PC architecture in China	China Electronics Corporation	China	Assembly/test and distribution	AT	March	1993
GEC Plessey	Europe	Custom ICs for read channel	Conner Peripherals	United States	2.5/3.5 hard disk drives	OT	March	1993
Unitrode IC Corporation	United States	Power control ICs	Toko Inc.	Japan	Cross-license agreement	SS	March	1993
EO Inc.	United States	Hand-held communications	Olivetti	Europe	Distribution and development	JD, IV	March	1993
Hitachi	Japan	1Mb SRAM	Asahi Chemical Industries	Japan	Facility	FA, OT	March	1993

(Continued)

Table 1 (Continued)
1993 Strategic Alliances

Company A	Region	Product	Company B	Region	Product	Type	Month	Year
Graphics Comm. Labs	Japan	HDTV joint venture	ASCII Corporation	Japan	Digital compression technology	JV	March	1993
Graphics Comm. Labs	Japan	HDTV joint venture	Hitachi	Japan	Digital compression technology	JV	March	1993
Graphics Comm. Labs	Japan	HDTV joint venture	Victor Company of Japan	Japan	Digital compression technology	JV	March	1993
Graphics Comm. Labs	Japan	HDTV joint venture	NTT Electronics Corporation	Japan	Digital compression technology	JV	March	1993
National Semiconductor	United States	Codevelop Toshiba ACMOS	Toshiba	Japan	Second source for NSC logic	JD	March	1993
Advanced RISC Machines	Europe	ARM processors	Sharp	Japan	License and manufacture	LA	March	1993
Bull Group	Europe	IC card reader patents	Toshiba	Japan	Patent fees	LA	March	1993
Bull Group	Europe	IC card reader patents	Hitachi	Japan	Patent fees	LA	March	1993
Bull Group	Europe	IC card reader patents	Oki	Japan	Patent fees	LA	March	1993
Bull Group	Europe	IC card reader patents	Toppan Printing	Japan	Patent fees	LA	March	1993
Bull Group	Europe	IC card reader patents	Kyodo Printing Company	Japan	Patent fees	LA	March	1993
Apple Computer	United States	Apple Newton	Siemens/Rolm	Europe	NotePhone telephony and fax	LA	March	1993
Schlumberger	Europe	Metering products	Motorola	United States	Manufacturing	JV	March	1993
Toshiba	Japan	LCD technology	Orion	Korea	Display manufacturer	LA	March	1993
Silikon	Russia	Design house	MIPS	United States	MIPS processor	LA	March	1993
Samsung	Korea	Synchronous DRAMs	OKI	Japan	Royalty and SS	SS	March	1993
Harris Corporation	United States	Digital microwave radios	Shenzhen Telecom Equipment Company (TEC)	China	Designs, services telecom networks	JV	March	1993
Teradyne Inc.	United States	Test equipment	E&M Engineering	Israel	Sells, supports, services board test equipment	JV	April	1993
Zeos International	United States	PC systems and workstations	Intel Corporation	United States	Motherboard manufacturing	AT	April	1993

(Continued)

Table 1 (Continued)
1993 Strategic Alliances

Company A	Region	Product	Company B	Region	Product	Type	Month	Year
Seagate Technology	United States	Disk drive ICs	SGS-Thomson	Europe	1.2µm BiCMOS tech	TE	April	1993
Motorola	United States	88110 MCM	IBM	United States	C-4 manufacturing and MCM technology	JD	April	1993
Motorola	United States	88110 MCM	CHPC	United States	Lynx massively parallel processor	JD	April	1993
Parlex Corporation	United States	Flex circuitry	Motorola	United States	Automotive electronic products	JD	April	1993
Silicon Graphics Inc.	United States	Servers	Siemens Nixdorf	Europe	Marketing rights to servers	LA	May	1993
VLSI Technology Inc.	United States	PC chipsets	Future Domain Corporation	United States	SCSI technology	LA	May	1993
Sierra Semiconductor	United States	DSP Aria chipsets	Archer Communications Inc.	United States	QSound Virtual Audio	LA	May	1993
Sun Microsystems CC	United States	SPARC II design rights	Fujitsu	Japan	MicroSPARC II manufacturing	FA	May	1993
Advanced RISC Machines	Europe	ARM architecture	Texas Instruments	United States	Develop ARM core in DSP devices	LA	May	1993
Motorola	United States	Paging products	Simplex	United States	Security systems	LA	May	1993
Motorola	United States	Microcontrollers	Aptronix Inc.	United States	Fuzzy logic software application tools	OT	May	1993
Hitachi	Japan	DRAMs	Nippon Steel Semiconductor Corporation	Japan	Foundry for 4Mb DRAMs	FA	May	1993
Sandia National Labs	United States	PZT semi thin film	Radiant Technologies	United States	Design/manufacture NDRO NV semiconductor memory	OT	May	1993
Tektronix	United States	Analog/digital ICs	TV/COM International	United States	Communications systems	JD	May	1993
AT&T	United States	Voice and data services	KDD	Japan	Voice and data services	CO	May	1993
AT&T	United States	Voice and data services	Singapore Telecom	Singapore	Voice and data services	CO	May	1993
IBM	United States	Operating system	NEC	Japan	OS for NEC machines	JD	May	1993

(Continued)

Table 1 (Continued)
1993 Strategic Alliances

Company A	Region	Product	Company B	Region	Product	Type	Month	Year
AMD	United States	Flash facility	Fujitsu	Japan	Flash facility in Japan	JV	May	1993
Sega	Japan	video games	Time Warner Entertainment	United States	Cable TV channels	JV	May	1993
AT&T	United States	Fiber optics	Yazaki Electric Wire	Japan	Cable	JV	May	1993
SuperMac Technology	United States	Video compression technology	Microsoft Corporation	United States	Integrate Cinepak into video for Windows	LA	May	1993
SuperMac Technology	United States	Video compression technology	Cirrus Logic	United States	Cinepak decompressor	LA	May	1993
Wang	United States	SIMMs patent	NMB Technologies Inc.	Japan	License SIMMs	LA	May	1993
VTC Inc.	United States	Supply unpackaged read/write preamps	HEI Inc.	United States	Mount/interconnect on flex circuitry	JD	May	1993
IBM	United States	RS/6000 and PowerPC	Harris	United States	UNIX System V	LA	May	1993
NeXT Inc.	United States	NeXTSTEP software	Hewlett-Packard	United States	PA-RISC architecture, servers, VectraPC	JD	May	1993
Kaleida Labs	United States	ScriptX Multimedia Language	Creative Technology	Singapore	Engineering support and alliance	OT	May	1993
Kaleida Labs	United States	ScriptX Multimedia Language	Mitsubishi	Japan	Engineering support and alliance	OT	May	1993
Kaleida Labs	United States	ScriptX Multimedia Language	Hitachi	Japan	Engineering support and alliance	OT	May	1993
Kaleida Labs	United States	ScriptX Multimedia Language	Toshiba	Japan	CD-ROM-based system support	OT	May	1993
AT&T	United States	Wireless transmission equipment	Spectrum Information Technology	United States	Cellular protocol patents	IV, LA	May	1993
Hughes	United States	Molecular beam epitaxy (MBE)	Texas Instruments	United States	MBE	OT	May	1993
Mitsubishi	Japan	16Mb flash 0.5µm CMOS	SGS-Thomson	Europe	16Mb flash 0.5µm CMOS	SS, JD	May	1993

(Continued)

Table 1 (Continued)
1993 Strategic Alliances

Company A	Region	Product	Company B	Region	Product	Type	Month	Year
Sanyo	Japan	MPEG-based audio decoders	SGS-Thomson	Europe	MPEG decoders	OT	May	1993
Applied Materials	United States	License technology	Komatsu Ltd.	Japan	Equity investment in ADT/AM subsystem	JV, LA, IV	June	1993
NCR	United States	Radio LAN systems	Ricoh	Japan	NCR radio LAN systems sales	LA	June	1993
NCR	United States	Radio LAN systems	Otsuka Shokai	Japan	NCR radio LAN systems sales	LA	June	1993
NCR	United States	Radio LAN systems	Ungermann-Bass KK	United States	NCR radio LAN systems sales	LA	June	1993
NCR	United States	Radio LAN systems	Macnica	Japan	NCR radio LAN systems sales	LA	June	1993
NCR	United States	Radio LAN systems	Net World	Japan	NCR radio LAN systems sales	LA	June	1993
AT&T	United States	SONET cable and transmis. equipment	GTE	United States	SONET fiber-optic rings	JD	June	1993
Bel Fuse Inc.	United States	Fuse products	Gould Inc.	United States	Electrical power fuses	TE	June	1993
Viewlogic Systems Inc.	United States	EDA tools	Texas Instruments	United States	FPGAs	OT	June	1993
NTT	Japan	Multimedia/ communications	ATT	United States	Multimedia and communications	JD	June	1993
Advantest	Japan	Measuring equipment	Tektronix Inc.	United States	North American rights to market measuring equipment	SA	June	1993
Austin Semiconductor	United States	Micron military products	Micron Semiconductor	United States	Military products	OT	June	1993
Electronic Data Systems	United States	InCASE CASE tool and 20 percent ownership	Amdahl	United States	Huron tools and 80 percent ownership	JV	June	1993
NEC	Japan	One-way pager protocol	Motorola	United States	FLEX TM paging protocol	LA	June	1993

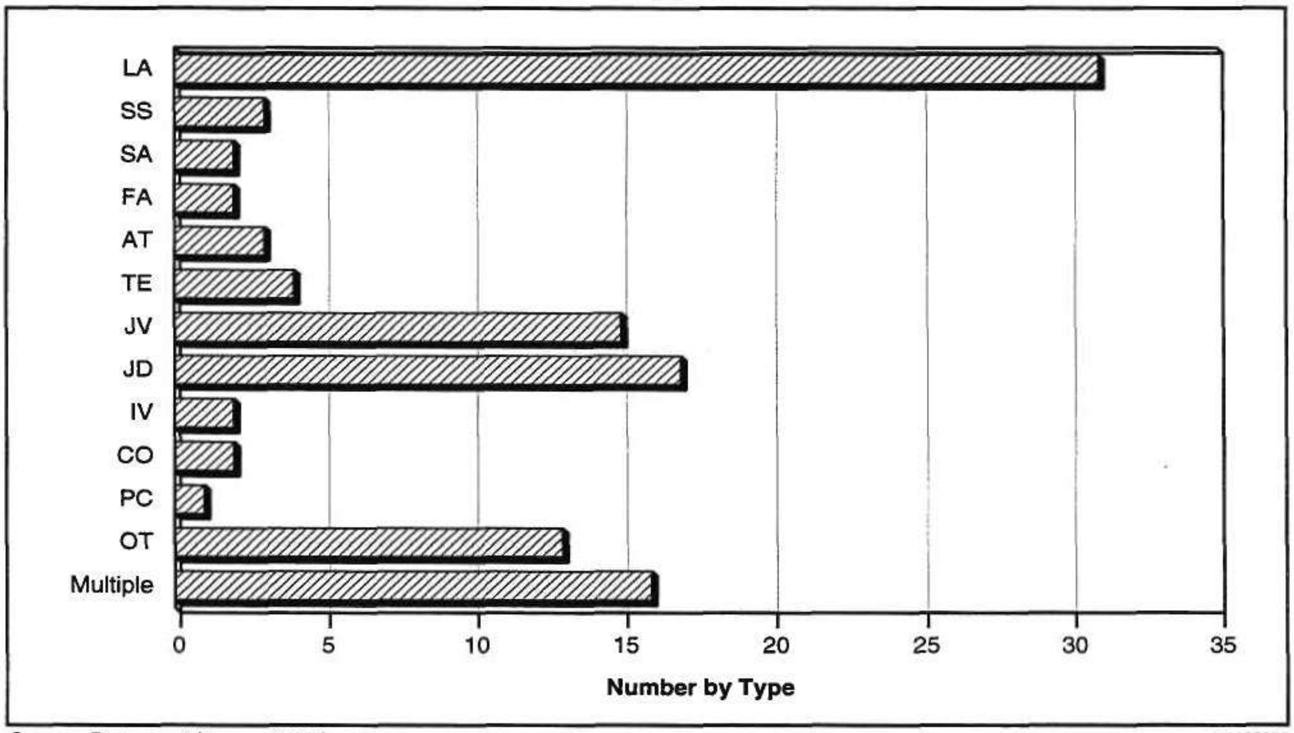
(Continued)

Table 1 (Continued)
1993 Strategic Alliances

Company A	Region	Product	Company B	Region	Product	Type	Month	Year
Ericsson	Europe	AXE public switching equipment	Tel Administration of Guangdong (GPTB)	China	Ttelecom	JV	June	1993
Viewlogic	United States	Investment	Sunrise Test Systems	United States	Software for ASIC design test	IV	June	1993
General Instrument Corporation	United States	Digital compression technology	Telecomunications Inc. (TCI)	United States	DigiCipher II/MPEG-2 cable TV	PC	June	1993
Micron Technology	United States	Patent cross license	Goldstar	Korea	Patent cross license	LA	June	1993
IBM	United States	Atmel FPGAs	Atmel	United States	License agreement on FPGAs	LA	June	1993
IBM	United States	Accelerator boards	Seattle Telecom & Data	United States	Accelerator boards	AT	June	1993
ATT	United States	Telecom switching/ 51 percent investment	Tata Industries Inc.	India	India market and 49 percent equity	JV	June	1993
IBM	United States	EDA products	Altium	United States	Desktop CAD/CAM/ CAE software	SA	June	1993
Texas Instruments	United States	Memory products	RTB Technology Inc.	United States	3-D memory cube technology	OT	June	1993

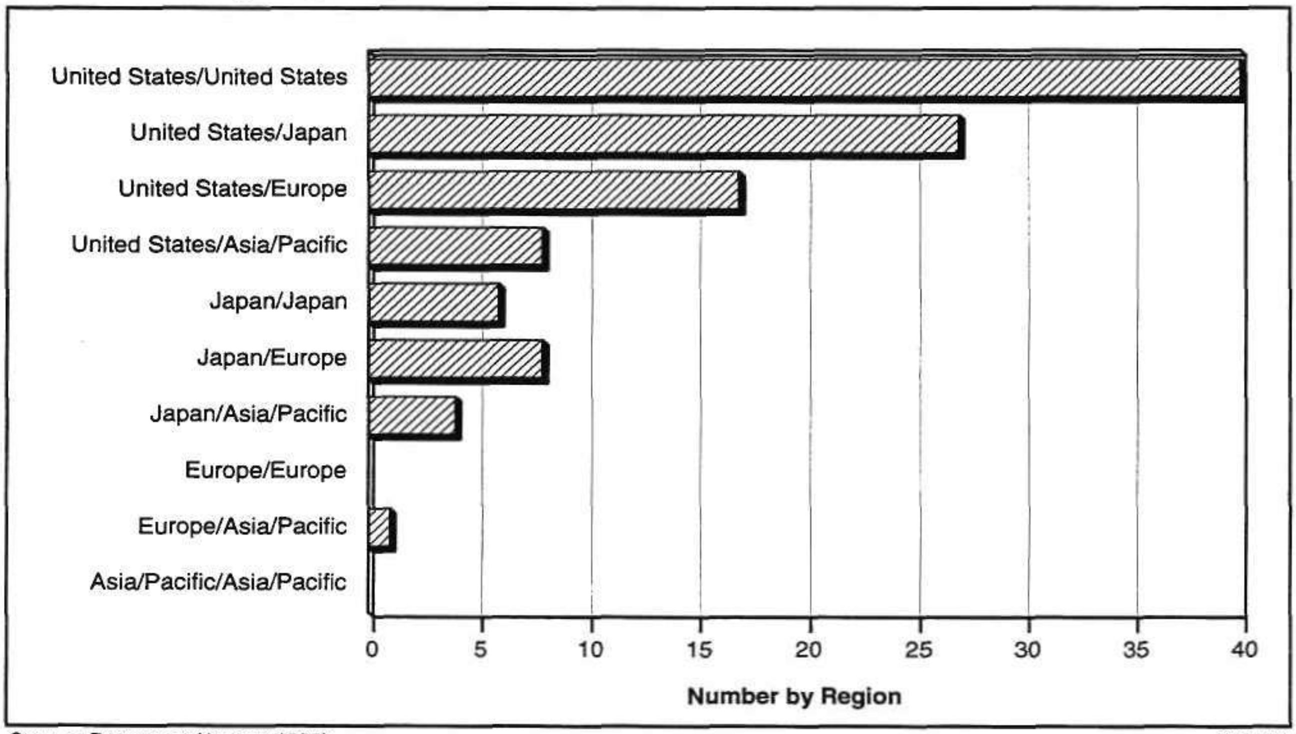
Source: Dataquest (August 1993)

Figure 1
1993 Strategic Alliances by Type



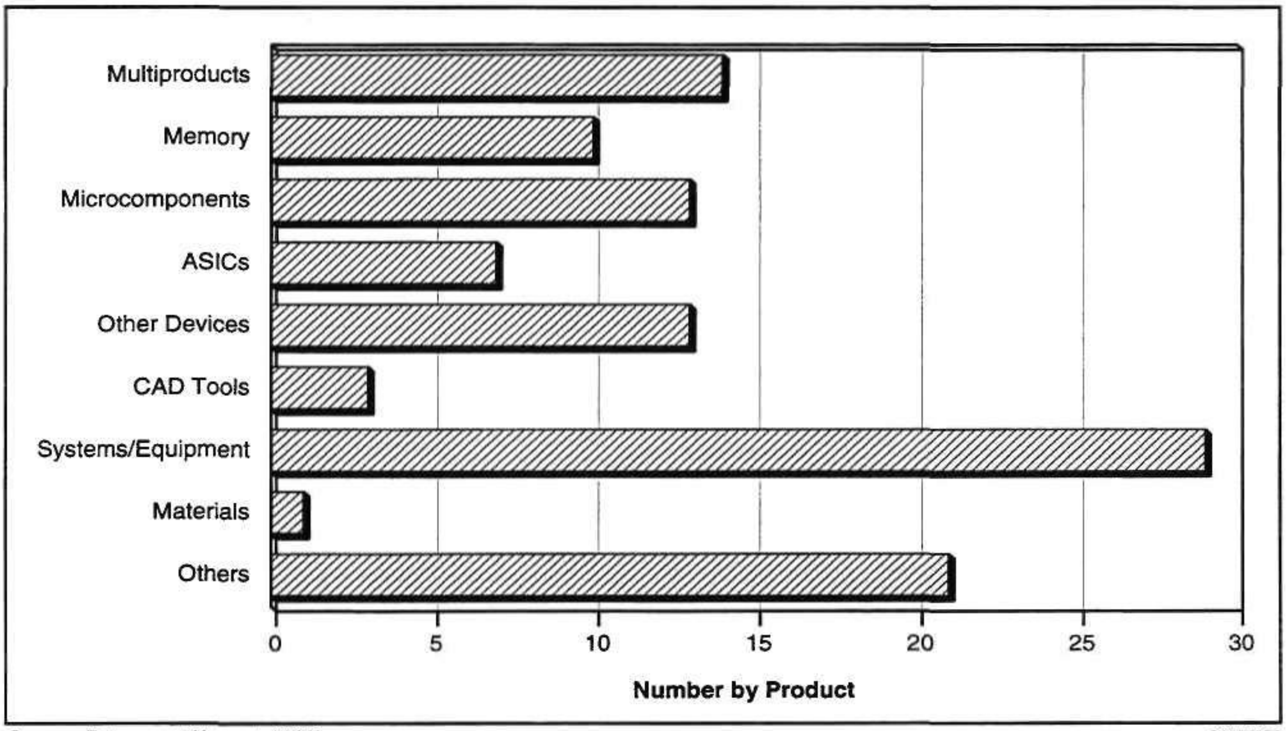
Source: Dataquest (August 1993) G3005053

Figure 2
1993 Alliances by Regional Companies



Source: Dataquest (August 1993) G3005054

Figure 3
1993 Alliances by Product Type



Source: Dataquest (August 1993)

G3005055

By Mary A. Olsson

```
N01SEMIWW SEMIWWDP9305 BH:   1 N:   1
Mr. Clark Fuhs
Dataquest Incorporated

******************
SJ - INTERNAL DISTRIBUTION
******************
```

For More Information...
Mary A. Olsson, Senior Industry Analyst .... (408) 437-8674
Via fax .... (408) 437-0292

Dataquest Perspective

Semiconductors

ASIC Worldwide

In This Issue

Japanese ASIC Suppliers Hit Hard Times in 1992

According to Dataquest's preliminary 1992 market share estimates, Japanese companies experienced a 3 percent decline in ASIC sales from 1991 to 1992, while North American companies posted an 8 percent increase in ASIC sales. The recession in Japan severely impacted the growth of most Japanese ASIC suppliers. Fujitsu was hardest hit with a 12 percent decline in ASIC sales. Not only was Fujitsu hurt by the recession, but also declining mainframe computer sales caused its bipolar gate array sales to plummet 21 percent. Although NEC only achieved a modest 2 percent growth in total 1992 ASIC sales, it was enough to close the gap on Fujitsu and make it a close race to the finish line for the No. 1 ASIC supplier of the year (see Figure 1). Fujitsu closed calendar year 1992 with a $3 million dollar lead over NEC, a photo finish.

This article first analyzes the 1992 market share data by product, then examines the critical success factors for future ASIC suppliers.

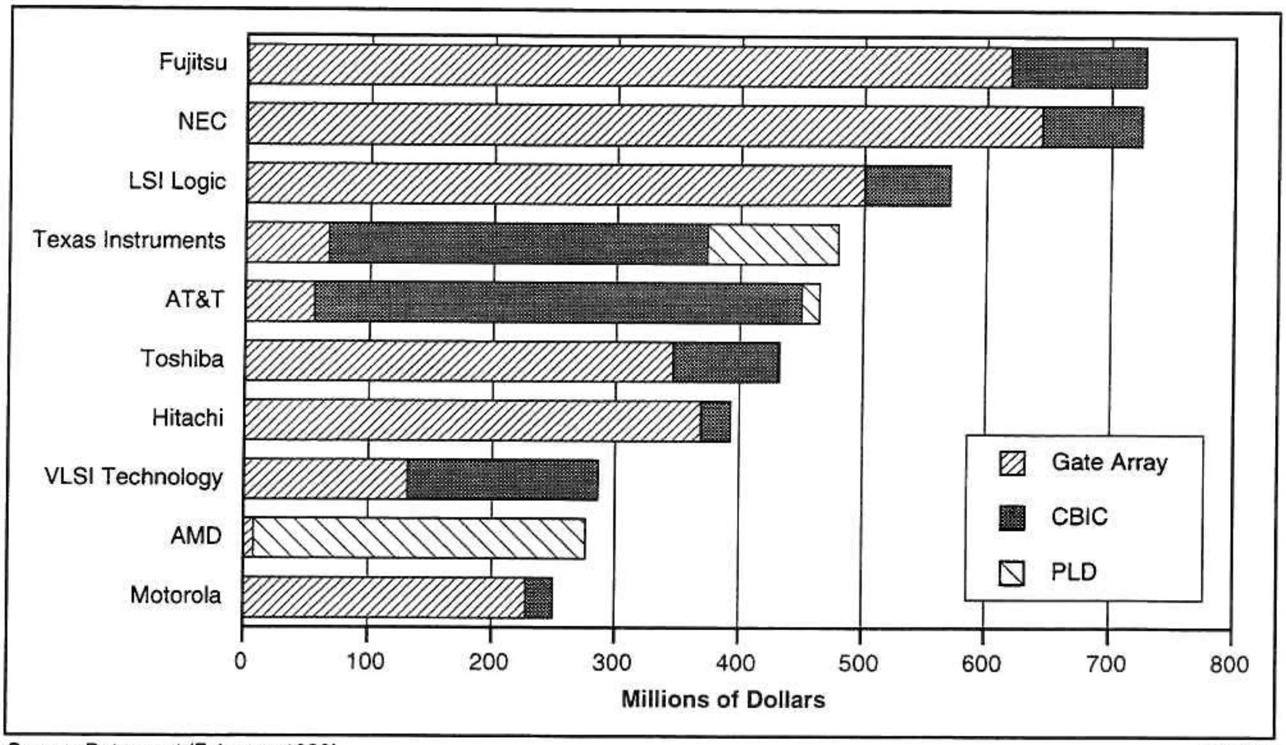
1992 ASIC Market Share Rankings

Table 1 shows Dataquest's preliminary 1992 estimates of the top 20 worldwide ASIC suppliers, with their respective revenue and market share.

Dataquest®
a company of The Dun & Bradstreet Corporation

Program: ASIC Worldwide
Product Code: ASIC-WW-DP-9301
Publication Date: February 22, 1993

Figure 1
1992 Top 10 Worldwide ASIC Suppliers



Source: Dataquest (February 1993) G3000154

Important points regarding ASIC market share rankings include the following:

- The year 1992 had the lowest growth in ASIC history, only 4 percent, primarily because of the Japan recession. With less than 1 percent growth, gate arrays are to blame. Cell-based ICs (CBICs) and PLDs had modest growth rates of 9 percent and 6 percent, respectively.
- Although the Japan recession reduced the ASIC dollar growth rate, it could have been much worse in dollar terms if the yen had not appreciated against the dollar. As previously stated, Japanese companies experienced a 3 percent decline in dollar ASIC sales. Japanese companies' ASIC sales declined 10 percent in yen-based sales (the yen appreciated 7 percent against the dollar).
- There has been a shift in focus for many ASIC suppliers from revenue growth to increasing profitability.

The following are footnotes to the ASIC market share estimates:

- Rankings are based on dollar shipments, which include the following revenue sources:
  - Intracompany revenue (sales to internal divisions)
  - Nonrecurring engineering (NRE) revenue
  - ASIC software revenue

Table 1
1992 Preliminary Worldwide Estimated Market Share Ranking: Total ASIC
(Millions of Dollars)

1992 Rank	1991 Rank	Company	1991 Revenue	1992 Revenue	Percent Change	1992 Market Share (%)
1	1	Fujitsu	822	727	-12	9.9
2	2	NEC	709	724	2	9.9
3	3	LSI Logic	555	570	3	7.8
4	4	Texas Instruments	453	480	6	6.5
5	5	AT&T	421	465	10	6.3
6	6	Toshiba	418	432	3	5.9
7	7	Hitachi	409	393	-4	5.3
8	9	VLSI Technology	249	286	15	3.9
9	8	Advanced Micro Devices	263	276	5	3.8
10	10	Motorola	218	250	15	3.4
11	11	Hewlett-Packard	206	209	1	2.8
12	12	GEC Plessey	187	185	-1	2.5
13	14	Xilinx	130	163	25	2.2
14	13	National Semiconductor	163	141	-13	1.9
15	19	NCR	99	137	38	1.9
16	18	SGS-Thomson	103	128	24	1.7
17	20	Mietec	94	106	13	1.4
18	16	Altera	107	102	-5	1.4
19	16	Seiko Epson	107	101	-6	1.4
20	21	Matsushita	92	92	0	1.3

Note: Full-custom ICs are excluded from this table.
Source: Dataquest (February 1993)

- PLD development kit revenue
- Device production revenue

- Full custom IC revenue is excluded from ASIC market share.
- ASIC product revenue is based on the combined revenue from digital, mixed analog/digital, and analog products.
- MOS rankings include the sales of CMOS, NMOS, and BiCMOS.
- Total rankings include the sales of CMOS, NMOS, BiCMOS, and bipolar.
- The U.S. dollar depreciated 5 percent against the European currency unit (ECU) during 1991. Dataquest's exchange rates: U.S.$1 = 0.81 ECU (1991); U.S.$1 = 0.77 ECU (1992).
- The U.S. dollar depreciated 7 percent against the yen during 1991. Dataquest's exchange rates: U.S.$1 = ¥136 (1991); U.S.$1 = ¥126 (1992).

Product Overview

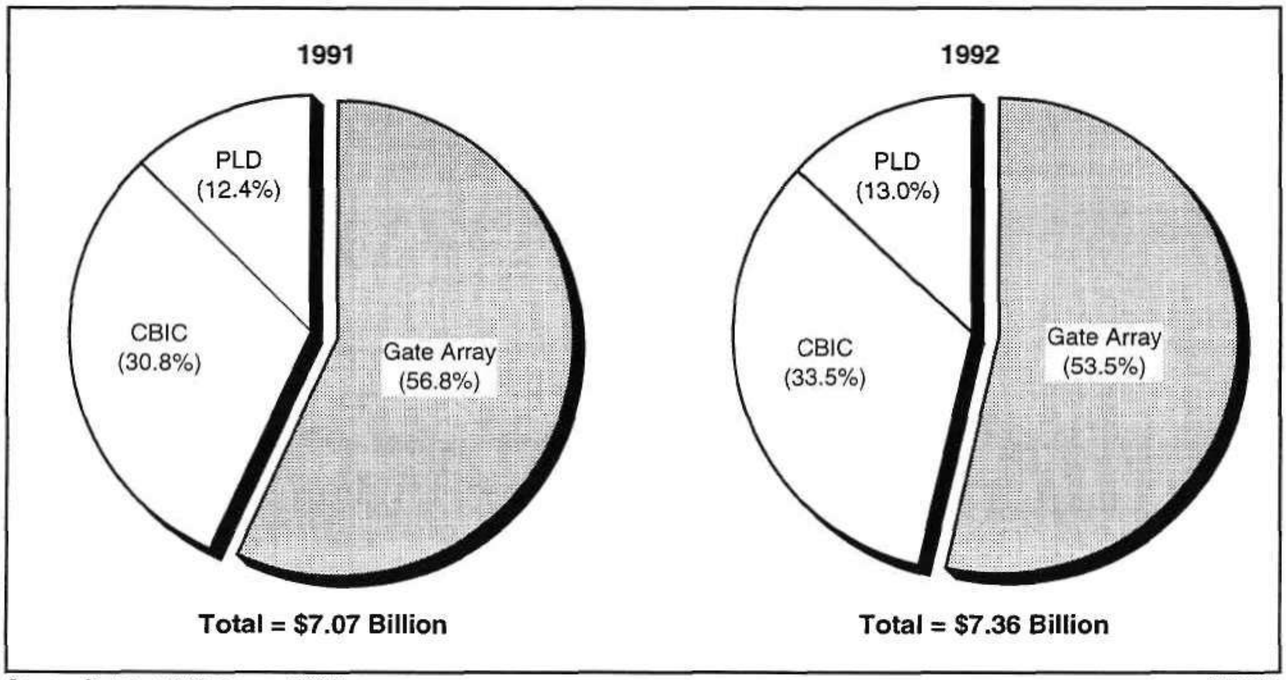
The worldwide 1992 ASIC market (excluding full custom revenue) grew about 4 percent over 1991 to $7.36 billion. Figure 2 presents the composition of the ASIC market by product and shows that gate arrays are the largest market. However, they declined as a percentage of the total market.

Gate Arrays

The year 1992 was the worst in gate array history; the total gate array market was virtually flat, with less than 1 percent growth. Bipolar gate array growth was dismal, with a 9 percent decline. MOS/BiCMOS gate array growth was also the lowest in history with a modest four percent growth. The primary reason for the low growth rates was that the gate array market is dominated by Japanese suppliers, and they were the hardest hit by global economic recession.

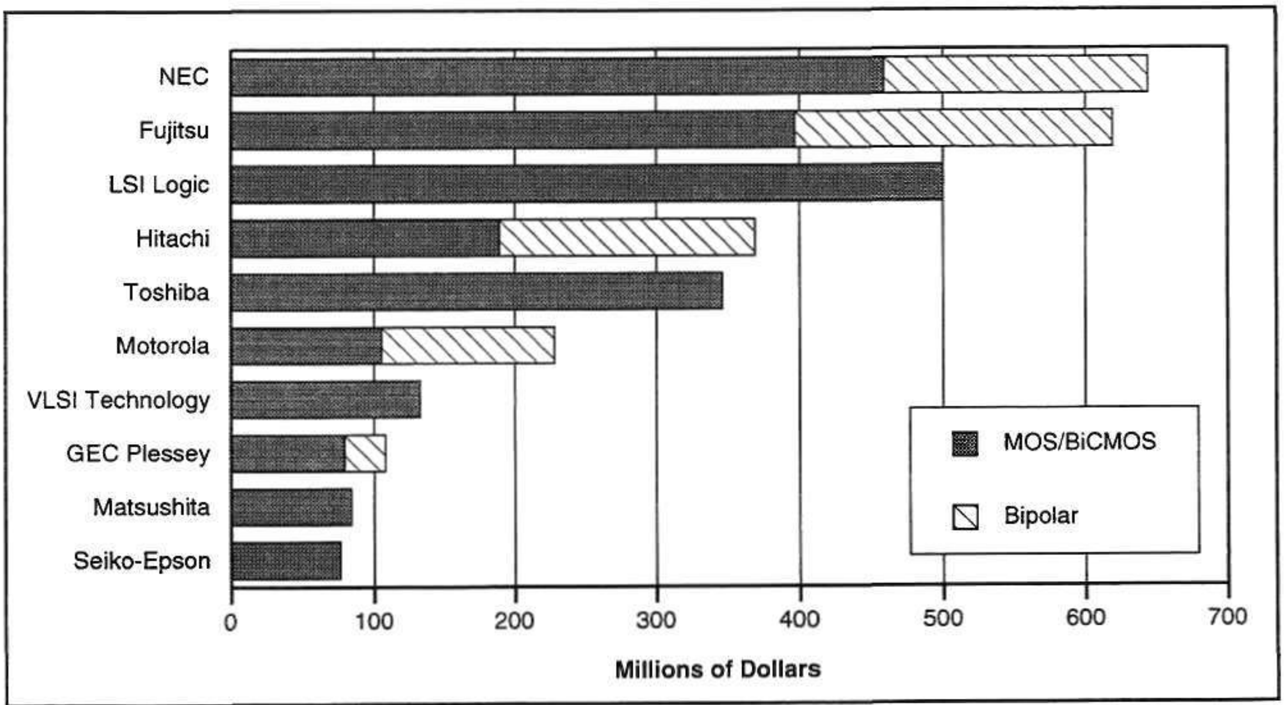
Figure 3 shows the top 10 1992 worldwide gate array supplier revenue by technology. Figure 4 shows the rapid decline in bipolar gate array revenue by the top 10 suppliers. Figure 5 shows the top 10 1992 MOS/BiCMOS gate array suppliers' revenue, while Figure 6 ranks the same suppliers by size of estimated merchant sales. Table 2 lists the hotly contested top 20 1992 worldwide MOS gate array suppliers and their respective revenue, growth rates, and market share. Figure 7 takes a snapshot of leading MOS/BiCMOS gate array suppliers in North America.

Figure 2
Preliminary Estimated 1992 ASIC Consumption, by Product



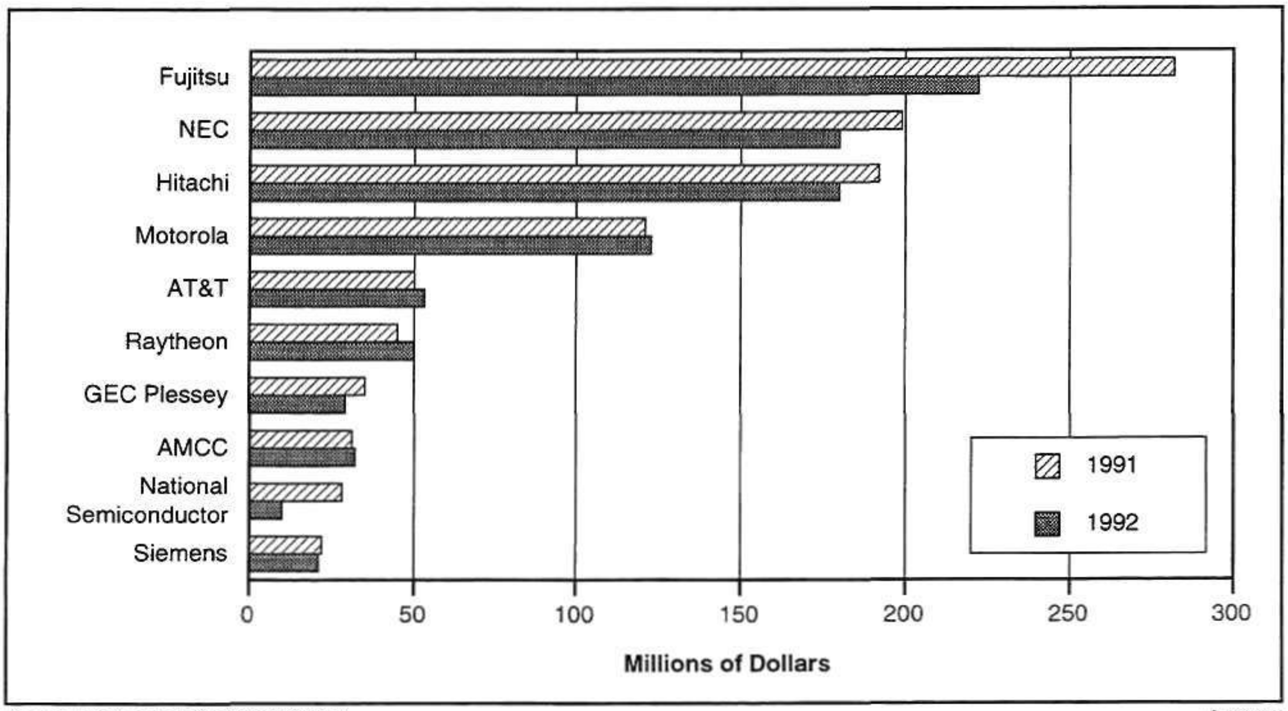
Source: Dataquest (February 1993) G3000155

Figure 3
1992 Top 10 Worldwide Gate Array Suppliers



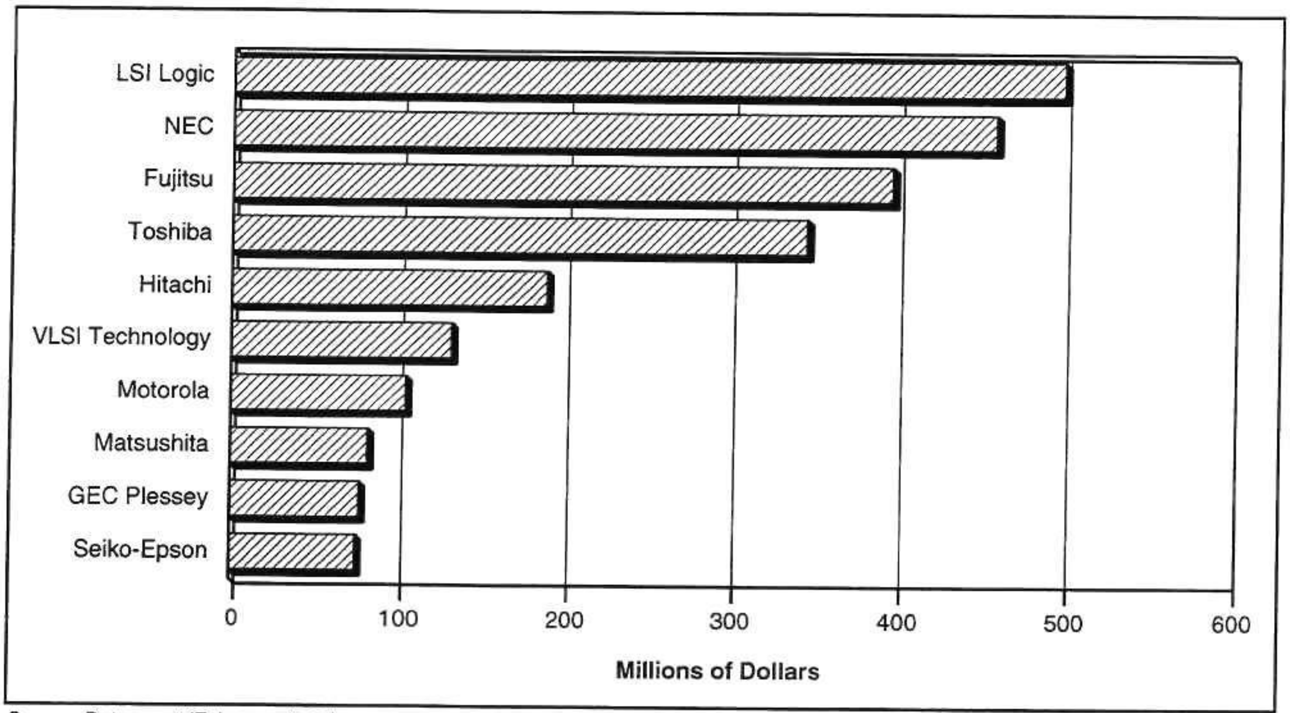
Source: Dataquest (February 1993) G3000156

Figure 4
1992 Top 10 Worldwide Bipolar Gate Array Suppliers



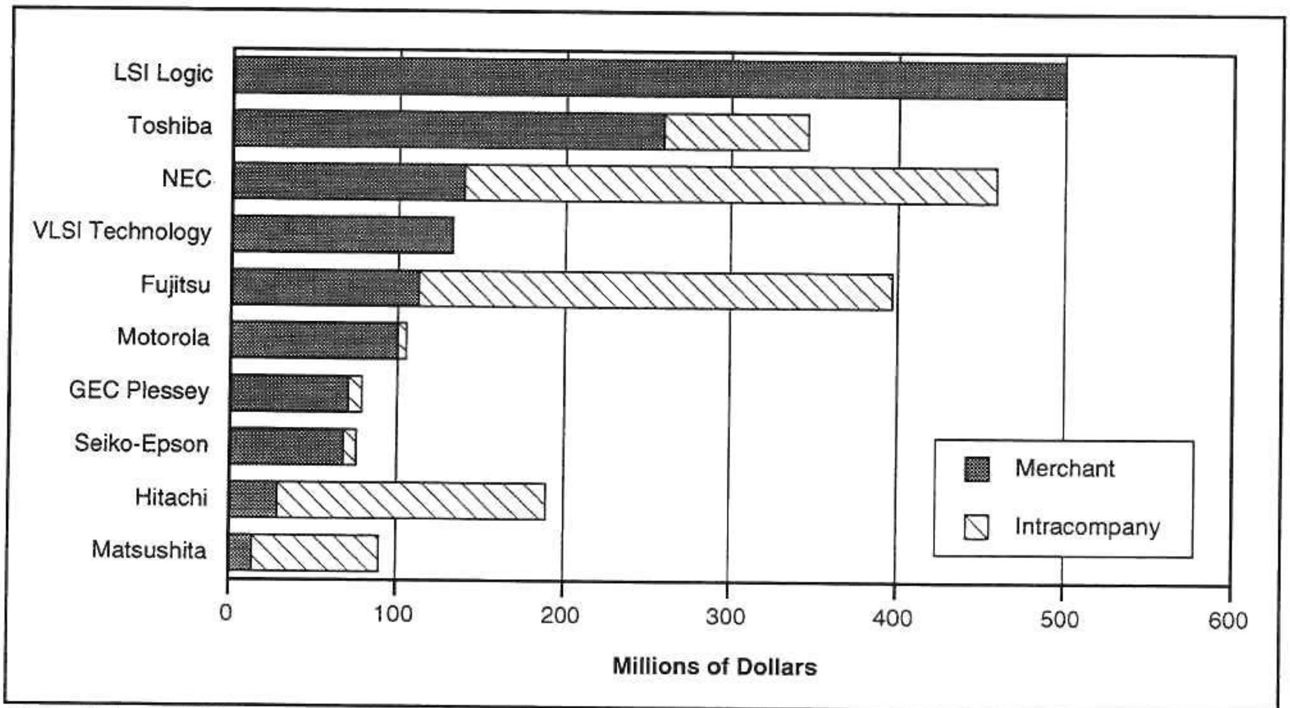
Source: Dataquest (February 1993) G3000157

Figure 5
1992 Top 10 Worldwide MOS/BiCMOS Gate Array Suppliers



Source: Dataquest (February 1993) G3000158

Figure 6
1992 Top 10 Worldwide MOS/BiCMOS Gate Array Suppliers, by Type of Sale



Source: Dataquest (February 1993) G3000159

Table 2
1992 Preliminary Worldwide Estimated Market Share Ranking: MOS/BiCMOS Gate Array (Millions of Dollars)

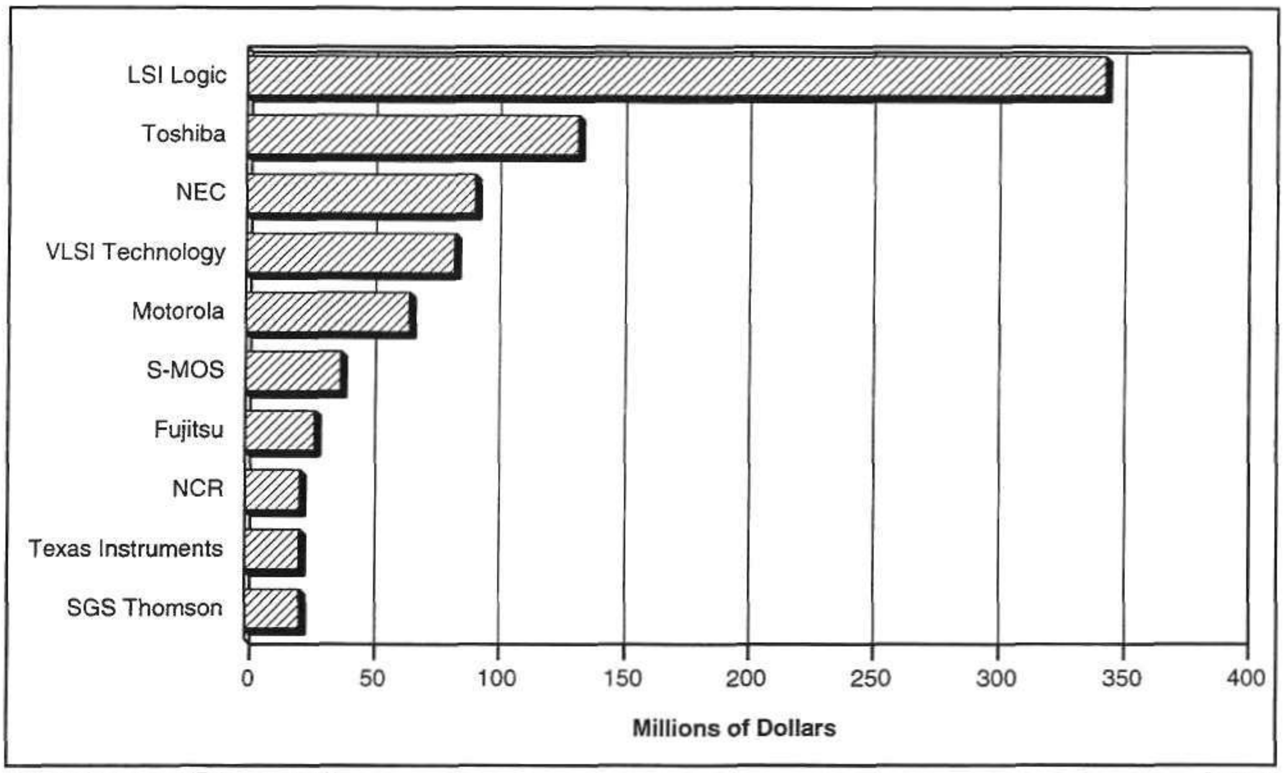
1992 Rank	1991 Rank	Company	1991 Revenue	1992 Revenue	Percent Change	1992 Market Share (%)
1	1	LSI Logic	497	500	1	16.9
2	2	NEC	440	459	4	15.5
3	3	Fujitsu	425	397	-7	13.4
4	4	Toshiba	333	346	4	11.7
5	5	Hitachi	203	189	-7	6.4
6	6	VLSI Technology	98	132	35	4.5
7	10	Motorola	77	105	36	3.6
8	8	Matsushita	83	84	1	2.8
9	9	GEC Plessey	78	79	1	2.7
10	7	Seiko Epson	91	76	-16	2.6
11	15	Texas Instruments	39	65	67	2.2
12	14	SGS-Thomson	40	59	48	2.0
13	12	National Semiconductor	58	50	-14	1.7
14	13	Mitsubishi	43	44	2	1.5
14	16	Sharp	37	44	19	1.5
16	11	Oki	73	43	-41	1.5
17	18	Sony	16	30	88	1.0
18	17	Matra MHS	22	25	14	0.8
19	21	NCR	15	22	47	0.7
20	21	Samsung	15	20	33	0.7

Source: Dataquest (February 1993)

Noteworthy points regarding the 1992 gate array rankings include the following:

- NEC passed Fujitsu in total 1992 gate array sales. NEC's total gate array sales were virtually flat, while Fujitsu experienced a 12 percent decline in sales. Fujitsu had a 21 percent decline in bipolar gate array sales and a 7 percent decline in MOS/BiCMOS gate array sales.
- National dropped out of the top 10 total gate array ranking.
- VLSI Technology experienced 35 percent growth in MOS gate arrays and moved from eighth to seventh place in total gate arrays.
- Motorola had a great year in MOS gate arrays, with 36 percent increase in sales, which rocketed it among the top 10 MOS gate array rankings from 10th to 7th place.
- LSI Logic remains the largest merchant gate array supplier as well as the largest gate array supplier in North America.

Figure 7
1992 Top 10 North American MOS/BiCMOS Gate Array Suppliers



Source: Dataquest (February 1993)

G3000160

- Samsung is the first Korean supplier to make the top 20 ranking in MOS gate arrays. Korean suppliers have targeted the gate array market for growth.

Cell-Based ICs

Although the 1992 CBIC growth rate also was the lowest in history with a modest 9 percent growth, it seems like good growth when compared to the gate array market. MOS CBICs accounted for 96 percent of the total 1992 CBIC market. The 1992 worldwide MOS CBIC market grew 9 percent, while the bipolar CBIC market was virtually flat, with 2 percent growth. The CBIC market grew faster than did the gate array market for the following reasons:

- Japan consumes more gate arrays than CBICs, therefore the CBIC market was not hit as hard by the Japan recession.
- Mainframe computers do not use many CBICs, thus the CBIC market was not impacted by declining mainframe computer sales.
- The military market is declining, and there is a high concentration of gate arrays in military system designs.
- An increase in PC and workstation shipments caused the disk drive market to pick up, which helped stimulate growth in the CBIC market.

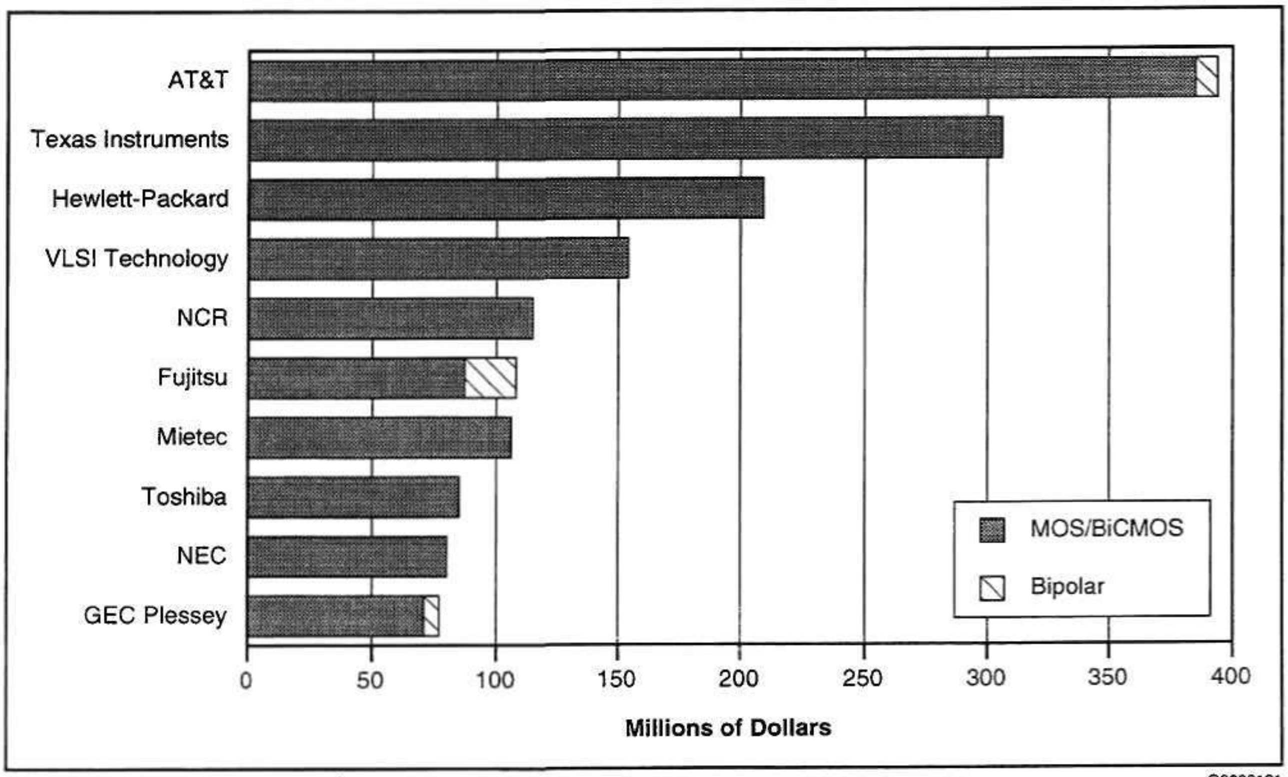
- Telecommunications applications continue to flourish, which is helping drive the growth of the CBIC market.

Figure 8 shows the top 10 1992 worldwide CBIC suppliers revenue, by technology. Table 3 shows the top 20 1992 worldwide MOS/BiCMOS CBIC suppliers by their respective revenue, growth rates, and market share. Figure 9 shows the top 10 worldwide MOS/BiCMOS CBIC suppliers, while Figure 10 shows the same suppliers ranked by estimated merchant sales. Figure 11 examines the top 10 1992 North American MOS/BiCMOS CBIC suppliers.

Noteworthy points regarding the 1992 CBIC rankings include the following:

- NCR jumped from seventh to fifth in total CBIC sales with a healthy 37 percent increase in CBIC sales. Part of this increase in sales was because of an increase in disk drive sales.
- NEC moved from 10th to 9th in total CBIC sales by increasing its internal consumption as well as making a strong push in the merchant market.
- If the rankings were based on merchant sales only, LSI Logic would be the fifth largest merchant CBIC supplier.

Figure 8
1992 Top 10 Worldwide CBIC Suppliers



Source: Dataquest (February 1993) G3000161

Table 3
1992 Preliminary Worldwide Estimated Market Share Ranking: MOS/BiCMOS Cell-Based IC (Millions of Dollars)

1992 Rank	1991 Rank	Company	1991 Revenue	1992 Revenue	Percent Change	1992 Market Share (%)
1	1	AT&T	355	385	8	16.2
2	2	Texas Instruments	293	306	4	12.9
3	3	Hewlett-Packard	206	209	1	8.8
4	4	VLSI Technology	151	154	2	6.5
5	7	NCR	84	115	37	4.9
6	5	Mietec	94	106	13	4.5
7	6	Fujitsu	91	87	-4	3.7
8	7	Toshiba	84	85	1	3.6
9	9	NEC	70	80	14	3.4
10	11	GEC Plessey	64	71	11	3.0
11	12	LSI Logic	58	70	21	3.0
12	13	SGS-Thomson	56	63	13	2.7
13	10	Harris	66	58	-12	2.4
14	14	Austria Mikro Systeme	55	57	4	2.4
15	15	European Silicon Structures	28	30	7	1.3
15	21	Gould AMI	20	30	50	1.3
17	NM	Integrated Circuit Systems	NA	26	NA	1.1
18	25	Seiko Epson	16	25	56	1.1
19	17	Hitachi	24	24	0	1.0
19	23	Sharp	19	24	26	1.0

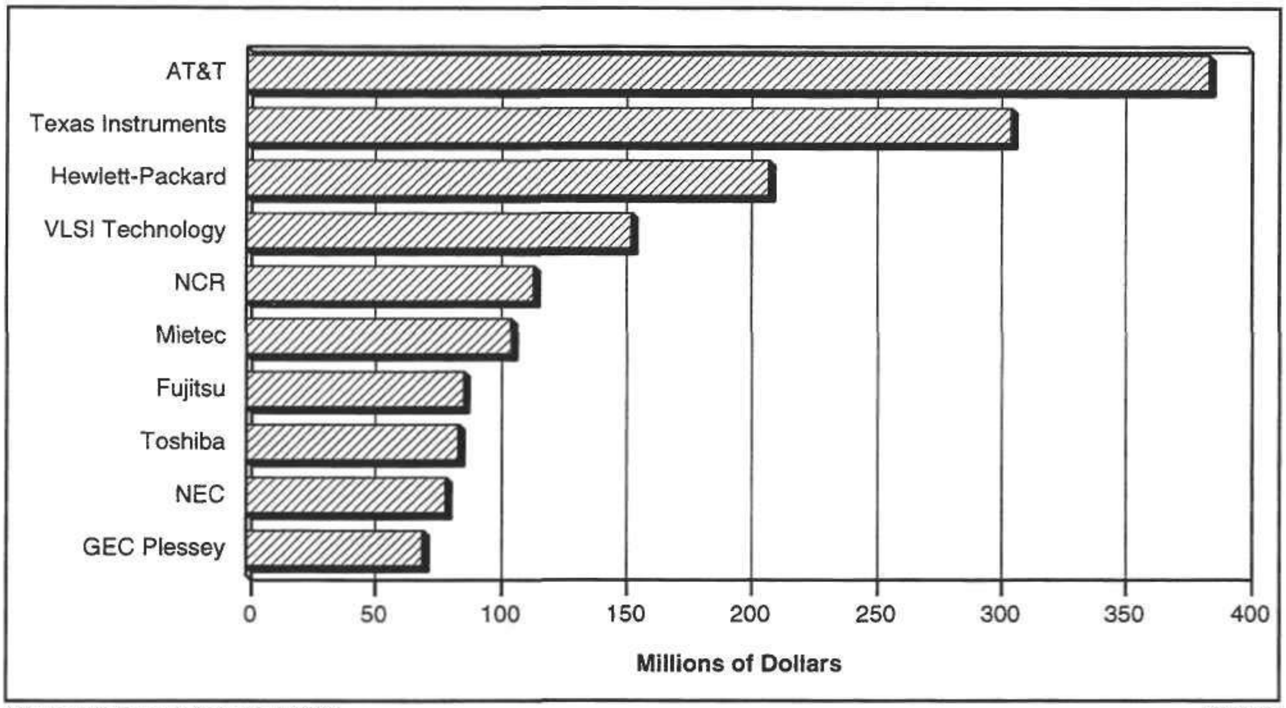
NM = Not meaningful
NA = Not available
Source: Dataquest (February 1993)

- Mietec is the only company with a large portion of the sales in BiCMOS products, which were primarily sold to European telecommunications equipment suppliers.
- Japanese suppliers are increasing their CBIC sales by focusing on high-volume applications such as video games, printers, and disk drives.

PLDs

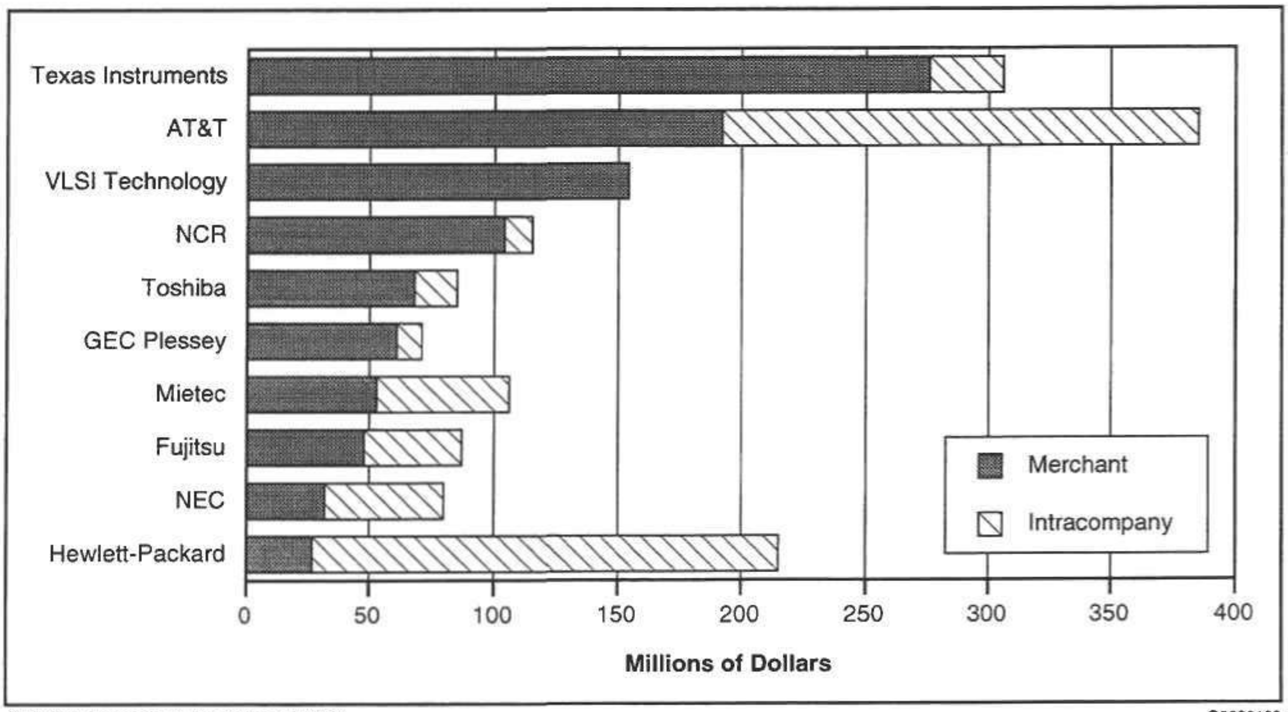
During 1992, some segments of PLD market were vibrant, while others were sluggish. The MOS PLD market outpaced the entire semiconductor industry with 20 percent growth over 1991. However, revenue from the bipolar PLD market fell 17 percent. Although the total PLD market only grew 6 percent, PLDs on average had the highest profit margins of any ASIC product.

Figure 9
1992 Top 10 Worldwide MOS/BiCMOS CBIC Suppliers



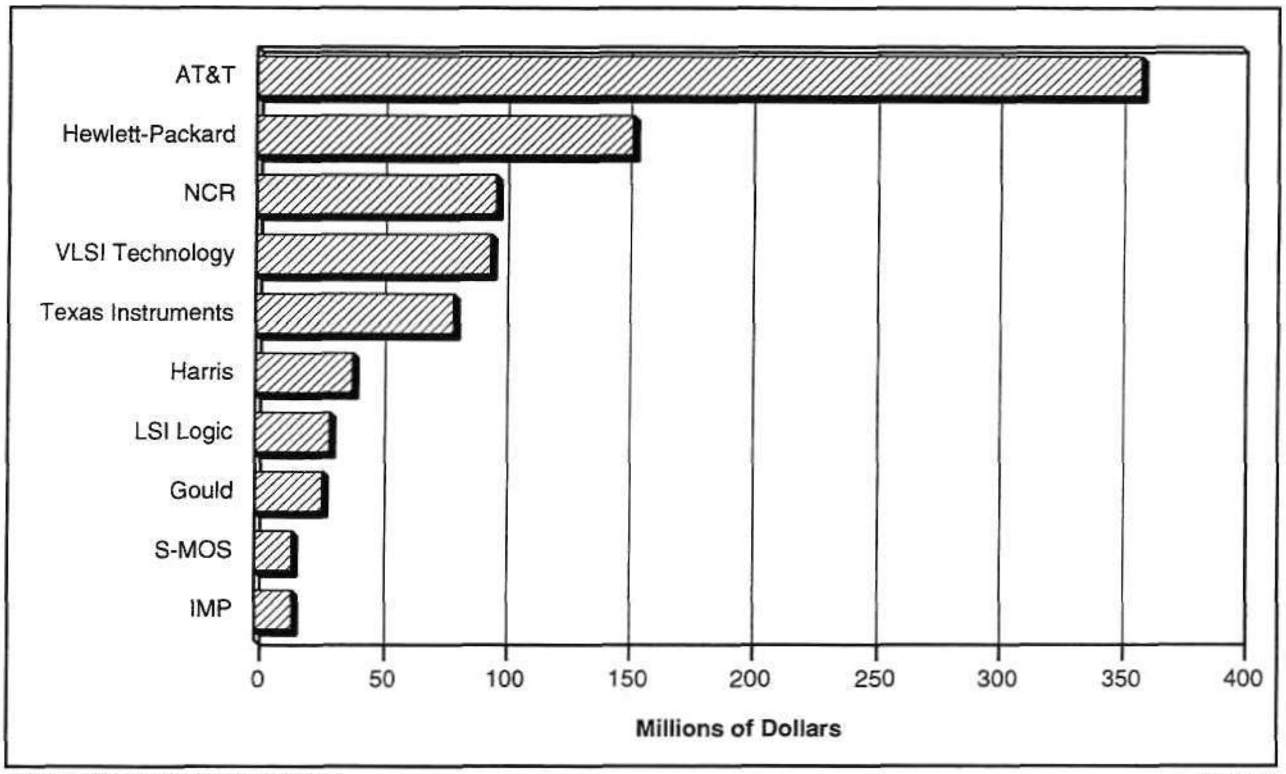
Source: Dataquest (February 1993) G3000162

Figure 10
1992 Top 10 Worldwide MOS/BiCMOS CBIC Suppliers, by Type of Sale



Source: Dataquest (February 1993) G3000163

Figure 11
1992 Top 10 North American MOS/BiCMOS CBIC Suppliers



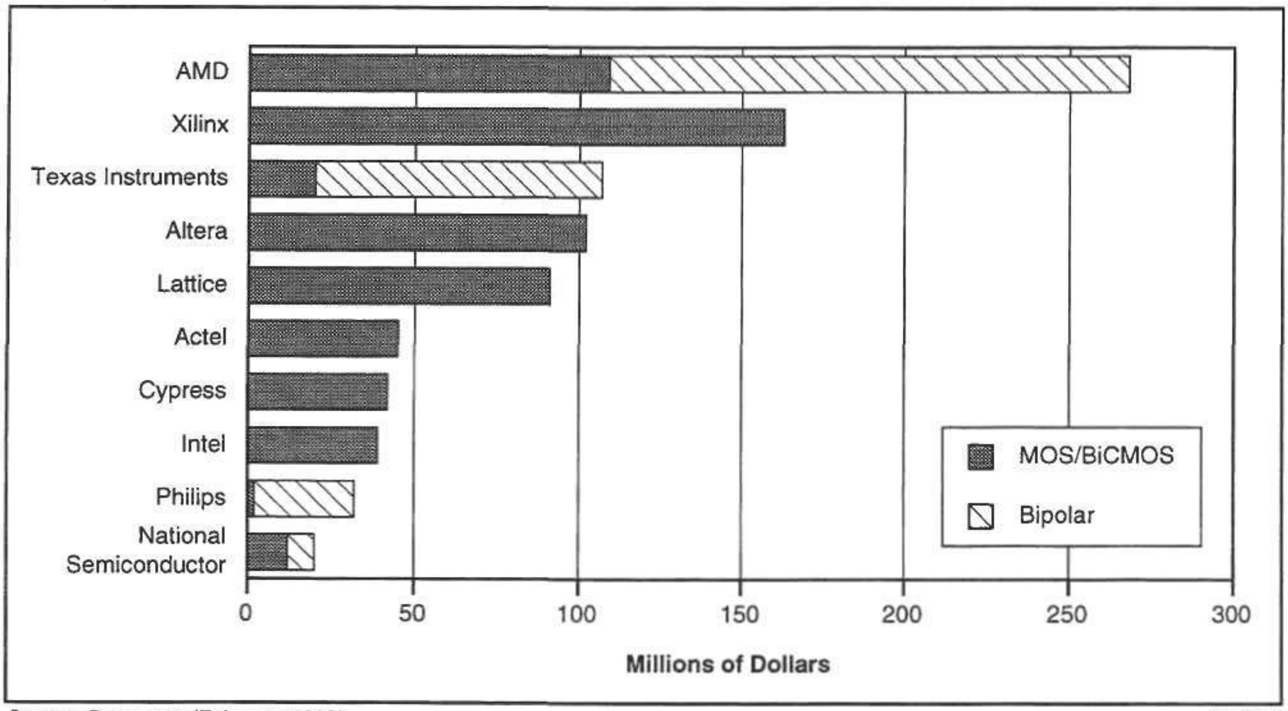
Source: Dataquest (February 1993) G3000164

Figure 12 shows the top 10 1992 worldwide PLD supplier revenue by technology. Figure 13 shows the leaders in the hotly contested MOS PLD market.

Noteworthy points regarding the 1992 PLD rankings include the following:

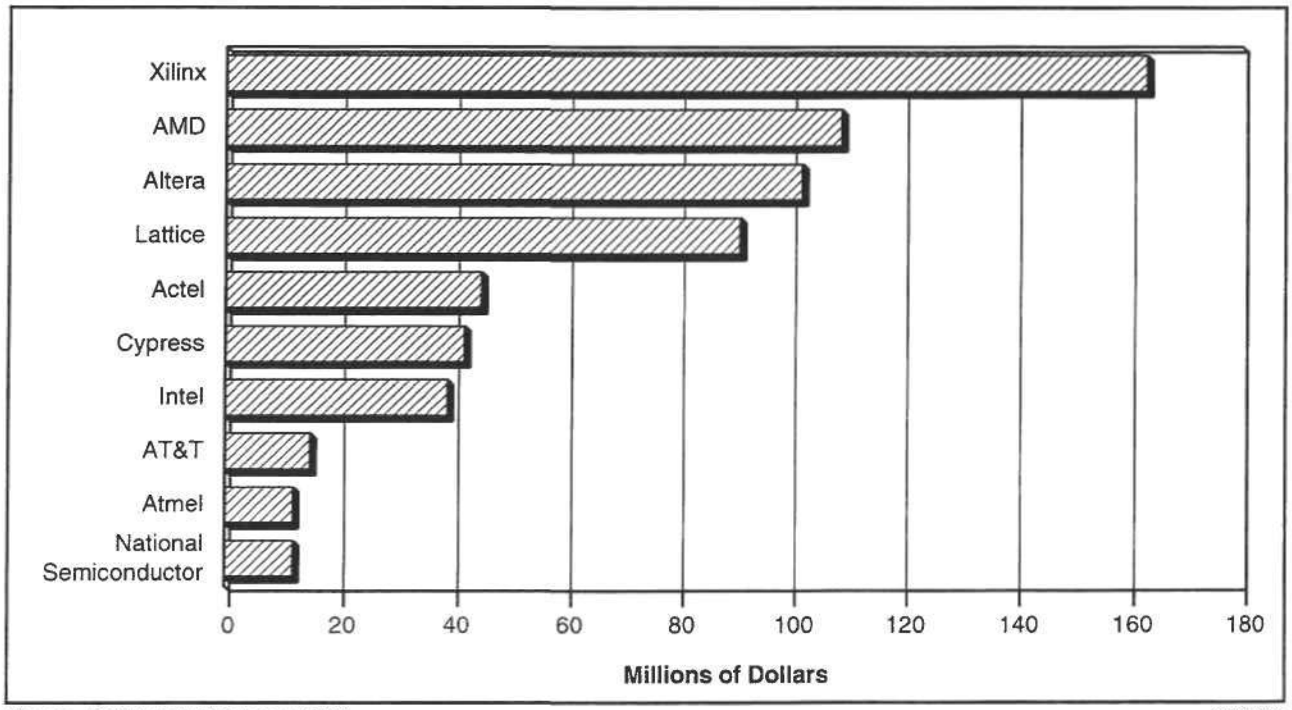
- AMD's total 1992 PLD revenue grew 6 percent, the industry average. The company experienced an outstanding 76 percent increase in 1992 MOS PLD shipments while also experiencing a 16 percent decline in 1992 bipolar PLD revenue. AMD clearly is willing to sacrifice its bipolar PLDs for higher-margin MOS devices.
- Xilinx outpaced the MOS PLD market with 24 percent growth and extended its lead as the No. 1 MOS PLD supplier.
- Actel jumped from sixth to fifth in MOS PLDs with an above-average growth rate of 22 percent.
- A surge in GAL sales caused Lattice to grow 28 percent.
- Altera and Cypress succumbed to a global economic recession and severe price competition, thus they posted negative growth rates in 1992.

Figure 12
1992 Top 10 Worldwide PLD Suppliers



Source: Dataquest (February 1993) G3000165

Figure 13
1992 Top 10 Worldwide MOS/BiCMOS PLD Suppliers



Source: Dataquest (February 1993) G3000166

Dataquest Perspective

What must ASIC suppliers do to increase sales and ultimately increase profits in this highly competitive market? Dataquest believes successful ASIC suppliers in the 1990s will have made major investments in the following four areas:

- Alliances
- High-value intellectual property
- Low-cost manufacturing
- System knowledge

Many kinds of alliances are important to ASIC companies. Most ASIC suppliers do not have the R&D budget to develop all the areas of concern, such as next-generation manufacturing processes, dedicated macrocell libraries, or competitive EDA tools. ASIC suppliers are forming relationships—either supplier-to-supplier, or supplier-to-user—to help cut their R&D costs. A good example of a supplier-to-supplier alliance that is working is the agreement among VLSI Technology, Compass, and Hitachi, who are codeveloping a common design environment, common processes, common gate array and CBIC products, and common libraries. A good example of a supplier-to-user alliance is the agreement between Motorola and Cray. The two companies have worked together for years in developing new gate array architecture, new processes, and innovative packaging technology. Alliances are critical for future ASIC suppliers.

High-value intellectual property also is important and comes in many forms. It ranges from dedicated cell libraries to unique packaging and test structures. The key to high-value intellectual property is finding a need, finding a cost-effective solution, and protecting it so other suppliers cannot copy it. Because a high number of ASIC suppliers all offer comparable products, unique intellectual property is mandatory for commanding respectable profit margins.

ASIC suppliers of the 1990s must seek out low-cost manufacturing, coupled with leading-edge processes. It is not mandatory for all ASIC suppliers to have a fab, they must just have guaranteed access to one. If a supplier will have a fab, the supplier must keep it full, which is easier said than done for some ASIC suppliers. Many ASIC suppliers in the 1990s will share fabs to reduce their costs. Other suppliers will elect to purchase fab capacity; this can be risky because the company may get turned off in an industry upturn. With many commodity ASIC product profit margins as low as they are today, low-cost manufacturing is a must to stay in the business.

The value of system knowledge should not be underestimated. Users want to form alliances with ASIC suppliers that understand their system requirements and bring unique value to their applications. It is far better to be the best ASIC supplier for selected applications than to be an average supplier competing on price alone in all applications.

By Bryan Lewis

Program in Another Good Year for Programmable Logic

The year 1992 saw a clear demarcation in the difference between simple programmable logic devices (SPLDs) and higher density complex programmable logic devices (CPLDs) and field-programmable gate arrays (FPGAs) (refer to Figure 1). While smaller, less complex programmable devices received a boost from a burgeoning PC industry, its higher-density brethren showed strong gains in finding new sockets throughout the world. In this article, we will analyze the results of 1992 and our projections for the future of programmable logic.

Bipolar PLDs Are Becoming an Endangered Species

With 1991 and 1992 growth rates for bipolar PLDs at negative 19 percent and negative 17 percent, respectively, the bipolar market is nearing the end of its life cycle. Many of these fuse-programmable devices—including 16L8s, 20R8s, and 22V10—once roamed on circuit boards across the world, but now they are being hunted to extinction by cooler-running MOS devices. Only four bipolar PLD vendors are of consequence: AMD, Texas Instruments, Philips (Signetics products), and National Semiconductor (see Table 1). Dataquest believes that the bipolar market will continue to decrease about 15 to 30 percent per year for the next five years, driven by the fact that the largest supplier of bipolar PLDs, AMD, is rapidly shifting its product mix to MOS PLDs. Technological advances in MOS PLDs by such companies as Cypress, Lattice, and AMD also are rapidly outpacing speed advances made by bipolar parts. We forecast that the bipolar PLD market will be less than $100 million by 1996.

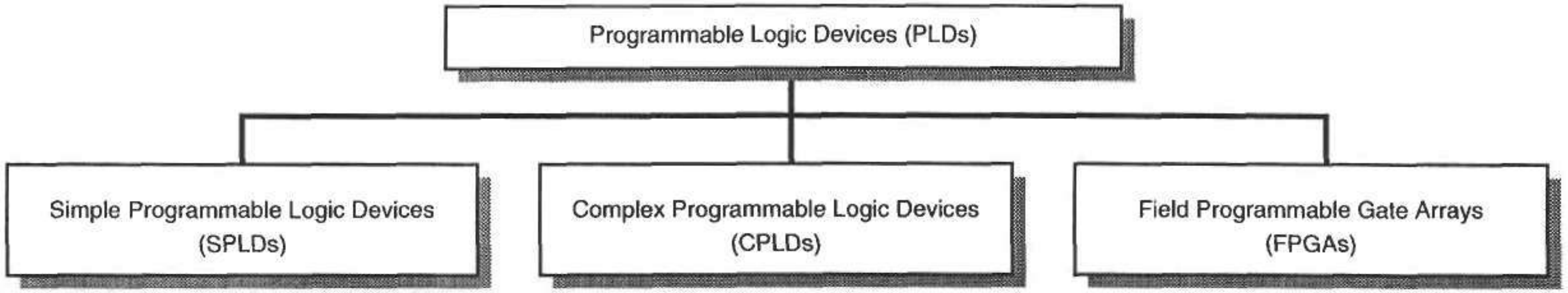
MOS SPLDs Rode the PC Consumption Wave in 1992

MOS SPLDs have effectively become the standard way to implement logic, replacing standard logic and bipolar PLDs. Indeed, in 1992 we saw that consumption of MOS SPLDs overtook its bipolar predecessor. But the growth rates for MOS SPLDs have remained constant for the past two years, at about 15 percent. Dataquest foresees some ominous signs that might be early warning signs of difficulty, including few barriers to entry, concentrated industry usage, and a decrease in end-user demand.

SPLD Software Tools Are Ubiquitous

Dataquest believes that few new markets are left for simple programmable logic devices to penetrate. Indeed, MOS SPLDs have become ubiquitous in the marketplace. The barriers to accessing the benefits of SPLDs fell long ago, with well over 40,000 seats of SPLD design software now in the market (this includes such tools as ABEL, CUPL, and PALASM, as well as tools offered in conjunction with large EDA suppliers such as ORCAD, Mentor Graphics, Cadence, and Viewlogic). We therefore no longer expect to see robust expansion because of new users "discovering" the benefits of SPLDs.

Figure 1
Programmable Logic Family Tree



Simple programmable logic devices have fixed or preconnected architectures capable of providing up to two levels of logic without using additional input, output, or I/O cells or pins. These devices also have universally connected product terms, so that there is no design-dependent decrease in utilization. Devices that fall into this category include but are not limited to the following:

16R6	16R4	16L8
16R8	16V8	18V10
20L8	20R4	20R6
20R8	20RA10	20V8
22V10	24L10	24R10
24R4	24R8	24V10
26CV12	ATV2500	ATV750
EP310E	P320	EP610
EP910	GAL6001	

Complex programmable logic devices are product-term-based devices that may or may not implement multiple levels of logic without using additional input, output, or I/O cells or pins. These devices also have predetermined but not universal routing resources. This means that these devices may have decreased utilization dependent upon the interconnect requirements of the design. Devices that fall into this category include but are not limited to the following:

All MACH family devices
All MAPL family devices
All MAX family devices
All pLSI and ispLSI devices
ATV5000 XC7xxx devices
EP1810

Field-programmable gate arrays are based on programmable interconnect technology. These devices typically have a limited number of preconnected signals (clock and reset lines) and consist of an X-Y matrix of logic modules interconnected with variable lengths of wire. Devices that fall into this category include but are not limited to the following:

ACT10XX and ACT12XX devices
XC2xxx, XC3xxx, and XC4xxx devices
CLi6xxx devices
CP20K devices
All pASIC devices

Source: Dataquest (February 1993)

G3000167

Table 1
1992 Preliminary Worldwide Estimated Market Share Ranking: Bipolar PLD (Millions of Dollars)

1992 Rank	1991 Rank	Company	1991 Revenue	1992 Revenue	Percent Change	1992 Market Share (%)
1	1	Advanced Micro Devices	190	159	-16.3	55.8
2	2	Texas Instruments	110	87	-20.9	30.5
3	3	Philips	28	30	7.1	10.5
4	4	National	14	8	-42.9	2.8
		All Others	1	1		
		Total Market	343	285	-16.9	100.0

Source: Dataquest (February 1993)

Close Ties to Data Processing Market a Cause for Concern

An additional cause for concern is that the SPLD market seems to be becoming more closely tied to its largest consumer industry, namely data processing. The data processing industry accounted for about 60 percent of MOS SPLD consumption in 1991. In summer 1992, Dataquest observed that an upsurge in personal computer market caused lead times to push out for devices traditionally thought of as mature, including TTL and bipolar PLDs. We saw lead times of MOS SPLDs, in particular GALs, become extended as well. In fact, the surge in the PC industry caused revenue for MOS SPLD providers such as Lattice and AMD to outpace industry growth in 1992. AMD in particular reaped substantial benefit, growing a whopping 76 percent in 1992 to become the second largest supplier of MOS programmable logic (see Table 2). To substantiate this claim, our research shows that security analysts have estimated that AMD's third and fourth quarter MOS PLD revenue was $30 million and $37 million, respectively. Although the close coupling of MOS SPLDs to their largest end market has been a temporary boon, it may signal the beginning of saturation for this device, and we expect that within two years the MOS SPLD market will have ended its high-growth phase and begin to keep pace with the overall semiconductor industry.

Users Want to Migrate to Higher-Density Programmable Logic

Perhaps the most important factor leading to our belief in declining growth for MOS SPLDs is the result of our research into the electronic design market. Dataquest surveyed electronic designers worldwide as to the number of devices in their current generation of boards, and how many of these same devices will be used in their next-generation design. Electronic designers worldwide are using significantly more simple programmable logic devices than are their high-density brethren (see Figure 2). However, this large number of devices is not necessarily a satisfactory solution. Use of multiple devices increases reliability problems, design size, and in certain situations, overall system cost. In

Table 2
1992 Preliminary Worldwide Estimated Market Share Ranking: MOS PLD
(Millions of Dollars)

1992 Rank	1991 Rank	Company	1991 Revenue	1992 Revenue	Percent Change	1992 Market Share (%)
1	1	Xilinx	130	163	25.4	24.3
2	4	Advanced Micro Devices	62	109	75.8	16.2
3	2	Altera	107	102	-4.7	15.2
4	3	Lattice	68	91	33.8	13.6
5	6	Actel	37	45	21.6	6.7
6	5	Cypress Semiconductor	47	42	-10.6	6.3
7	7	Intel	33	39	18.2	5.8
8	10	Texas Instruments	9	20	122.2	3.0
9	9	AT&T	10	15	50.0	2.2
10	8	Atmel	11	12	9.1	1.8
10	10	National Semiconductor	9	12	33.3	1.8
12	13	SGS-Thomson	7	6	-14.3	0.9
13	14	Gould AMI	5	4	-20.0	0.6
14	16	Toshiba	1	1	0	0.1
14	16	Ricoh	1	1	0	0.1
NM	10	Philips	9	0	-100.0	0
NM	15	GEC Plessey	3	0	-100.0	0
		All Others	10	9	-10.0	1.3
		Total Market	559	671	20.0	100.0

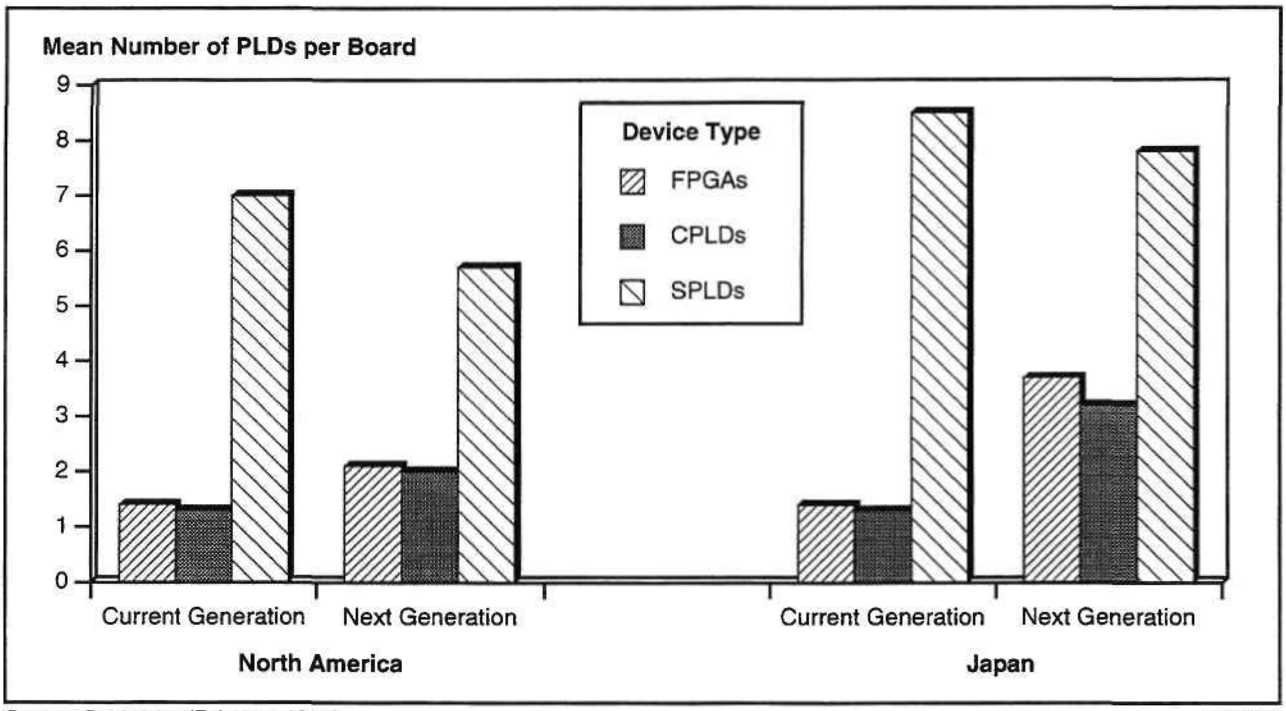
NM = Not meaningful
Source: Dataquest (February 1993)

response to these pressures, as well as projected lower costs for higher-density devices, users expect to decrease the total number of SPLDs used by between 8 and 24 percent in their next-generation design. This logic is migrating to larger CPLDs or FPGAs.

The Complex PLD Market Had a Difficult Year

It is a testament to the high hopes the industry has for programmable logic that a 20 percent year-to-year growth rate may be deemed a disappointment, but such is the case for complex programmable logic devices. Comparing the three MOS PLD markets, MOS SPLDs grew 14 percent in 1992, CPLDs grew 20 percent, and FPGA grew 30 percent over the prior year. Had it not been for severe price competition on the MAX 5000 family of CPLDs between Altera and Cypress, combined with a downturn in Japan for Altera, the CPLD market may have easily posted growth rates commensurate with FPGAs. This difficulty impacted the bottom line for both companies, and Altera and Cypress were the only two major vendors of programmable logic to post a downturn in MOS PLD revenue.

Figure 2
Mean Number of Programmable Logic Devices per Board



Source: Dataquest (February 1993)
G3000168

FPGA: Continued Stellar Growth

The FPGA market has shown stellar growth since its inception in 1986, and Dataquest expects it to continue to outpace the overall semiconductor growth rate by a factor of 1.5 to 2 over the next three to five years. The year 1992 saw the FPGA market grow by about 30 percent over 1991, and FPGAs will enjoy a compounded annual growth rate of 25 percent over the next five years. FPGAs also will benefit from its wide industry distribution, with 80 percent of its revenue evenly distributed among data processing, communications, and industrial sectors, making it less susceptible to industry-specific economic factors.

We base our optimistic forecast upon the following assumptions:

- Technological improvement
- Price decreases
- Migration of traditional ASIC business
- Vendor stabilization

Technological Improvement

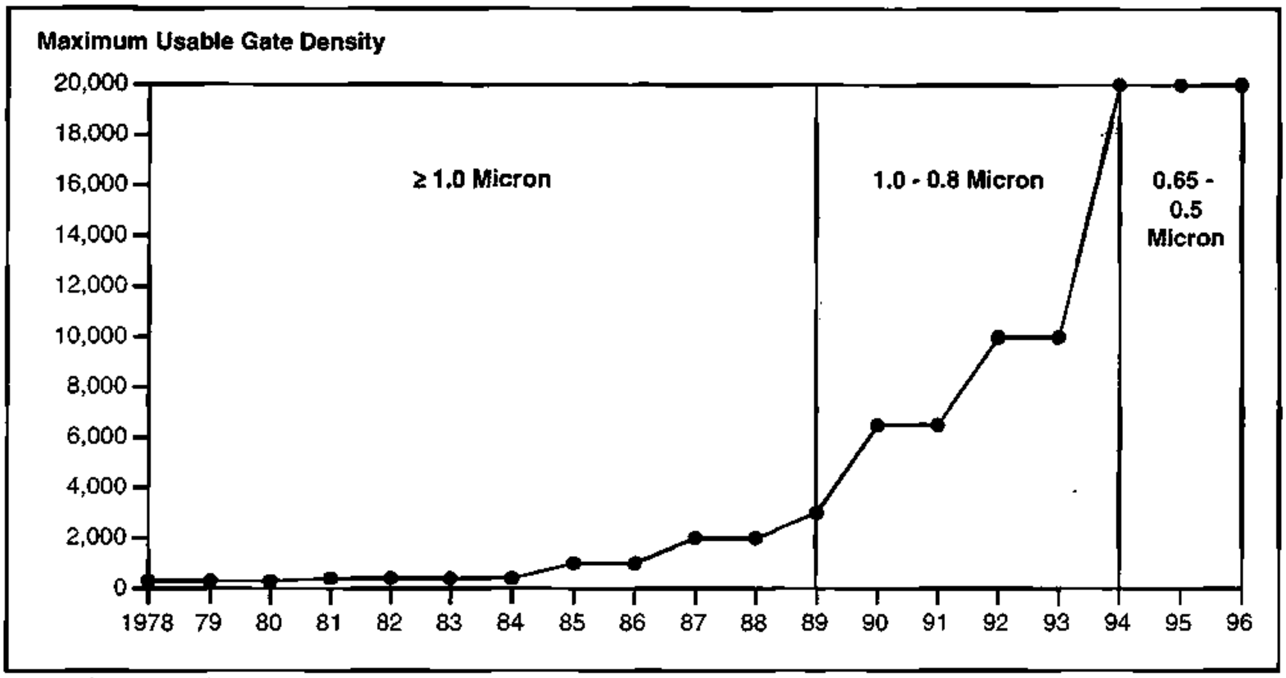
FPGA architectures are still somewhat immature. FPGAs have only been commercially available for seven years, and a large amount of fine-tuning still is to be done. Unlike their mask-programmable brethren, in which there is little die size penalty for interconnection, the programmability overhead of these devices tend to make the die sizes exceedingly large in comparison. Therefore a significant investment must be made in the architectural improvement to optimize the total number of gates that can be placed upon a given die size. Extensive research is being conducted not only at vendor sites, but also in the academic community, where universities are hard at work developing new software algorithms and optimal chip architectures.

Dataquest frowns upon using gate densities as a density measure of these devices, because vendor claims and counterclaims have made this metric almost meaningless. However, as an industry, it is safe to say that FPGAs can address the majority of ASIC designs of less than 10,000 gates, based solely upon density. This is a long way from the half-million gate devices being introduced by gate array suppliers. Dataquest believes that FPGAs will continue to extend its density capability over the coming years, based upon process migration, architectural, and software improvements (see Figure 3). The extensions in both speed and density will help to expand the total market that FPGAs address.

Price Decreases

The FPGA market over the past two years has shown price decreases as it benefited from economies of scale. Yet price is still a major obstacle in the usage of these devices. Dataquest end-user research shows that FPGAs still predominantly are used for prototyping and ASIC emulation (see Figure 4). A large potential upside exists as these devices approach a price point that makes them production-worthy.

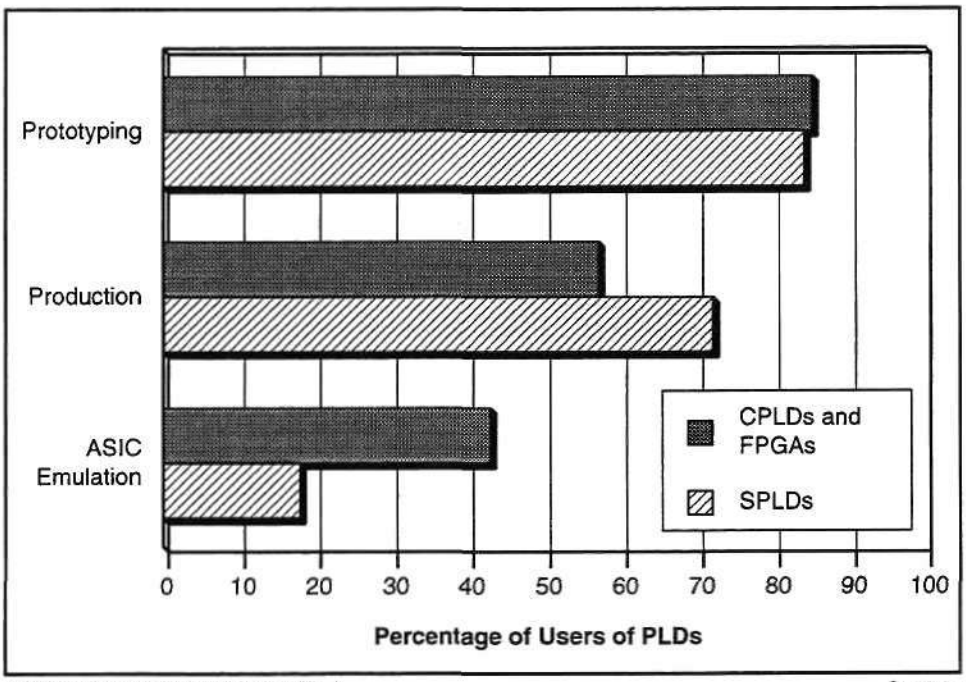
Figure 3
Programmable Logic Gate Density History and Projections



Source: Dataquest (February 1993)

G3000169

Figure 4
North American Usage of Programmable Logic



Source: Dataquest (February 1993) G3000170

Migration of Traditional ASIC Business

The price-per-gate of programmable solutions continues to decline, and Dataquest believes that sufficient elasticity exists in the market to expand overall revenue with these price reductions. Beyond that, many believe that a certain price-multiple exists that makes a programmable solution more appealing than a traditional mask-programmed ASIC. However, Dataquest believes that this argument may be misleading. The programmability overhead of these devices will continue to make programmable devices an inferior solution to gate arrays based upon price, speed, and density. Even a twofold price differential between gate arrays and FPGAs quickly becomes significant based upon volumes larger than 10,000 units. Making the programmable solution more untenable versus gate arrays is the shortening of gate array lead times, reducing the incentive to use a programmable solution, and the emergence of software tools that may quickly and easily translate a design from a programmable to a mask-based technology.

Dataquest continues to believe that FPGAs will become the workhorse of logic implementation of less than 20,000 gates in the mid- to late 1990s. This is not based solely on the reduction in prices made by FPGA vendors, but rather on the migration of ASIC vendors from this market. Dataquest believes that, for gate array and cell-based suppliers to remain profitable, they must migrate sales toward products in which they have core competencies, namely in process technology and cell-based design. Pricing pressure at low densities has made this an unprofitable market. Indeed, Dataquest has seen anecdotal evidence of this movement, with large ASIC vendors bidding high prices for low-volume 10,000-gate designs. The vacuum created by ASIC vendors will be supplanted by programmable technologies, namely FPGAs.

Vendor Stabilization

Dataquest believes that too many suppliers of FPGAs are in the market. To date, we have seen devices positioned as FPGAs from the following suppliers:

- Actel
- AT&T
- Concurrent Logic
- Crosspoint Solutions
- GEC Plessey
- QuickLogic
- Texas Instruments
- Xilinx

Those that have announced intentions include Hitachi, Motorola, and Toshiba. And those that have technology capability include Fujitsu, Kawasaki Steel, NEC, and Seiko.

This blossoming of product offerings is causing significant supply-side pressure, which will help to grow the overall FPGA market. Unfortunately, an extremely competitive market with such a mass of vendors is destined to be pruned in the next three years. To gain substantial market acceptance, Dataquest believes that newcomers to the market must be able to easily show a 50 percent or better improvement in speed, density, or cost. Only those companies able to clearly separate themselves from the current storm of claims and counterclaims regarding these features have a chance at gaining market share from the established leaders.

A potential rudder in the storm of marketing hype may be the efforts of Programmable Electronics Performance (PREP) Corporation. This organization of PLDs and software suppliers is attempting to establish a set of benchmarks so that users may more easily ascertain which product offering may be best suited for their applications. Unfortunately, political infighting has caused the definition and ratification of benchmarks to be extended far beyond what it should be, and one can hardly blame the vendors. This effort is clearly not in the best interest of the PLD vendors, as it may cast their devices in an unfavorable light in comparison to their competitors. Dataquest is still hopeful that the effort will bear fruit, and that this effort will help at least to dispel some of the confusion that exists.

PLD Forecast

Table 3 is Dataquest's most recent forecast for the programmable logic market. This forecast has been revised and supersedes all previously

Table 3
Preliminary Worldwide Estimated Programmable Logic Market History and Forecast, by Technology (Millions of Dollars)

		1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
Total PLD	Total PLD	673	695	824	902	956	1,046	1,160	1,280	1,400	1,538	10.0
Bipolar	Bipolar SPLDs	501	432	423	343	285	228	182	142	106	82	-22.0
CMOS	Total CMOS	172	263	401	559	671	818	978	1,138	1,294	1,456	16.8
	SPLD	143	197	249	286	325	371	413	435	447	459	7.1
	CPLD	2	5	35	84	101	126	151	186	216	247	19.6
	FPGA	27	61	117	189	245	321	414	517	631	751	25.1
CPLD + FPGA		29	66	152	273	346	447	565	703	847	997	23.6
All SPLDs		644	629	672	629	610	599	595	577	553	541	-2.4

Source: Dataquest (February 1993)

published forecasts. The adjustments have been made based upon recently gathered information regarding 1992 market share information.

Dataquest Perspective

The programmable logic market continues to show steadfast growth, and we do not expect a significant downturn in the near future. However, with the plethora of companies in high-density programmable logic, there are bound to be winners and losers in the next three years. Existing leaders must continue to strive to reduce the price per gate by investing large percentages of total revenue into R&D of new circuit structures and architectures. This will keep them ahead of the competition, as well as expand the reach of high-density programmable logic into price-sensitive markets. New entrants to the market must be able to exhibit significant, quantitative advantages to gain market share, either in speed, density, or price.

By Robert K. Beachler

For More Information...

Bryan Lewis, Sr. Industry Analyst .... (408) 437-8668
Via fax.. (408) 437-0292

Dataquest®
a company of The Dun & Bradstreet Corporation

Dataquest Perspective

Semiconductors

Semiconductors

In This Issue

Historical Market Share Revisions and New Methodology

Dataquest published major revisions to many of our company estimates for 1989, 1990, and 1991 in our *Final Worldwide Semiconductor Market Share* document dated June 29, 1992 (SCWW-PMT-MS-9201). These revisions were necessary to more correctly reflect our current methodology for reporting company revenue as well as market sizes.

The methodology that Dataquest now uses to determine company and market statistics has evolved over the years as we continually strived to increase quality and reliability. Although our approach evolves as the nature of the market changes, there were more changes in 1992 than in the past. Highlights of the changes introduced are as follows:

- We adopted the technique of more rigorously comparing our market statistics with those of standard industry and government trade associations, such as MITI/MOF and WSTS. We go to great lengths to understand the methodology used by these groups in arriving at their numbers and to identify explicable differences between the two estimates.
- We eliminated double counting of foundry revenue, which is revenue that one company in our survey receives for providing foundry services for another company in our survey. We only show revenue for the finished product sold to an end customer by the company paying for the foundry service and that has its company's trademark affixed to the device. The company providing the foundry service actually gets no revenue credit for this service in our market share statistics.

Dataquest®
a company of The Dun & Bradstreet Corporation

Program: Semiconductors Worldwide
Product Code: SCND-WW-DP-9301
Publication Date: February 8, 1993

Dataquest has this revenue in a separate database, but because we want our market share total statistics to be consistent with other trade and government associations, we exclude foundry revenue.

- We revised and reinforced our definitions to provide for more accurate value of sales to internal divisions of vertically integrated companies.
- We eliminated tariffs and value-added taxes from survey data.
- We eliminated revenue derived from totally captive fabs contained within systems divisions of vertically integrated companies.
- We eliminated intellectual property revenue.

We now believe that our revised statistics better represent the merchant market size and the companies in our survey. It also should be noted that there are still explicable differences between our data and the WSTS organization. Some of these differences are as follows:

- We include hybrid ICs in our analog and total IC and total semiconductor figures, and WSTS does not.
- We include the Taiwanese semiconductor manufacturers, and WSTS does not at present. However, we understand that WSTS plans to do so at some time in the near future.
- At present we include more companies in the United States and Europe than does WSTS.
- We include nonrecurring engineering charges in our ASIC revenue, and WSTS "may" include this revenue, as its definitions state.

As far as explicable differences between MITI/MOF and our numbers, we believe that manufacturers report production revenue, whereas we capture market revenue from the companies in our statistics.

Our analyses allow us to better understand and interpret these differences and thus provide our clients with another dimension to the market research process.

By Gene Norrett

Preliminary 1992 Data: Semiconductor Market Shares Show Supplier Shift

There were important changes to the semiconductor market during 1992. Changes in the pattern of regional consumption and regional supplier growth have altered the picture of the semiconductor market and affected many of the regional trend lines. A single year does not make a trend, but the signs seem to point toward a market shift away from Japanese market and supplier dominance and toward an improving North American position and the continued growth of the Asia/Pacific-Rest of World (ROW) market. The North American market recovered strongly after three years of indecision, with North American suppliers reaping the rewards of a strong computer market rebound. Table 1 summarizes the 1991-to-1992 semiconductor consumption growth by region.

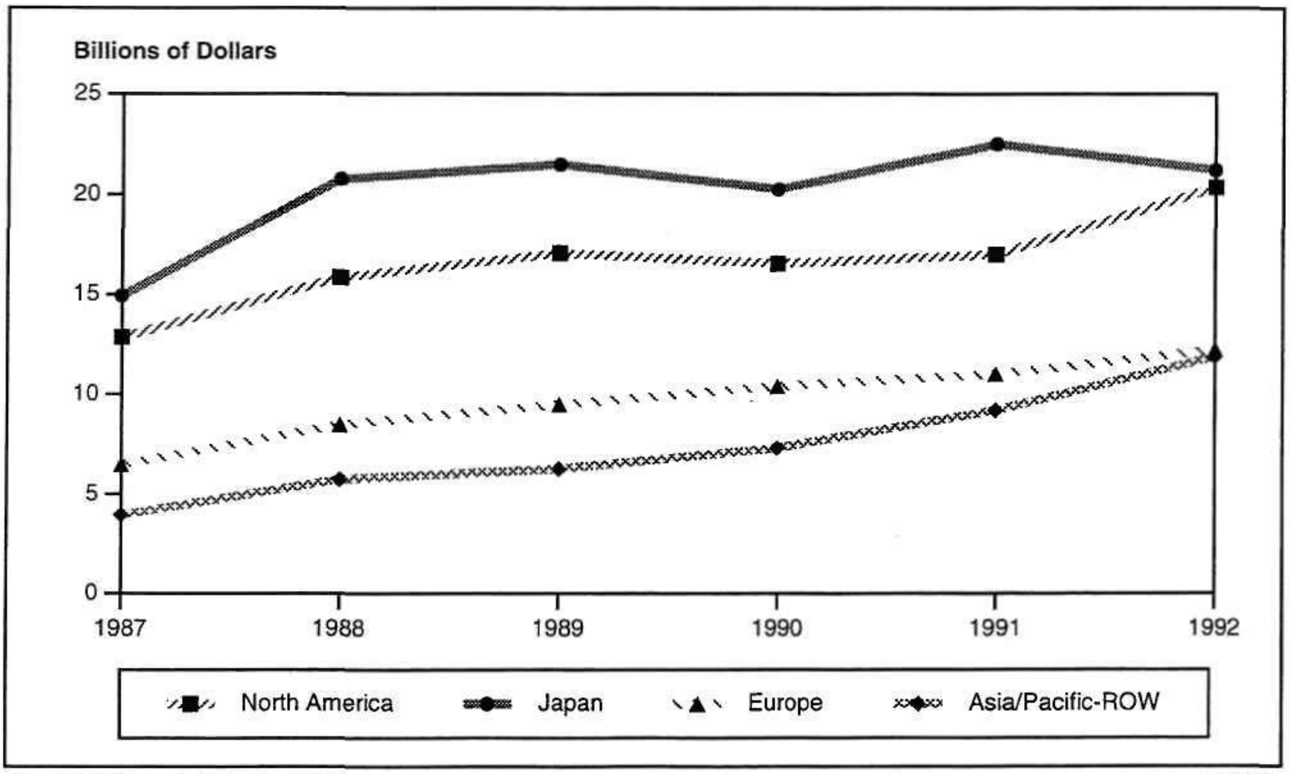
Figure 1 shows the six-year history of semiconductor consumption by region. Although the Asia/Pacific-ROW and European regions showed consistent growth over this period, both Japan and North America showed relatively little growth after 1988. The year 1992, however, shows North American consumption on the rebound and Japanese consumption down. This could simply be another year-to-year variation, although the trends suggest longer-term changes in the market.

Table 1
Semiconductor Consumption and Growth, by Region (Revenue in Millions of Dollars)

Region	1991	1992	Growth (%) 1991-1992
North America	16,990	20,341	19.7
Japan	22,496	21,107	-6.2
Europe	11,014	12,238	11.1
Asia/Pacific-ROW	9,194	11,901	29.4
Total Semiconductor	59,694	65,587	9.9

Source: Dataquest (February 1993)

Figure 1
Regional Consumption History



Source: Dataquest (February 1993)

G3001015

Japanese suppliers saw little growth. The domestic consumer and computer markets were drastically down, resulting in declines of 10 percent in the consumption of analog consumer-specific ICs and MPUs. In contrast, North American suppliers benefited from strong growth in domestic microcomponent consumption. Europe's microcomponent consumption was up significantly, the benefits going mainly to North American suppliers. Because the European consumer market was flat, European vendors saw small gains. Table 2 shows how the changes in semiconductor consumption translated into growth for the semiconductor suppliers by region.

Growth by Product

Growth by product category in 1992 varied widely as computers gained and consumer equipment declined (see Table 3). The strength of the computer markets in North America and Europe provided important gains for memory and microprocessor ICs. Analog ICs, discrete devices, and optoelectronics suffered from substandard growth because of a strong dependence (about 40 percent of revenue) on Japanese consumer equipment production.

Table 2
Regional Vendor Growth (Revenue in Millions of Dollars)

Regional Suppliers	1991 Revenue	% of Total	1992 Revenue	% of Total	Growth (%) 1991-1992
North America	22,940	38	26,958	41	17.5
Japan	27,684	46	28,069	43	1.4
Europe	6,336	11	6,669	10	5.2
Asia/Pacific-ROW	2,734	5	3,891	6	42.3
Total Semiconductor	59,694	100	65,587	100	9.9

Source: Dataquest (February 1993)

Table 3
Worldwide Product Growth (Revenue in Millions of Dollars)

Product Type	1991	1992	Growth (%) 1991-1992
Memory IC	13,197	15,606	18.3
Microcomponent IC	11,867	14,436	21.6
Logic IC	12,879	13,154	2.1
Analog IC	10,912	11,542	5.8
Total IC Revenue	48,855	54,738	12.0
Discrete Device	8,035	8,199	2.0
Optical Semiconductor	2,804	2,650	-5.5
Total Semiconductor	59,694	65,587	9.9

Source: Dataquest (February 1993)

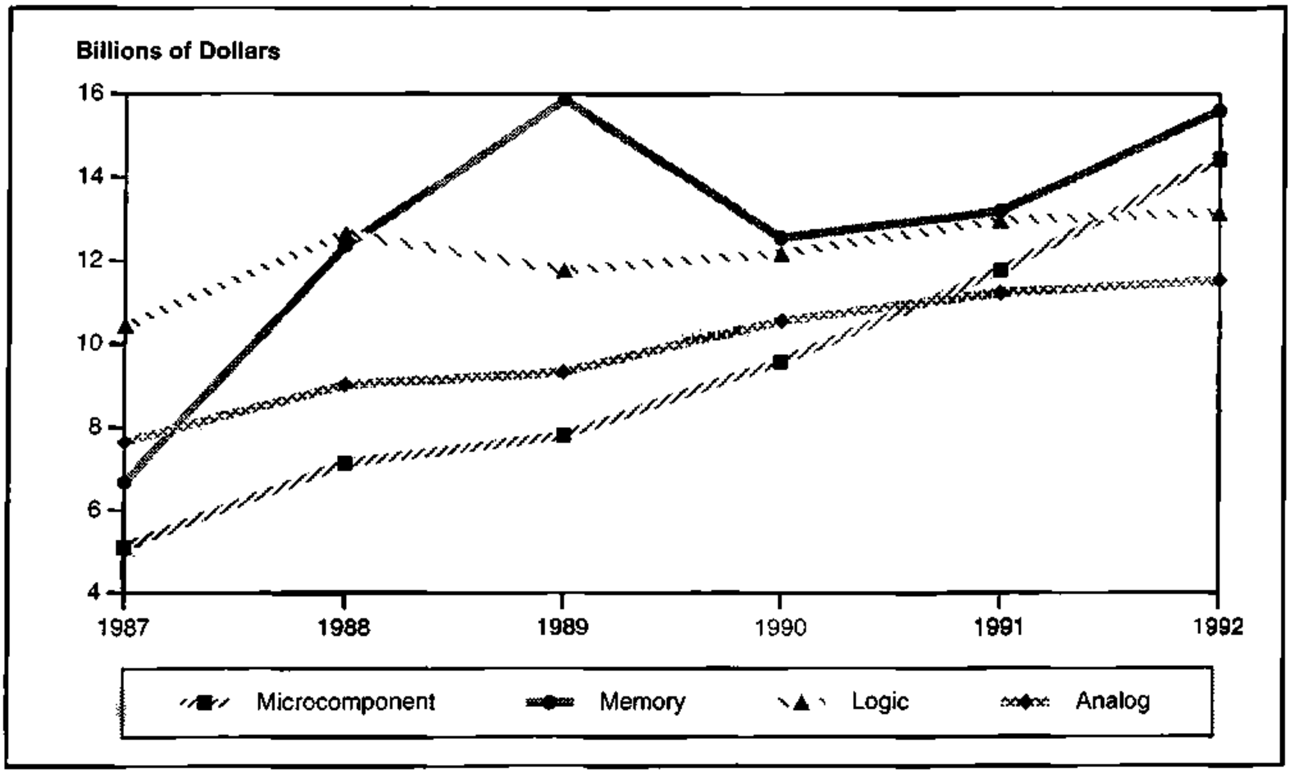
Logic ICs, a functional group that may be expected to grow on the coat-tails of computers and systems, showed low growth. Although there are some notable growth areas in logic, logic functions are integrated at a much faster rate than are analog functions. Many of these more complex application-specific logic functions remain in the logic category, but many other ASSPs and ASICs pass into other categories such as microperipherals or telecom-specific ICs.

Figure 2 shows six years of revenue history for the four IC product categories. Microcomponents show a consistently strong growth pattern, quite unlike the more volatile memory category. Analog ICs show the growth consistency typical of this category, although the growth rate remains lower than that of either microcomponents or memories.

Gains in microprocessor consumption, especially in the North American market, as well as the decline in the Japanese consumer market, were key to the changes in semiconductor rankings (see Table 4). South Korean suppliers (Samsung, Goldstar, and Hyundai) advanced in position with substantial DRAM revenue growth.

Intel hurdled past NEC and Toshiba by being in the dominant position in the fastest growing product segments. Last year we looked at the

Figure 2
IC Revenue History, by Product



Source: Dataquest (February 1993)

G3001016

Table 4
1992 Preliminary Worldwide Market Share Estimates and Ranking, Total Semiconductor (Revenue in Millions of Dollars)

1992 Rank	1991 Rank	Company	1991 Revenue	1992 Revenue	Percent Change	1992 Market Share (%)
1	3	Intel	4,019	5,064	26	7.7
2	1	NEC	4,774	4,976	4	7.6
3	2	Toshiba	4,579	4,765	4	7.3
4	4	Motorola	3,802	4,635	22	7.1
5	5	Hitachi	3,765	3,902	4	5.9
6	6	Texas Instruments	2,738	3,052	11	4.7
7	7	Fujitsu	2,705	2,583	-5	3.9
8	8	Mitsubishi	2,303	2,307	0	3.5
9	10	Philips	2,022	2,108	4	3.2
10	9	Matsushita	2,037	1,929	-5	2.9
11	12	Samsung	1,473	1,902	29	2.9
12	11	National Semiconductor	1,602	1,797	12	2.7
13	13	SGS-Thomson	1,436	1,605	12	2.4
14	17	Advanced Micro Devices	1,226	1,502	23	2.3
15	15	Sharp	1,318	1,388	5	2.1
16	14	Sanyo	1,362	1,369	1	2.1
17	16	Siemens	1,263	1,220	-3	1.9
18	18	Sony	1,196	1,150	-4	1.8
19	19	Oki	981	976	-1	1.5
20	21	AT&T	713	924	30	1.4
21	20	Rohm	934	886	-5	1.4
22	32	Goldstar	307	635	107	1.0
23	23	Harris	623	627	1	1.0
24	22	LSI Logic	670	615	-8	0.9
25	35	Hyundai	248	556	124	0.8
26	25	Micron Technology	455	516	13	0.8
27	24	Analog Devices	464	511	10	0.8
28	27	Hewlett-Packard	442	445	1	0.7
29	26	Sanken	451	439	-3	0.7
30	28	VLSI Technology	414	430	4	0.7
31	29	GEC Plessey	392	427	9	0.7
32	31	Fuji Electric	319	317	-1	0.5
33	33	Telefunken Electronic	300	277	-8	0.4
34	36	International Rectifier	238	270	13	0.4
35	34	Cypress Semiconductor	281	264	-6	0.4
36	30	ITT	340	254	-25	0.4

(Continued)

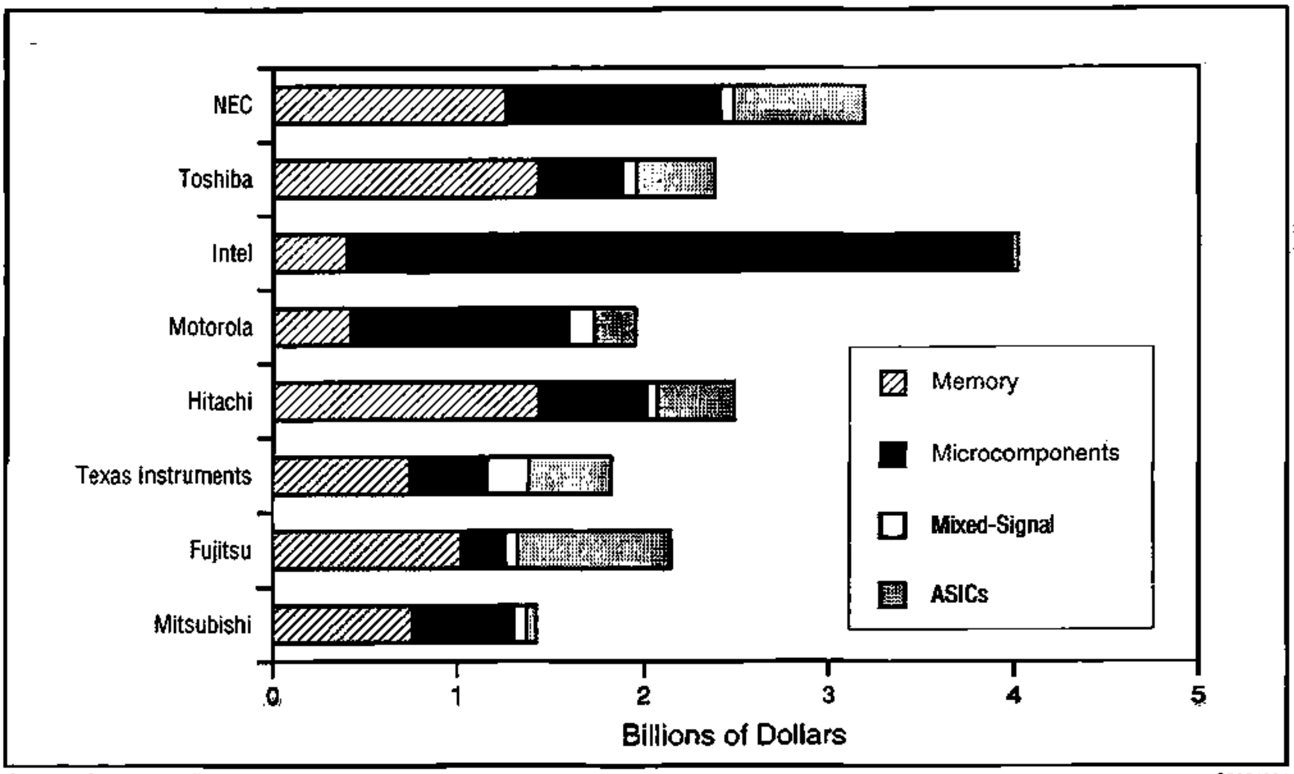
Table 4
1992 Preliminary Worldwide Market Share Estimates and Ranking, Total Semiconductor (Revenue in Millions of Dollars) (Continued)

1992 Rank	1991 Rank	Company	1991 Revenue	1992 Revenue	Percent Change	1992 Market Share (%)
37	47	Cirrus Logic	152	250	64	0.4
38	43	Silicon Systems	184	241	31	0.4
39	37	Seiko Epson	220	232	5	0.4
40	50	NCR	145	221	52	0.3
		All Others	6,801	8,020	18	12.2
		Total Market	59,694	65,587	10	100.0

Source: Dataquest (February 1993)

growth potential of the top semiconductor suppliers based on their product position in the fastest growing product segments (only their memory, microcomponent, ASIC, and mixed-signal IC revenue counted). Figure 3, which appeared in that discussion, shows the strong position in growth markets that Intel enjoyed in 1992.

Figure 3
Top Suppliers, Revenue by Growth Products



Source: Dataquest (November 1992)

G2001264

Figure 3 suggests that 1992 was not a temporary market share dislocation because of a slowdown in the Japanese market. Although it is possible for NEC or Toshiba to overtake Intel in 1993, the forecast product growth trends tend to favor Intel.

A major driver of this change in ranking was the microprocessor. Table 5 shows that the 22 percent growth in microcomponents was largely absorbed by Intel, which grew by $1.1 billion. With 32.5 percent share of the market, Intel absorbed more than 43 percent of the total revenue growth in microcomponents in 1992. Motorola, in contrast, cornered only 10.1 percent of the total microcomponent revenue growth but showed a strong 25 percent growth over 1991. The 386 product gave Advanced Micro Devices a substantial growth of 56 percent, but this was on a much smaller revenue base. Microcomponent growth was helped by 60 percent MPU growth in the heated North American market.

Table 5
1992 Preliminary Worldwide Market Share Estimates and Ranking, Microcomponent ICs (Revenue in Millions of Dollars)

1992 Rank	1991 Rank	Company	1991 Revenue	1992 Revenue	Percent Change	1992 Market Share (%)
1	1	Intel	3,578	4,690	31	32.5
2	2	Motorola	1,171	1,464	25	10.1
3	3	NEC	1,149	1,158	1	8.0
4	8	Advanced Micro Devices	416	648	56	4.5
5	4	Hitachi	583	616	6	4.3
6	7	Texas Instruments	429	537	25	3.7
7	5	Mitsubishi	543	487	-10	3.4
8	6	Toshiba	454	457	1	3.2
9	9	National Semiconductor	341	436	28	3.0
10	12	Philips	212	287	35	2.0
11	10	Matsushita	321	274	-15	1.9
12	11	Fujitsu	244	233	-5	1.6
13	17	Cirrus Logic	151	207	37	1.4
14	13	Western Digital	209	192	-8	1.3
15	14	SGS-Thomson	167	167	0	1.2
16	15	VLSI Technology	165	142	-14	1.0
17	18	Oki	137	135	-1	0.9
17	22	Zilog	110	135	23	0.9
19	19	Sharp	134	131	-2	0.9
20	19	Siemens	134	125	-7	0.9
		All Others	1,219	1,915	57	13.3
		Total Market	11,867	14,436	22	100.0

Source: Dataquest (February 1993)

Memory ICs

The worldwide memory market grew a strong 18 percent in 1992, paced by 25 percent DRAM revenue growth. Microsoft Windows and other graphics-intensive applications software created a step-function increase in PC system memory requirements that was met by a step-function increase in DRAM consumption. This increase in consumption initially resulted in price erosion, but antidumping actions and concerns stopped the decline, resulting in stronger revenue growth than might have otherwise occurred.

This growth in DRAM consumption provided the silver lining to a generally cloudy year for the major Japanese suppliers. The major beneficiary, however, was Samsung, which catapulted past NEC into the No. 3 position in memories with revenue growth of 42 percent (see Table 6).

Table 6
1992 Preliminary Worldwide Market Share Estimates and Ranking, Memory ICs (Revenue in Millions of Dollars)

1992 Rank	1991 Rank	Company	1991 Revenue	1992 Revenue	Percent Change	1992 Market Share (%)
1	2	Toshiba	1,425	1,622	14	10.4
2	1	Hitachi	1,429	1,611	13	10.3
3	4	Samsung	1,066	1,516	42	9.7
4	3	NEC	1,261	1,439	14	9.2
5	5	Fujitsu	1,022	1,018	0	6.5
6	6	Mitsubishi	762	904	19	5.8
7	7	Texas Instruments	741	877	18	5.6
8	10	Motorola	415	614	48	3.9
9	16	Goldstar	249	557	124	3.6
10	17	Hyundai	248	556	124	3.6
11	8	Sharp	476	523	10	3.4
12	9	Micron Technology	455	516	13	3.3
13	12	Oki	380	429	13	2.7
14	11	Intel	395	324	-18	2.1
15	13	Advanced Micro Devices	322	316	-2	2.0
16	14	Siemens	298	315	6	2.0
17	15	SGS-Thomson	273	304	11	1.9
18	18	Matsushita	217	221	2	1.4
19	20	Sony	183	202	10	1.3
20	19	Cypress Semiconductor	186	180	-3	1.2
		All Others	1,394	1,562	12	10.0
		Total Market	13,197	15,606	18	100.0

Source: Dataquest (February 1993)

Logic ICs

Logic ICs include a broad and dissimilar set of products. One of the basic cuts is by process technology, bipolar logic and MOS logic, which roughly track an "old versus new" division. In keeping with these "old/new" expectations, bipolar logic continued past trends and declined 9 percent in 1992, while MOS logic showed 9 percent revenue growth. Bipolar and MOS logic combined showed 2 percent growth. Texas Instruments, the leader in bipolar logic, saw a 13 percent decline in bipolar logic, but compensated with a 27 percent growth in MOS logic (moving up from sixth place to fourth place). The net effect for TI was a 5 percent combined growth in logic ICs (see Table 7). With flat revenue in bipolar logic and 13 percent growth in MOS logic, Motorola was able to displace Toshiba in the No. 3 position in the combined logic IC category.

Table 7
1992 Preliminary Worldwide Market Share Estimates and Ranking, Logic ICs (Revenue in Millions of Dollars)

1992 Rank	1991 Rank	Company	1991 Revenue	1992 Revenue	Percent Change	1992 Market Share (%)
1	1	NEC	1,277	1,292	1	9.8
2	2	Texas Instruments	1,043	1,097	5	8.3
3	4	Motorola	938	1,013	8	7.7
4	5	Toshiba	918	900	-2	6.8
5	3	Fujitsu	981	877	-11	6.7
6	6	Hitachi	729	688	-6	5.2
7	7	LSI Logic	555	570	3	4.3
8	8	Philips	468	528	13	4.0
9	10	AT&T	402	474	18	3.6
10	11	Advanced Micro Devices	394	434	10	3.3
11	9	National Semiconductor	447	431	-4	3.3
12	13	Matsushita	390	363	-7	2.8
13	12	Oki	393	349	-11	2.7
14	14	Sharp	280	297	6	2.3
15	15	VLSI Technology	249	286	15	2.2
16	16	Hewlett-Packard	206	209	1	1.6
17	18	Sanyo	169	191	13	1.5
18	24	Yamaha	146	189	29	1.4
19	20	Sony	160	187	17	1.4
20	17	Siemens	175	175	0	1.3
		All Others	2,559	2,604	2	19.8
		Total Market	12,879	13,154	2	100.0

Source: Dataquest (February 1993)

Analog, Discrete, and Optoelectronic

Consumer entertainment products, being largely audio and video, are intrinsically analog in nature and typically have consumed about 40 percent of all analog ICs. Besides analog ICs, discrete semiconductor devices and optical semiconductors also are dependent on the consumer market. The big declines seen last year in the consumer market, especially in Japan and Europe, severely impacted the growth of analog ICs, discretes, and optical semiconductors, resulting in respective growths of 6 percent, 2 percent and negative 5 percent. Tables 8, 9, and 10 show the preliminary 1992 rankings for these product categories. Suppliers of analog ICs into nonconsumer markets (National, Motorola, and Silicon Systems, for example) had good growth in 1992.

Table 8
1992 Preliminary Worldwide Market Share Estimates and Ranking, Analog ICs
(Revenue in Millions of Dollars)

1992 Rank	1991 Rank	Company	1991 Revenue	1992 Revenue	Percent Change	1992 Market Share (%)
1	2	National Semiconductor	629	739	17	6.4
2	1	Philips	664	675	2	5.8
3	5	SGS-Thomson	578	658	14	5.7
4	7	Motorola	456	651	43	5.6
5	3	Toshiba	612	614	0	5.3
6	4	Sanyo	599	599	0	5.2
7	9	Texas Instruments	439	475	8	4.1
8	8	Analog Devices	444	472	6	4.1
9	6	Mitsubishi	477	441	-8	3.8
10	10	NEC	422	429	2	3.7
11	11	Matsushita	412	404	-2	3.5
12	12	Sony	394	384	-3	3.3
13	13	Hitachi	358	351	-2	3.0
14	14	Rohm	341	316	-7	2.7
15	15	AT&T	242	259	7	2.2
16	18	Silicon Systems	184	241	31	2.1
17	17	GEC Plessey	185	212	15	1.8
18	16	Harris	226	205	-9	1.8
19	20	Fujitsu	179	176	-2	1.5
20	19	Siemens	181	165	-9	1.4
		All Others	2,890	3,076	6	26.7
		Total Market	10,912	11,542	6	100.0

Source: Dataquest (February 1993)

Table 9
1992 Preliminary Worldwide Market Share Estimates and Ranking, Discrete Devices
(Revenue in Millions of Dollars)

1992 Rank	1991 Rank	Company	1991 Revenue	1992 Revenue	Percent Change	1992 Market Share (%)
1	1	Toshiba	884	891	1	10.9
2	2	Motorola	794	857	8	10.5
3	3	Hitachi	598	573	-4	7.0
4	5	Philips	531	551	4	6.7
5	4	NEC	544	537	-1	6.5
6	6	Matsushita	379	357	-6	4.4
7	7	Rohm	374	354	-5	4.3
8	9	SGS-Thomson	299	335	12	4.1
9	8	Mitsubishi	325	286	-12	3.5
10	14	International Rectifier	237	269	14	3.3
11	10	Fuji Electric	263	260	-1	3.2
12	11	Sanken	259	256	-1	3.1
13	12	Sanyo	250	248	-1	3.0
14	15	General Instrument	200	218	9	2.7
15	13	Siemens	245	216	-12	2.6
16	20	Harris	107	153	43	1.9
17	16	Fujitsu	152	151	-1	1.8
18	17	Shindengen Electric	134	130	-3	1.6
19	23	Samsung	92	121	32	1.5
20	21	Korean Electronic Company	95	110	16	1.3
		All Others	1,273	1,326	4	16.2
		Total Market	8,035	8,199	2	100.0

Source: Dataquest (February 1993)

Table 10
1992 Preliminary Worldwide Market Share Estimates and Ranking, Optical Semiconductors (Revenue in Millions of Dollars)

1992 Rank	1991 Rank	Company	1991 Revenue	1992 Revenue	Percent Change	1992 Market Share (%)
1	1	Sharp	362	373	3	14.1
2	2	Matsushita	318	310	-3	11.7
3	3	Toshiba	286	281	-2	10.6
4	4	Sony	279	218	-22	8.2
5	6	Hewlett-Packard	191	187	-2	7.1
6	7	Siemens	189	184	-3	6.9
7	5	Sanyo	193	136	-30	5.1
8	8	Fujitsu	127	128	1	4.8
9	10	NEC	121	121	0	4.6
10	9	Rohm	122	116	-5	4.4
11	11	Telefunken Electronic	74	78	5	2.9
12	12	Hitachi	68	63	-7	2.4
13	14	Optek	52	55	6	2.1
14	16	Quality Technologies	34	46	35	1.7
15	13	Texas Instruments	58	42	-28	1.6
16	17	AT&T	32	39	22	1.5
17	19	Motorola	28	36	29	1.4
18	18	Oki	30	27	-10	1.0
18	20	Honeywell	25	27	8	1.0
20	20	Mitsubishi	25	23	-8	0.9
		All Others	190	160	-16	6.0
		Total Market	2,804	2,650	-5	100.0

Source: Dataquest (February 1993)

Market Share Summary of Product Sales, by Region

Table 11 summarizes revenue for each product type for the suppliers headquartered in the four major geographical regions. Read across the table to find the percentage of product revenue generated by companies headquartered within a specific region. In Memory ICs, for example, Japanese vendors have 53 percent of the market, with North American, Asia/Pacific-ROW, and European suppliers following with 24, 18, and 5 percent, respectively.

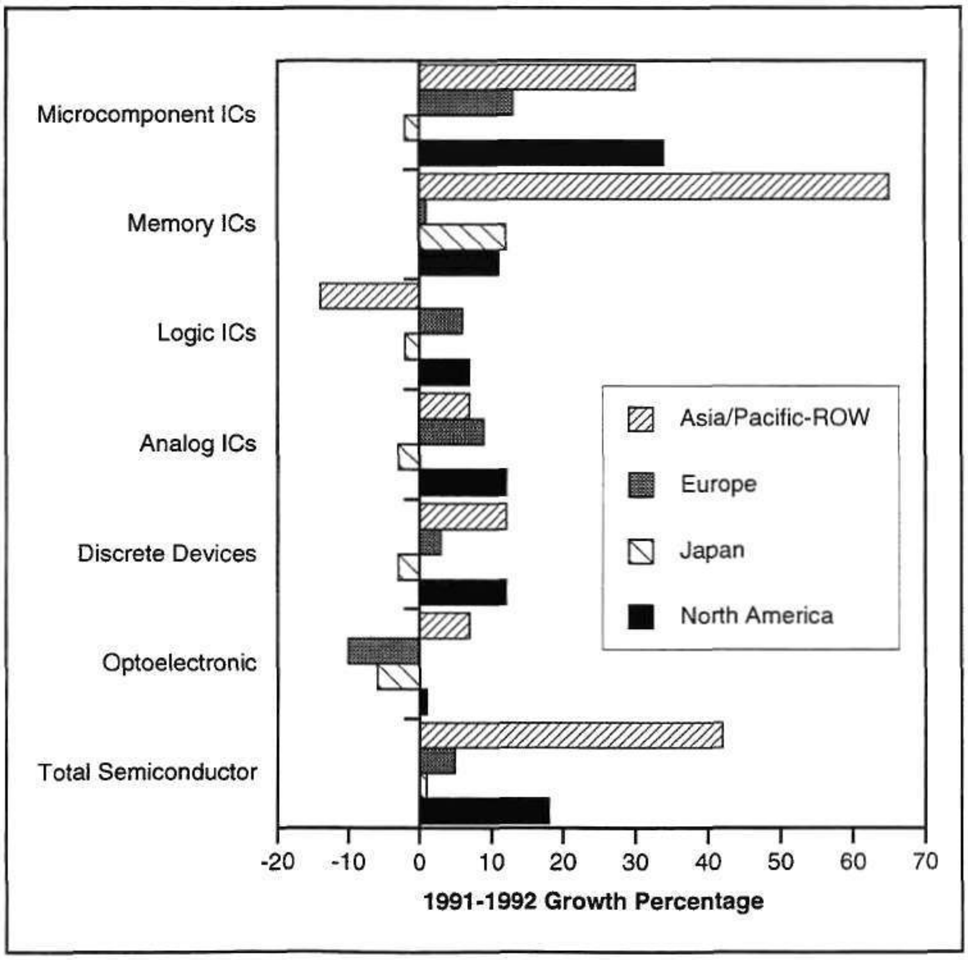
Figure 4 shows 1992 growth by product and supplier region. The strong growth of the South Korean suppliers in DRAMs swelled the Asia/Pacific-ROW vendor growth in memory ICs beyond a 60 percent rate. Asia/Pacific-ROW suppliers also showed growth in microcomponents, but on a revenue base that only represents 1 percent of the total market. The substantial North American supplier growth in microcomponents, led by Intel, is all the more impressive when realized that it is growth on

Table 11
Vendor Share of Product Category Revenue, by Company Base of Origin

		Percentage of Revenue by Home Base of Vendor			
Product Consumed	Revenue ($M)	North America	Europe	Japan	Asia/ROW
Memory IC	15,606	24.1	4.6	53.1	18.2
Microcomponent IC	14,436	68.3	4.4	26.1	1.2
Logic IC	13,154	44.1	9.6	43.9	2.4
Analog IC	11,542	42.8	18.3	36.5	2.4
Total IC	54,738	44.5	8.7	40.2	6.6
Discrete Devices	8,199	26.1	19.9	50.9	3.2
Optical Semiconductor	2,650	17.2	11.4	70.3	1.2
Total Semiconductor	65,587	41.1	10.2	42.8	5.9

Source: Dataquest (February 1993)

Figure 4
1992 Growth, by Product and Region



Source: Dataquest (February 1993) G3001017

a revenue base that represents two-thirds of the total microcomponent market.

The positive side of the 1992 market for Japanese suppliers was DRAM. Revenue for Japanese suppliers of memories was 12 percent; Japanese suppliers lost revenue in all other categories.

Dataquest Perspective

Although regional variations in growth are commonplace, rarely has it been as dramatic as in 1992. The question remains whether these regional and product growth changes represent long-term trends or normal variances. The rise of microcomponents as a product group, North America as a consuming region, and South Korea as a supplier of memory ICs has shaken up the supplier rankings. Once again, the semiconductor industry has demonstrated that it is alive and well and just as dynamic as it was in the past.

By Gary Grandbois

For More Information...

Gary Grandbois, Sr. Industry Analyst .... (408) 437-8251
Via fax .... (408) 437-0292

Dataquest®
a company of The Dun & Bradstreet Corporation

Dataquest Perspective

Semiconductors

Memories Worldwide

In This Issue

1992 Worldwide MOS Memory Market Posts 19 Percent Growth

The worldwide MOS memory market grew 19 percent in 1992 from 1991 to $15.3 billion, according to Dataquest preliminary market share estimates (see Table 1). Despite significant price erosion in all products, especially in DRAMs, the 1992 market was a record shipment year, exceeding the peak shipment level of the last cycle (1989) by about 3 percent.

Table 2 shows the MOS memory market makeup for the years 1988 to 1992, by major product group.

Profits Sparse

Unlike the prior peak level in 1989, profits in the 1992 MOS memory market were sparse and probably less than a few hundred million dollars for all suppliers combined. Despite a record shipment level, we are at the trough of the profit cycle, with nowhere to go but up. The Micron Technology dumping suit and the poor performance of Japanese conglomerates in their fiscal 1991 and first-half fiscal 1992 results brought

Dataquest®
a company of The Dun & Bradstreet Corporation

Program: Memories Worldwide
Product Code: MMRY-WW-DP-9301
Publication Date: February 8, 1993

Table 1
Preliminary 1992 MOS Memory Market Consumption, by Region (Millions of Dollars)

	Asia/Pacific-ROW	Japan	Europe	North America	Worldwide
DRAM	1,812	1,867	1,552	3,504	8,735
SRAM	421	1,058	489	1,083	3,051
EPROM	229	319	280	417	1,245
Flash	12	10	69	153	244
ROM	309	826	75	211	1,421
EEPROM	46	86	136	154	422
Other Memory	18	8	41	120	187
Total	2,847	4,174	2,642	5,642	15,305
Growth, 1991-1992 (%)	44	-1	24	25	19

Source: Dataquest (February 1993)

Table 2
Worldwide MOS Memory Market, 1988-1992 (Millions of Dollars)

	1988	1989	1990	1991	1992*
DRAM	6,530	8,323	6,437	6,982	8,735
SRAM	2,250	3,329	2,434	2,576	3,051
EPROM	1,806	1,809	1,446	1,358	1,245
Flash	1	11	35	124	244
ROM	836	1,069	1,132	1,253	1,421
EEPROM	268	320	292	336	422
Other Memory	107	151	174	212	187
Total	11,798	15,012	11,950	12,841	15,305

*Preliminary
Source: Dataquest (February 1993)

the spotlight on the weak profitability of DRAMs. Several Japanese companies were said to be reconsidering their participation in the DRAM market altogether. (In fact, as of press time Nippon Steel had bought a controlling interest in NMB Semiconductor.) Cypress Semiconductor and IDT's problems highlighted the tough competitive climate in fast SRAMs. In almost every market, demand was strong but supply was in excess for most of the year. For MOS memory makers, 1993 promises to be much better for profits than was 1992.

Competition: Toshiba Stays on Top

Toshiba retained its No. 1 ranking for all MOS memory, with an estimated $1.62 billion in shipments, up 14 percent from 1991 (see Table 3). Second, third, and fourth place went to Samsung, Hitachi and NEC, each of which shipped more than $1.4 billion during the year. More than

Table 3
Preliminary 1992 Estimated Worldwide Market Share Ranking, MOS Memory (Millions of Dollars)

1992 Rank	1991 Rank	Company	1991 Revenue	1992 Revenue	Percent Change	1992 Market Share (%)
1	1	Toshiba	1,425	1,622	14	10.6
2	4	Samsung	1,066	1,516	42	9.9
3	2	Hitachi	1,330	1,512	14	9.9
4	3	NEC	1,242	1,421	14	9.3
5	5	Fujitsu	909	927	2	6.1
6	6	Mitsubishi	762	904	19	5.9
7	7	Texas Instruments	738	874	18	5.7
8	10	Motorola	412	611	48	4.0
9	16	Goldstar	249	557	124	3.6
10	17	Hyundai	248	556	124	3.6
11	8	Sharp	476	523	10	3.4
12	9	Micron Technology	455	516	13	3.4
13	12	Oki	380	429	13	2.8
14	11	Intel	395	324	-18	2.1
15	13	Siemens	298	315	6	2.1
16	14	SGS-Thomson	273	304	11	2.0
17	15	Advanced Micro Devices	270	281	4	1.8
18	18	Matsushita	217	221	2	1.4
19	20	Sony	183	202	10	1.3
20	19	Cypress Semiconductor	186	180	-3	1.2
21	29	NMB Semiconductor	60	136	127	0.9
22	NM	MOSel/Vitelic	NA	135	NA	0.9
23	21	Integrated Device Technology	128	134	5	0.9
24	22	National Semiconductor	112	113	1	0.7
25	26	Atmel	78	99	27	0.6
		All Others	949	893	-6	5.8
		North American Companies	3,298	3,692	12	24.1
		Japanese Companies	7,141	8,073	13	52.7
		European Companies	682	698	2	4.6
		Asia/Pacific-ROW Companies	1,720	2,842	65	18.6
		Total Market	12,841	15,305	19	100.0

NA = Not available
Source: Dataquest (February 1993)

50 suppliers shipped MOS memory for revenue in 1992, but the top six had more than 50 percent of the total market, a fraction that has changed little in the past two decades.

Performance Differentiators for 1992

As ever, many factors separated those that gained market share from those that lost in 1992. The most important considerations that defined greater or lesser success in the 1992 MOS memory market were the following:

Regional Emphasis

Several regional sales profile factors significantly impacted the performance of MOS memory producers in 1992. One factor was the relative weakness of demand in the Japanese market. Japanese suppliers control more than 85 percent of the Japanese MOS memory market, and about 50 percent of their MOS memory shipments historically were into their home market. In 1992, the Japanese MOS Memory market contracted 1 percent, forcing Japanese producers to sell more of their product outside of Japan, and they increased their external sales about as fast as the market grew.

A second factor was the strong Asian market outside of Japan. Although accounts in Europe and the United States (and Japan, for Japanese makers) have been the first emphasis for most major manufacturers, the fastest growing region in 1992 by far was the Asian region, which saw DRAM consumption exceed 48 percent in 1992. The Asia/Pacific region outside of Japan is already a bigger MOS memory market opportunity than Europe, and is growing faster. It grew 44 percent in 1992, compared with just 19 percent for the world as a whole.

Product Focus

Korean suppliers' initial and most potent impact has been in the DRAM market, where they had more than 80 percent of their 1992 MOS memory sales in DRAMs. Conversely, a relatively small effort by the Japanese in EPROMs, a market that was soft for most of 1992, left them less vulnerable. The ROM market is dominated by Japanese producers that sell into the Japanese market. Though they felt some pressure from Samsung and Goldstar, Japanese ROM makers accounted for almost all of the ROM market's growth in 1992. Intel and Advanced Micro Devices (AMD) made up virtually all of the growth in the 1992 flash market.

Outlook Favorable

Price pressure began to abate during the summer quarter—and manufacturers began to see signs of hope for the future—when manufacturers began to recognize that excess capacity was being exhausted and that spending to replenish the stock of capital was weak. Demand surprised almost everyone, persisting through an unseasonably strong summer quarter and rolling into 1993 with a good backlog, good demand, and stable prices.

Forecasts and Capacity in Place

The 1992 market exceeded virtually all expectations, which left some companies' capacity constrained earlier in the year than others, and unable to take full advantage of the opportunities that waited. In 4Mb DRAMs, in particular, estimates of the 1992 market done in January 1992 ranged from about 300 million units to less than 400 million. The market roared past the 400-million milestone before Thanksgiving dishes were clean, and came to rest at about 450 million units.

Because facilities expansion had jumped the gun on the cyclical upturn in demand in 1990-1991 (because of the drawn-out cycle, which lengthened to about five years this time), many vendors not only had poor profitability (for underutilized capacity), but also halted further expansion for 1992. For the Japanese in particular, capital spending in fiscal 1992 was down 30 percent from 1991 levels. It was not until late in 1992 that the capacity expansion projects were taken off the back burner and restarted.

The Changing Face of MOS Memory in 1992

Patents and royalty payments constitute a significant barrier to entry in the MOS memory market, and have since TI launched its patent offensive in 1987. Royalty payments for MOS memory patents probably exceeded $500 million in 1992, not to mention technology that was cross-licensed without a fee, or held as proprietary.

Worldwide DRAM Market Increases 25 Percent

The worldwide DRAM market grew by 25 percent in 1992 (see Table 4). Bit growth exceeded all expectations from a year earlier and left several DRAM makers strapped for capacity as the year closed.

The major changes in the market resulted from the quick run-up of Korean DRAM makers Goldstar and Hyundai. Both increased their revenue by more than 100 percent from the prior year and earned lawsuits from Micron Technology for allegedly dumping product in the United States and for patent infringement. Samsung, which has been within striking distance of DRAM market leadership since 1988, emerged on top in 1992, largely because of its balanced global sales. It is the volume leader in both 1Mb and 4Mb DRAMs and has an improving product technology and account base.

Outlook Favorable

The outlook for 1993 is favorable for DRAM makers, with strong demand and stable prices. Should Japanese demand start to accelerate, there will be some reason for concern about assured supplies as we move into the summer quarter. The hard drive of the Korean DRAM makers has been attenuated somewhat in anticipation of the final U.S. Department of Commerce and International Trade Commission ruling, but the dominant consideration is the matching of supply and demand as we move through the year. The Koreans all have new capacity coming on as we move into 1993, but must certainly be constrained on how aggressively they play the DRAM business. Capacity appears to be tight at Hitachi, Mitsubishi, Oki, Micron Technology, and Toshiba. Second-tier Japanese companies NMB, Matsushita, and Sharp can contribute incremental supply, but they are not major players and have been stretched to the breaking point by investment requirements and the steady decline in profits since late 1989.

Table 4
Preliminary 1992 Estimated Worldwide Market Share Ranking, DRAM
(Millions of Dollars)

1992 Rank	1991 Rank	Company	1991 Revenue	1992 Revenue	Percent Change	1992 Market Share (%)
1	2	Samsung	886	1,192	35	13.6
2	1	Toshiba	957	1,114	16	12.8
3	3	NEC	743	882	19	10.1
4	4	Hitachi	661	823	25	9.4
5	5	Texas Instruments	575	667	16	7.6
6	6	Mitsubishi	515	654	27	7.5
7	7	Fujitsu	503	537	7	6.1
8	12	Goldstar	228	513	125	5.9
9	13	Hyundai	186	416	124	4.8
10	8	Micron Technology	365	411	13	4.7
11	11	Motorola	276	384	39	4.4
12	9	Oki	346	368	6	4.2
13	10	Siemens	287	315	10	3.6
		All Others	454	459	1	5.3
		North American Companies	1,384	1,569	13	18.0
		Japanese Companies	4,011	4,730	18	54.1
		European Companies	287	315	10	3.6
		Asia/Pacific-ROW Companies	1,300	2,121	63	24.3
		Total Market	6,982	8,735	25	100.0

Source: Dataquest (February 1993)

NEC reduced its spending less than did other Japanese companies in 1992, and has moved forward apace at its Roseville, California plant and with its 1993 plans in anticipation of strong demand. Texas Instruments has substantial capacity coming on at KTI, TECH Semiconductor (late in 1993), and incremental improvement at TI-Acer and Avezzano, Italy.

Worldwide SRAM Market Increases 18 Percent

Calendar year 1992 was good for the world of SRAMs. While the North America, Europe, and Asia/Pacific-ROW markets moved into growth, the Japan market performed as well in 1992 as it did in 1991. Worldwide SRAM revenue grew 18 percent, from $2.58 billion to $3.05 billion (see Table 5).

At the beginning of the year, as the major markets firmed up, slower and denser SRAMs started to regain their former run rates. Most importantly, conversion from 256Kb to 1Mb density got back on track, after stalling in

Table 5
Preliminary 1992 Estimated Worldwide Market Share Ranking, SRAM
(Millions of Dollars)

1992 Rank	1991 Rank	Company	1991 Revenue	1992 Revenue	Percent Change	1992 Market Share (%)
1	1	Hitachi	449	494	10	16.2
2	4	NEC	241	269	12	8.8
3	3	Toshiba	242	268	11	8.8
4	2	Fujitsu	261	247	-5	8.1
5	7	Motorola	132	222	68	7.3
6	5	Sony	172	184	7	6.0
7	10	Samsung	93	170	83	5.6
8	6	Mitsubishi	151	163	8	5.3
9	12	Hyundai	48	131	173	4.3
10	9	Sharp	109	123	13	4.0
11	8	Cypress Semiconductor	125	112	-10	3.7
12	11	Micron Technology	90	101	12	3.3
		All Others	463	567	22	18.6
		North American Companies	551	710	29	23.3
		Japanese Companies	1,742	1,882	8	61.7
		European Companies	82	55	-33	1.8
		Asia/Pacific-ROW Companies	201	404	101	13.2
		Total Market	2,576	3,051	18	100.0

Source: Dataquest (February 1993)

1991 because of systems houses reluctant to phase out older systems and replace them with new designs. These designs were released to manufacturing in 1992, and the 1Mb density moved quite swiftly into the position it should have held at the end of 1991.

Lead times have stretched out for slower parts, especially 256Kb and 1Mb in surface-mount packages, and most significantly for those devices in TSOP packages.

Prices for the faster components began to firm up after midyear, indicating heavier consumption that mainly can be attributed to increasing sales in cached PCs, especially in anticipation of a better Christmas market than in the last two years. Spot market prices for 25ns 8K x 8 hit a low of about $1.50 at the end of the summer, but had moved back up to $1.80 by year-end. It appears that the slow SRAM market is a leading indicator for trends in the high-speed SRAM market.

Performance of companies based in the Asia/Pacific region grew the most, nearly doubling their share of the worldwide SRAM market from

7.8 percent to 13.2 percent. Samsung, Hyundai, Goldstar, and Winbond all had stellar growth, in all cases improving their standing in the market. North American companies improved sales by 29 percent. More than half of this growth came directly from Motorola, whose worldwide sales grew from $132 million to $222 million, all from the sales of dense high-speed (and high-price) SRAMs.

Japan-based companies had a slim 8 percent growth, part of which can be attributed to a stagnant domestic market and part to losses to Asia/Pacific companies. European companies declined by 33 percent, with a $27 million drop in sales caused by the combination of Philips leaving the SRAM market halfway through 1991 and a decline in revenue at SGS-Thomson of 53 percent that was only slightly offset by a $2 million increase in Matra MHS' SRAM revenue.

Hyundai made its debut in the top 10 list, forcing Cypress to No. 11. Although the two of the top four juggled positions, Hitachi stayed on top by a significant margin. Fujitsu dropped from No. 2 to No. 4, and NEC rose from No. 4 to No. 2. Toshiba retained its No. 3 ranking. The downward repositioning of Sony, Mitsubishi, and Sharp all came from significant increases realized by Motorola, Samsung, and Hyundai. Motorola moved to No. 5 from its No. 7 1991 slot, Samsung moved from No. 10 to No. 7, and Hyundai from No. 12 to No. 9.

Nonvolatile Memory: A Year Marked by Flash Growth Pains

As a group, nonvolatile (NV) memory is made up of flash, EPROM, OTP, EEPROM, mask, ROM, and NV-RAM. Dataquest's preliminary worldwide revenue estimates for nonvolatile memories show an 8 percent increase for the market in 1992, from $3.1 billion to $3.3 billion. Table 6 shows the ranks of the top 10 companies that participated in the nonvolatile memory market. The U.S., Japanese, and European markets each grew by about 5 percent. The real growth (41 percent) came from Asia/Pacific companies.

Worldwide EPROM Market Decreases 8 Percent

A slightly turbulent year for EPROMs, 1992 saw a worldwide market contraction of about 8 percent partly attributed to weak demand from Japan and partly to the ongoing shift from EPROM to flash. Intel was the first to implement such a shift; AMD is following a similar but less drastic conversion strategy. EPROM supply is getting tighter and prices are firming up. AMD maintained its top ranking in the EPROM market, even as it experienced a 7 percent drop in revenue (see Table 7). Intel dropped in rank from No. 2 to No. 4 and was replaced by TI. SGS-Thomson maintained its No. 3 position.

Worldwide Flash Memory Market: Demand Outstrips Intel

The major story in the flash memory market was that supply problems at Intel during the third quarter of 1992 became evident as the company was unable to keep up with demand for 8Mb devices. Intel planned to

Table 6
Preliminary 1992 Estimated Worldwide Market Share Ranking, Nonvolatile Memory (Millions of Dollars)

1992 Rank	1991 Rank	Company	1991 Revenue	1992 Revenue	Percent Change	1992 Market Share (%)
1	2	Sharp	306	346	13	10.4
2	1	Intel	311	279	-10	8.4
3	3	NEC	258	270	5	8.1
4	4	Advanced Micro Devices	237	253	7	7.6
5	7	SGS-Thomson	208	245	18	7.4
6	5	Toshiba	226	240	6	7.2
7	8	Texas Instruments	159	203	28	6.1
8	6	Hitachi	220	195	-11	5.9
9	13	Samsung	87	154	77	4.6
10	9	Fujitsu	145	143	-1	4.3
		All Others	935	1,004	7	30.1
		North American Companies	1,216	1,278	5	38.4
		Japanese Companies	1,382	1,458	5	43.8
		European Companies	275	287	4	8.6
		Asia/Pacific-ROW Companies	219	309	41	9.3
		Total Market	3,092	3,332	8	100.0

Note: Some columns may not add to 100 percent because of rounding.
Source: Dataquest (February 1993)

transfer production of its 8Mb parts to NMB semiconductor, which was not able to bring up production by the end of 1992 as expected, causing a severe supply problem that at least temporarily stagnated Intel's exponential growth in this market.

Beyond the supply problems of high-density flash, a number of companies joined in or expanded production. Intel maintained its No. 1 ranking with about 69 percent of the worldwide market (see Table 8). AMD grew by 309 percent to command almost 19 percent of the market, Atmel grew by 450 percent, and Hitachi by 400 percent. As a group, North American companies controlled about 95 percent of the market. Toshiba dropped in rank from No. 3 to No. 8, overtaken by suppliers of Intel-compatible NOR-type flash. However, Toshiba formed a couple of important flash alliances in 1992 with National Semiconductor and Samsung, which should strengthen the Toshiba NAND-type flash camp. The flash supply problems will probably ease by the end of 1993, and the market will get back on track on a high-growth path.

Table 7
Preliminary 1992 Estimated Worldwide Market Share Ranking, EPROM (Millions of Dollars)

1992 Rank	1991 Rank	Company	1991 Revenue	1992 Revenue	Percent Change	1992 Market Share (%)
1	1	Advanced Micro Devices	225	209	-7	16.8
2	4	Texas Instruments	136	197	45	15.8
3	3	SGS-Thomson	158	180	14	14.5
4	2	Intel	205	122	-40	9.8
5	5	Fujitsu	86	75	-13	6.0
6	6	National Semiconductor	81	69	-15	5.5
7	10	Hitachi	59	59	0	4.7
8	9	Mitsubishi	67	56	-16	4.5
9	8	Toshiba	68	48	-29	3.9
10	10	Philips	59	40	-32	3.2
		All Others	214	190	-11	15.3
		North American Companies	774	728	-6	58.5
		Japanese Companies	367	290	-21	23.3
		European Companies	217	220	1	17.7
		Asia/Pacific-ROW Companies	0	7	NA	0.6
		Total Market	1,358	1,245	-8	100.0

NA = Not available
Note: Some columns may not add to 100 percent because of rounding.
Source: Dataquest (February 1993)

Table 8
Preliminary 1992 Estimated Worldwide Market Share Ranking, Flash (Millions of Dollars)

1992 Rank	Company	1992 Revenue	1992 Market Share (%)
1	Intel	157	68.9
2	Advanced Micro Devices	43	18.9
3	Atmel	11	4.8
4	Hitachi	5	2.2
5	Catalyst	3	1.3
6	Toshiba	2	0.9
6	Texas Instruments	2	0.9
6	SGS-Thomson	2	0.9
9	Mitsubishi	1	0.4
9	SEEQ Technology	1	0.4
9	NEC	1	0.4
	North American Companies	217	95.4
	Japanese Companies	9	4.1
	European Companies	2	0.5
	Asia/Pacific-ROW Companies	0	0
	Total Market	228	100.0

Source: Dataquest (February 1993)

Worldwide EEPROM Market Increases 29 Percent

The worldwide EEPROM market grew by 29 percent over 1991, from $326.2 million to an estimated $422 million in 1992, stellar performance indeed (see Table 9). This growth resulted from an ever-increasing use of small-density EEPROMs (256 bits to 16Kb). However, for all practical purposes flash has killed high-density EEPROM development (1Mb and higher), because EEPROMs are far more expensive at those densities. Flash supply problems are not about to change the fate of high-density EEPROMs. Low-density EEPROMs will keep finding new applications. However, average selling prices are in the mud and there are no supply problems in that market. The process "recipe" is well understood, and plenty of vendors are ready and willing to service this market. The market is growing, but no one is getting excessively rich.

U.S. companies held about 64.5 percent of the worldwide market in 1992, with Japanese and European companies (SGS-Thomson) splitting the remainder.

Table 9
Preliminary 1992 Estimated Worldwide Market Share Ranking, EEPROM
(Millions of Dollars)

1992 Rank	Company	1992 Revenue	1992 Market Share (%)
1	Xicor	89	21.1
2	SGS-Thomson	63	14.9
3	Atmel	50	11.8
4	Catalyst	34	8.1
5	NEC	32	7.6
6	National Semiconductor	28	6.6
7	Dallas Semiconductor	25	5.9
7	SEEQ Technology	25	5.9
9	Microchip Technology	20	4.7
10	Samsung	16	3.8
	All Others	40	9.5
	North American Companies	272	64.5
	Japanese Companies	68	16.1
	European Companies	65	15.4
	Asia/Pacific-ROW Companies	17	4.0
	Total Market	422	100.0

Source: Dataquest (February 1993)

Worldwide Mask ROM Market Increases 18 Percent

Calendar 1992 showed 18 percent growth over 1991 in revenue from mask ROM. Worldwide revenue increased from almost $1.2 billion in 1991 to more than $1.4 billion in 1992 (see Table 10).

Dataquest did not break out mask ROM revenue separately from other nonvolatile memory revenue until 1992, so there is no 1991 ranking of mask ROM revenue to use for market share comparison between the two years.

Sharp is first in the top 10 ranking, with sales 70 percent higher than that of its nearest competitor, NEC. Sharp has an enviable 24 percent of the worldwide mask ROM market, almost equal to the combined market share of the next two suppliers. The second and third places are taken by NEC and Toshiba, whose sales are estimated to be within 5 percent of each other.

Samsung and Hitachi share the third rung of the ladder, with sales within 6 percent of each other, and double the sales of the next lower company, Matsushita. The combined market share of the bottom six

Table 10
Preliminary 1992 Estimated Worldwide Market Share Ranking, Mask ROM (Millions of Dollars)

1992 Rank	Company	1992 Revenue	1992 Market Share (%)
1	Sharp	343	24.1
2	NEC	204	14.4
3	Toshiba	192	13.5
4	Samsung	138	9.7
5	Hitachi	131	9.2
6	Matsushita	69	4.9
7	Fujitsu	58	4.1
8	Macronix	57	4.0
9	United Microelectronics	38	2.7
10	Oki	28	2.0
10	Mitsubishi	28	2.0
	All Others	135	9.5
	North American Companies	36	2.5
	Japanese Companies	1,100	77.4
	European Companies	0	0
	Asia/Pacific-ROW Companies	285	20.1
	Total Market	1,421	100.0

Source: Dataquest (February 1993)

companies in the survey amounted to less than Sharp's market share alone.

Other MOS Memory Market Decreases 2 Percent

Dataquest's other MOS memory (OMM) category includes SRAM-based devices such as cache-tag RAM, first-in/first-out (FIFO) and content-addressable memory (CAM), and other MOS devices including ferroelectric memories.

Calendar 1992 saw a 2 percent drop in OMM revenue, from $191 million to $187 million (see Table 11). Dataquest does not see this drop as significant, and attributes it largely to continued soft pricing lasting from the difficult markets of 1991. The most important part of the OMM category is FIFO, a part that tends to be used mainly in top-dollar equipment, a market that failed to take off in 1992. We expect to see growth in high-end equipment in 1993.

The status of OMM manufacturers did not change significantly in 1992. IDT is still top dog, with the dominant share of the FIFO market.

Table 11
Preliminary 1992 Estimated Worldwide Market Share Ranking, Other MOS Memory (Millions of Dollars)

1992 Rank	1991 Rank	Company	1991 Revenue	1992 Revenue	Percent Change	1992 Market Share (%)
1	1	Integrated Device Technology	83	76	-8	40.6
2	2	SGS-Thomson	27	41	52	21.9
3	3	Cypress Semiconductor	24	29	21	15.5
4	4	Advanced Micro Devices	17	16	-6	8.6
5	NM	Hyundai	0	8	NA	4.3
6	NM	Micron Technology	0	4	NA	2.1
7	7	Harris	6	3	-50	1.6
8	8	Sanyo	5	2	-60	1.1
9	9	Quality Semiconductor	1	1	0	0.5
9	9	Sharp	1	1	0	0.5
		All Others	27	6	-78	3.2
		North American Companies	147	135	-8	72.2
		Japanese Companies	6	3	-50	1.6
		European Companies	38	41	8	21.9
		Asia/Pacific-ROW Companies	0	8	NA	4.3
		Total Market	191	187	-2	100.0

NA = Not available
NM = Not meaningful
Source: Dataquest (February 1993)

SGS-Thomson placed second, based upon cache-tag RAM sales, and Cypress Semiconductor took third place. Like IDT, Cypress also contributes heavily to the FIFO market. In fourth place was AMD, which is an industry leader in CAM sales and has an aging line of FIFO subject to recent price erosion.

Market share rank positions after fourth place historically have been in a state of flux, with new entrants to the market and others dropping out. This phenomenon is not surprising, given the small size of the overall market and the many different devices that contribute to the OMM category. Additions to the list are Hyundai and Micron Technology, the former a new participant in the market and the latter now selling FIFO announced in years past.

Although Dataquest estimates that there are now 17 manufacturers of FIFO, it is interesting to note that only 6 of the companies in Table 11 had sales in this area of a measurable size.

Dataquest Perspective

The 1992 worldwide MOS memory market, though thin on profits and weak in Japan, surprised almost everyone with its strength throughout the year in other regions of the world. The rising throughput of silicon during the year went far in absorbing the excess capacity on hand as the year opened, leaving the market far tighter as the year closed with a rush of demand. This will most likely make 1993 look like a banner year for revenue and profits for MOS memory makers.

The reality of market demand for flash memory was validated by the overwhelming response to Intel's reduced prices on 2Mb, 4Mb, and 8Mb flash offerings. But the lack of sufficient production frustrated users depending on available supplies, and they often found themselves backpedaling to EPROMs as the year closed.

By Lane Mason, Nicolas Samaras, and Jim Handy

1992 North American MOS Memory Market Shows 25 Percent Expansion

The North American MOS memory market grew about 25 percent from 1991 to 1992 (see Table 1), and left the year on an accelerating growth curve. The North American MOS memory market size, at $5.64 billion, was nearly equal to the worldwide MOS memory market in 1987, at about the same point in the cycle (low profitability, pre-upturn). DRAMs made up more than 62 percent of the North American revenue base, a record high made all the more remarkable because historically the DRAM share of the market reaches a cyclical low of less than 45 percent of MOS memory in times of tight profits, such as 1992.

Table 1
Preliminary 1992 Estimated North American Market Share Ranking, MOS Memory (Millions of Dollars)

1992 Rank	1991 Rank	Company	1991 Revenue	1992 Revenue	Percent Change	1992 Market Share (%)
1	1	Toshiba	600	639	7	11.3
2	2	Samsung	409	583	43	10.3
3	3	Hitachi	352	507	44	9.0
4	5	NEC	338	440	30	7.8
5	4	Micron Technology	341	388	14	6.9
6	6	Mitsubishi	297	376	27	6.7
7	7	Texas Instruments	285	324	14	5.7
8	9	Motorola	193	318	65	5.6
9	17	Goldstar	62	222	258	3.9
10	15	Hyundai	93	207	123	3.7
11	12	Oki	138	178	29	3.2
12	8	Intel	206	152	-26	2.7
13	10	Fujitsu	164	139	-15	2.5
14	11	Cypress Semiconductor	148	136	-8	2.4
15	13	Advanced Micro Devices	114	127	11	2.3
		All Others	770	906	18	16.1
		North American Companies	1,742	1,968	13	34.9
		Japanese Companies	2,053	2,494	21	44.2
		European Companies	144	162	13	2.9
		Asia/Pacific-ROW Companies	571	1,018	78	18.0
		Total Market	4,510	5,642	25	100.0

Source: Dataquest (February 1993)

Toshiba remained the leading MOS memory supplier to the U.S. market, with sales of $639 million, $56 million ahead of hard-charging Samsung. Hitachi and NEC followed in the ranking, and Micron Technology dropped from fourth in 1991 to fifth in 1992.

North American DRAM Market: $3.5 Billion

The North American DRAM market exceeded $3.50 billion in 1992, up 35 percent from 1991 (see Table 2). A host of hard-driving PC makers, plus an aftermarket that supplied the installed base of more than 45 million machines, offered plenty of business for everyone. Still, events led to price erosion of about 35 percent for the year, and to dumping lawsuits filed by Micron Technology against the Korean DRAM makers. Demand showed no immediate signs of abating as 1993 opened.

Table 2
Preliminary 1992 Estimated North American Market Share Ranking, DRAM (Millions of Dollars)

1992 Rank	1991 Rank	Company	1991 Revenue	1992 Revenue	Percent Change	1992 Market Share (%)
1	2	Samsung	362	504	39	14.4
2	1	Toshiba	381	408	7	11.6
3	3	NEC	285	376	32	10.7
4	4	Micron Technology	275	317	15	9.0
5	5	Mitsubishi	235	315	34	9.0
6	7	Hitachi	185	298	61	8.5
7	6	Texas Instruments	219	249	14	7.1
8	12	Goldstar	60	219	265	6.3
9	11	Hyundai	72	185	157	5.3
10	9	Motorola	118	183	55	5.2
11	8	Oki	134	170	27	4.9
		All Others	275	280	2	8.0
		North American Companies	696	804	16	22.9
		Japanese Companies	1,362	1,732	27	49.4
		European Companies	49	60	22	1.7
		Asia/Pacific-ROW Companies	494	908	84	25.9
		Total Market	2,601	3,504	35	100.0

Note: Some columns may not add to 100 percent because of rounding.
Source: Dataquest (February 1993)

Samsung took the top supplier spot from Toshiba in 1993, with sales estimated at $504 million. Together, Goldstar and Hyundai racked up sales growth of more than 200 percent to $400 million, to earn the fast-growth title, along with their legal papers.

North American SRAM Market: $1.1 Billion

The North American market surpassed the Japanese market in SRAMs in 1992, in part because of the North American recovery and in part to flat 1991-to-1992 revenue in Japan, which is usually the dominant market for SRAMs.

The total North American market for SRAMs was $1.08 billion, up 22 percent from 1991's $889 million (see Table 3).

Motorola leaped ahead two places to become the No. 2 player in North American SRAM sales. Hitachi holds its first place position relatively precariously. In 1991, Motorola displaced Cypress Semiconductor as the top North American SRAM supplier to the world, but found itself behind Cypress in SRAM sales to the North American market. The other rising star in the table is Samsung, which in the middle of the year

Table 3
Preliminary 1992 Estimated North American Market Share Ranking, SRAM (Millions of Dollars)

1992 Rank	1991 Rank	Company	1991 Revenue	1992 Revenue	Percent Change	1992 Market Share (%)
1	1	Hitachi	112	153	37	14.1
2	4	Motorola	75	135	80	12.5
3	2	Toshiba	107	120	12	11.1
4	3	Cypress Semiconductor	101	84	-17	7.8
5	5	Micron Technology	66	67	2	6.2
6	6	Fujitsu	65	57	-12	5.3
7	11	Samsung	28	56	100	5.2
8	8	NEC	43	53	23	4.9
9	7	Mitsubishi	48	50	4	4.6
10	9	Sony	38	45	18	4.2
		All Others	206	263	28	24.3
		North American Companies	383	477	25	44.0
		Japanese Companies	444	513	16	47.4
		European Companies	15	9	-40	0.8
		Asia/Pacific-ROW Companies	47	84	79	7.8
		Total Market	889	1,083	22	100.0

Source: Dataquest (February 1993)

announced its entry into fast SRAMs, the other half of the SRAM marketplace. Dataquest expects these two manufacturers to continue their aggressive thrusts into the North American SRAM market, and for them to move even higher in 1993. Both place a strong emphasis on the development of leading-edge speeds at high densities, which fills an important need in the North American market. The only 1991 top 10 member to be displaced from the list is IDT, which seems to be recovering quickly and will probably make the list again in 1993.

From a regional headquarters perspective, European semiconductor manufacturers fared the worst in the North American market, losing nearly half their revenue. SGS-Thomson dropped from $12 million to $6 million, and Matra MHS increased from $2 million to $3 million (offset by Philips' exit from the market midway through 1991, removing the $1 million posted for its 1991 North American SRAM sales).

More than compensating for the decline suffered by European companies were those companies headquartered in Asia/Pacific, which saw an increase of 79 percent in their North American SRAM sales. Winbond's sales were up 200 percent, followed by a 100 percent gain by Samsung and gains of about 50 percent by Hyundai and Goldstar. Three-fourths of the growth can be attributed to Samsung's doubling in sales.

North American companies' sales to the North American market grew an even 25 percent, nearly two-thirds of which came from an 80 percent growth in Motorola's sales. The rest came from smaller contributions from numerous companies, offset by even smaller reductions from even more companies. The growth in sales by North America-headquartered companies into the North American market was closer to that of the actual market than was the sales growth of companies based anywhere else. We attach no particular significance to this phenomenon, although it is interesting to note.

North American Nonvolatile Memory Market: $935 Million

The overall North American nonvolatile memory market grew by 4 percent, from $895 million to $935 million (see Table 4). Intel ranked first, followed by Toshiba and AMD. There were no major changes in rank, but Xicor dropped from sixth to eighth place, while both SGS-Thomson and Atmel rose by one spot. As a group, North American companies accounted for 63 percent of the worldwide market, followed by Japanese companies with 26 percent.

Table 4
Preliminary 1992 Estimated North American Market Share Ranking, Nonvolatile Memory (Millions of Dollars)

1992 Rank	1991 Rank	Company	1991 Revenue	1992 Revenue	Percent Change	1992 Market Share (%)
1	1	Intel	150	129	-14	13.8
2	2	Toshiba	112	111	-1	11.9
3	3	Advanced Micro Devices	90	107	19	11.4
4	4	Texas Instruments	64	73	14	7.8
5	5	Hitachi	55	56	2	6.0
6	7	SGS-Thomson	44	55	25	5.9
7	8	Atmel	43	49	14	5.2
8	6	Xicor	48	39	-19	4.2
9	9	National Semiconductor	36	34	-6	3.6
9	10	Cypress Semiconductor	31	34	10	3.6
		All Others	222	248	12	26.5
		North American Companies	556	590	6	63.1
		Japanese Companies	246	248	1	26.5
		European Companies	63	72	14	7.7
		Asia/Pacific-ROW Companies	30	25	-17	2.7
		Total Market	895	935	4	100.0

Source: Dataquest (February 1993)

North American EPROM Market: $417 Million

The North American EPROM market declined by 5 percent from $438 million to $417 million (see Table 5). Intel dropped from second place to fourth, consistent with its shift in emphasis from EPROM to flash. Revenue for SGS-Thomson, TI, Cypress, Hitachi, and Toshiba increased, while AMD, National Semiconductor, and Philips' revenue dropped.

North American Flash Memory Market: $130 Million

Table 6 lists the revenue and market share of the flash memory suppliers to the North American market. Intel dominates the list with 69 percent market share, AMD is second with 20 percent, and Atmel is third with slightly more than 6 percent. The North American flash memory market was $130 million, or about 57 percent of the worldwide $228 million market.

Table 5
Preliminary 1992 Estimated North American Market Share Ranking, EPROM (Millions of Dollars)

1992 Rank	1991 Rank	Company	1991 Revenue	1992 Revenue	Percent Change	1992 Market Share (%)
1	1	Advanced Micro Devices	83	80	-4	19.2
2	3	Texas Instruments	58	69	19	16.5
3	4	SGS-Thomson	36	45	25	10.8
4	2	Intel	75	39	-48	9.4
5	6	Cypress Semiconductor	31	34	10	8.2
6	5	National Semiconductor	32	27	-16	6.5
7	7	Toshiba	20	21	5	5.0
8	9	Philips	18	17	-6	4.1
9	10	Hitachi	14	16	14	3.8
10	11	Waferscale Integration	13	14	8	3.4
		All Others	58	55	-5	13.2
		North American Companies	317	290	-9	69.5
		Japanese Companies	67	65	-3	15.6
		European Companies	54	62	15	14.9
		Asia/Pacific-ROW Companies	0	0	NA	0
		Total Market	438	417	-5	100.0

NA = Not available
Source: Dataquest (February 1993)

Table 6
Preliminary 1992 Estimated North American Market Share Ranking, Flash (Millions of Dollars)

1992 Rank	Company	1992 Revenue	1992 Market Share (%)
1	Intel	90	69.2
2	Advanced Micro Devices	26	20.0
3	Atmel	8	6.2
4	Catalyst	3	2.3
5	Texas Instruments	2	1.5
6	SEEQ Technology	1	0.8
	North American Companies	130	100.0
	Japanese Companies	0	0
	European Companies	0	0
	Asia/Pacific-ROW Companies	0	0
	Total Market	130	100.0

Source: Dataquest (February 1993)

North American EEPROM Market: $154 Million

Table 7 lists the top 10 EEPROM vendors that supplied devices into North America. The U.S. companies were a major force here, accounting for 80 percent of the total North American market.

North American Mask ROM Market: $211 Million

Dataquest estimates the North American mask ROM market at $211 million in 1992, less than 15 percent of the worldwide market (see Table 8). Given this small participation, it is not surprising that North American companies contributed less than 11 percent of North American ROM sales, and 2.5 percent of worldwide sales. What is surprising is the difference in ranking the top ROM players show in comparison to the worldwide ROM market.

Members of the worldwide top 10 not on the North American top 10 list are Macronix, Mitsubishi, Oki, and United Microelectronics. Manufacturers on the North American top 10 that do not appear in the worldwide top 10 are Gould AMI, International Microelectronic Products, and ITT, all North America-based manufacturers. Combined, the top 10 ranked suppliers reap 97.4 percent of the overall ROM revenue from the North American market.

Table 7
Preliminary 1992 Estimated North American Market Share Ranking, EEPROM (Millions of Dollars)

1992 Rank	Company	1992 Revenue	1992 Market Share (%)
1	Xicor	39	25.3
2	Atmel	28	18.2
3	SEEQ Technology	18	11.7
4	Dallas Semiconductor	16	10.4
5	Catalyst	11	7.1
6	SGS-Thomson	10	6.5
7	Samsung	7	4.5
7	National Semiconductor	7	4.5
9	Oki	5	3.2
10	Microchip Technology	4	2.6
10	NEC	4	2.6
	All Others	5	3.2
	North American Companies	124	80.5
	Japanese Companies	13	8.4
	European Companies	10	6.5
	Asia/Pacific-ROW Companies	7	4.5
	Total Market	154	100.0

Note: Some columns may not add to 100 percent because of rounding.
Source: Dataquest (February 1993)

North American Other MOS Memory Market: $120 Million

It is hardly a surprise that the bulk of the worldwide OMM market was in North America. Devices in the OMM category are typically used in more expensive equipment, a market that is the domain of North American systems manufacturers. Of the $187 million worldwide market for OMM, $120 million, or 64 percent, of the revenue was realized in North America (see Table 9). This entire market is regional, with North American manufacturers shipping mainly to North American users, largely because of the ease of communication among manufacturers and users, who are on the same continent. Such a phenomenon stands to reason with niche products such as these.

North American manufacturers served 72 percent of the worldwide OMM market in 1992. North American OMM manufacturers supplied more than 80 percent of the overall product in the North American market. The ranking of top OMM manufacturers' sales to North America subsequently copied the ranking for these manufacturers worldwide, with the exception that Hyundai, which ranked No. 5 worldwide, stands in the No. 7 position in North America, falling quite naturally behind

Table 8
Preliminary 1992 Estimated North American Market Share Ranking, Mask ROM (Millions of Dollars)

1992 Rank	Company	1992 Revenue	1992 Market Share (%)
1	Toshiba	90	42.7
2	Hitachi	40	19.0
3	Sharp	17	8.1
4	Samsung	16	7.6
5	Matsushita	13	6.2
6	Gould AMI	12	5.7
7	Fujitsu	5	2.4
7	International Microelectronic Products	5	2.4
9	ITT	4	1.9
10	NEC	3	1.4
	All Others	6	2.8
	North American Companies	23	10.9
	Japanese Companies	170	80.6
	European Companies	0	0
	Asia/Pacific-ROW Companies	18	8.5
	Total Market	211	100.0

Source: Dataquest (February 1993)

Table 9
Preliminary 1992 Estimated North American Market Share Ranking, Other MOS Memory (Millions of Dollars)

1992 Rank	1991 Rank	Company	1991 Revenue	1992 Revenue	Percent Change	1992 Market Share (%)
1	1	Integrated Device Technology	62	54	-13	45.0
2	2	SGS-Thomson	16	21	31	17.5
3	2	Cypress Semiconductor	16	18	13	15.0
4	4	Advanced Micro Devices	12	11	-8	9.2
5	NM	Micron Technology	0	4	NA	3.3
6	6	Harris	5	3	-40	2.5
		All Others	14	9	-36	7.5
		North American Companies	107	97	-9	80.8
		Japanese Companies	1	1	0	0.8
		European Companies	17	21	24	17.5
		Asia/Pacific-ROW Companies	0	1	NA	0.8
		Total Market	125	120	-4	100.0

NA = Not available
NM = Not meaningful
Note: Some columns may not add to 100 percent because of rounding.
Source: Dataquest (February 1993)

three North American companies and surprisingly behind Sharp of Japan, a company not based within the market it serves.

Revenue dropped more significantly in North America than it did worldwide, yet the reduction was only 4 percent, signifying a stagnant rather than a lowering trend. As with the worldwide totals, Dataquest expects to see growth in the North American OMM market in 1993.

Dataquest Perspective

The 1992 North American MOS memory market, led by DRAMs but confused by the mismatch of supply and demand for flash products, grew 25 percent in 1992. DRAM demand was led by x86 price wars, the newer demand forces of software such as Windows 3.1, and a vast market for upgrades to the installed base of existing PCs. Despite predictions that the U.S. PC business would substantially move to the Far East, IBM and Apple remained the largest sellers of PCs in 1992, and Compaq, Dell, and such innovators as Gateway 2000 kept domestic U.S. demand for DRAMs and SRAMs for cache memories strong throughout the entire year.

Lane Mason, Nicolas Samaras, and Jim Handy

For More Information...

Lane Mason, Director/Principal Analyst.................................(408) 437-8120
Via fax...(408) 437-0292

Dataquest®
a company of The Dun & Bradstreet Corporation

Market Statistics

Dataquest®

Dataquest®

Semiconductors

Semiconductor Consumption Forecast

Market Statistics

1993 Preliminary

Program: Semiconductors
Product Code: SCND-WW-MS-9301
Publication Date: April 26, 1993 (Reprint of March 22, 1993 document)

Dataquest®

Semiconductors

Semiconductor Consumption Forecast

Market Statistics

1993 Preliminary

Program: Semiconductors
Product Code: SCND-WW-MS-9301
Publication Date: April 26, 1993 (Reprint of March 22, 1993 document)

Revised Semiconductor Consumption Forecast

The Market Statistics (1993 Preliminary) document entitled, "Semiconductor Consumption Forecast" (SCND-WW-MS-9301, published March 22, 1993) contained errors in some of the regional estimates of 1991 microcomponent revenue. The corrected estimates are given in the table below, along with the previously published erroneous estimates.

Revenue from Microcomponents Shipped to Each Region for Use in All Applications (Millions of U.S. Dollars)

	1991 (previously published)	1991 (corrected)
North America	3,841	3,916
Japan	3,638	3,579
Asia/Pacific-Rest of World	2,258	2,197

The regional errors were reflected in numerous growth tables and carried through to the worldwide estimates. This republished document contains correct data for all tables.

Table of Contents

List of Tables

Note: All tables show estimated data.

List of Tables (Continued)

Note: All tables show estimated data.

Semiconductor Consumption Forecast

Introduction

This document contains detailed information on Dataquest's view of the semiconductor device market. Included in this document are the following:

- 1988-1992 historical data
- 1993-1997 forecast data

Worldwide market revenue estimates combine data from many countries, each of which has a different and fluctuating exchange rate. Estimates of non-U.S. market revenue are based on the average exchange rate for the given year. Refer to the section entitled "Exchange Rates" for more information regarding these average rates. As a rule, Dataquest's estimates are calculated in local currencies and then converted to U.S. dollars.

The average exchange rate for a quarter is estimated as the simple arithmetic mean of the average monthly values for the three months of the quarter. Similarly, the average exchange for a year is estimated as the simple arithmetic mean of the average monthly values for the 12 months of the year. The 1992 revenue estimates are taken from the preliminary market share estimates for 1992.

Dataquest does not forecast exchange rates per se; however, we do forecast semiconductor markets in several regions of the world, and we use the U.S. dollar as a common currency for market comparisons. In the forecast period, Dataquest assumes that the most recent actual month's exchange rate will apply throughout all future months of the forecast. For example, the current semiconductor forecast uses actual exchange rates through January 1993, and assumes that the January rate applies throughout all future months. Then the quarterly and annual exchange rates are estimated as described in the previous paragraph.

More detailed data on this market may be requested through Dataquest's client inquiry service. Qualitative analysis of these data is provided in the *Dataquest Perspectives* located in the binder of the same name.

Segmentation

This section outlines the market segments specific to this document. Dataquest's objective is to provide data along the lines of segmentation that are logical, appropriate to the industry in question, and immediately useful to clients.

For a detailed explanation of Dataquest's market segmentation, refer to the *Dataquest Research Methodology* document located in the *Source: Dataquest* binder.

Dataquest defines the semiconductor industry as the group of competing companies primarily engaged in manufacturing semiconductors and related solid-state devices. Important products of the semiconductor industry include integrated circuits, discrete devices, and optoelectronic devices.

For forecasting purposes, Dataquest defines the semiconductor market according to the following functional segmentation scheme:

- Total Semiconductor (Monolithic + Hybrid)
- Total Hybrid Integrated Circuit
- Total Monolithic Semiconductor
  - Total Integrated Circuit
    - Bipolar Digital
      - Bipolar Memory
      - Bipolar Logic
    - MOS Digital
      - MOS Memory
      - MOS Microcomponent
      - MOS Logic
    - Monolithic Analog
  - Total Discrete
  - Total Optoelectronic

Definitions

This section lists the definitions used by Dataquest to present the data in this document. Definitions for semiconductor devices can be found in the *Dataquest Semiconductor Market Definitions Guide.*

Total Semiconductor (Total Monolithic Semiconductor + Hybrid Integrated Circuit). Defined as any active semiconductor product that contains semiconducting material (such as silicon, germanium, or gallium arsenide, but excluding ceramics) and reacts dynamically to an input signal, whether by modifying its shape or adding energy to it. Includes monolithic IC and hybrid IC. This definition excludes stand-alone passive components such as capacitors, resistors, inductors, oscillators, crystals, transformers, and relays.

Total Hybrid Integrated Circuit. Defined as a semiconductor product consisting of more than one die contained in a single package. A hybrid IC may perform 100 percent linear, 100 percent digital, or mixed-signal (both linear and digital) functions. Includes hybrid implementation of all monolithic IC functions described in the following categories. Includes all hybrid ICs manufactured using bipolar, MOS, or BiCMOS technologies.

Total Monolithic Semiconductor (Total Integrated Circuit + Total Discrete + Total Optoelectronic; also, Total Semiconductor - Total Hybrid IC). Defined as any active semiconductor product that contains semiconducting material (such as silicon, germanium, or gallium arsenide, but excluding ceramics) and reacts dynamically to an input signal, whether by modifying its shape or adding energy to it. Includes monolithic IC only. This definition excludes standalone passive components such as capacitors, resistors, inductors, oscillators, crystals, transformers, and relays.

Total Monolithic Integrated Circuit (Digital Monolithic Bipolar IC + Digital Monolithic MOS IC + Monolithic Analog IC). A monolithic IC is defined as a large number of passive and/or active discrete semiconductor circuits integrated onto a single die and contained in a single package.

Bipolar Digital IC (Bipolar Digital Memory IC + Bipolar Logic IC). A bipolar digital IC is defined as a monolithic semiconductor product in which 100 percent of the die area performs digital functions, and concurrently, 100 percent of the die area is manufactured using bipolar semiconductor technology. A digital function is one in which data-carrying signals vary in discrete values.

Bipolar Digital Memory. Defined as a bipolar digital product in which binary data are stored and electronically retrieved. Includes ECL random-access memory (RAM), read-only memory (ROM), programmable ROM (PROM), last-in/first-out (LIFO) memory, and first-in/first-out (FIFO) memory. Not included are products made with mixed bipolar CMOS (that is, BiCMOS) with TTL or ECL outputs, which are classified as MOS.

Bipolar Digital Logic IC (Bipolar Digital Logic Application-Specific IC + Other Bipolar Digital Logic + Bipolar Digital Microcomponent). Defined as a bipolar digital IC product in which more than 50 percent of the die area performs logic functions. Includes bipolar digital microcomponent ICs.

MOS Digital IC (MOS Digital Memory IC + MOS Digital Microcomponent IC + MOS Digital Logic IC). A MOS digital IC is defined as a monolithic semiconductor product in which 100 percent of the die area performs digital functions, and concurrently, any portion of the die area that is manufactured using metal-oxide semiconductor (MOS) technology. A digital function is one in which data-carrying signals vary in discrete values. Includes mixed technology manufacturing, such as BiMOS and BiCMOS, where some MOS technology is employed.

MOS Digital Memory IC (DRAM + SRAM + Nonvolatile Memory + Other MOS Digital Memory IC). Defined as a MOS digital IC in which binary data are stored and electronically retrieved.

MOS Digital Microcomponent IC (MOS Digital Microprocessor + MOS Digital Microcontroller + MOS Digital Microperipheral). Defined as a MOS digital IC that contains a data processing unit or serves as an interface to such a unit. Includes both complex-instruction-set computing (CISC) and reduced-instruction-set computing (RISC) architectures.

MOS Digital Logic IC (MOS Digital Application-Specific IC + Other MOS Digital Logic). Defined as a MOS digital IC product in which more than 50 percent of the die area performs logic functions. Excludes MOS digital microcomponent ICs.

Monolithic Analog IC (Monolithic Linear IC + Monolithic Mixed-Signal IC). A monolithic analog IC is a semiconductor that deals in the realm of electrical signal processing, power control, or electrical drive capability. It is one in which some of the inputs or outputs can be defined in terms of continuously or linearly variable voltages, currents, or frequencies. Includes all monolithic analog ICs manufactured using bipolar, MOS, or BiCMOS technologies.

Total Discrete (Transistor + Diode + Thyristor + Other Discrete). A discrete semiconductor is defined as a unit building block performing a fundamental semiconductor function.

Total Optoelectronic (LED Lamp/Display + Optocoupler + CCD + Laser Diode + Photosensor + Other Optoelectronic). Defined as a semiconductor product in which photons induce the flow of electrons, or vice versa. Other functions may also be integrated onto the product. This category does not include LCD, incandescent displays, fluorescent displays, cathode ray tubes (CRTs), or plasma displays.

Regional Definitions

North America: Includes Canada, Mexico, and the United States.

Japan: Japan is the only single-country region.

Europe: Western Europe includes Austria, Belgium, Denmark, Eire, Finland, France, Germany (including former East Germany), Greece, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, and Rest of Western Europe (Cyprus, Iceland, Malta, Turkey, and others). Eastern Europe includes Albania, Bulgaria, Czech and Slovak republics, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Republics of the former USSR (including Belorussia, Russia, and Ukraine), and others.

Asia/Pacific: Includes Asia/Pacific's newly industrialized economies (NIEs) and the Rest of Asia/Pacific regions. NIEs include Hong Kong, Singapore, South Korea, and Taiwan. The Rest of Asia/Pacific region includes Australia, Cambodia, China, India, Indonesia, Laos, Malaysia, Maldives, Myanmar, Nepal, New Zealand, Philippines, Thailand, and Vietnam.

Rest of World: Includes Africa, Caribbean, Central America, Middle East, Oceania, and South America.

Line Item Definitions

Factory revenue is defined as the money value received by a semiconductor manufacturer for its products. Dataquest includes all revenue, both merchant and captive, for semiconductor suppliers selling to the merchant market. The data exclude completely captive suppliers where devices are manufactured solely for the company's own use. A product that is used internally is valued at the market price rather than at the transfer or factory price.

Forecast Methodology and Assumptions

Dataquest publishes five-year revenue forecasts for the semiconductor market during the first and third quarters of each year. In doing so, Dataquest uses a variety of forecasting techniques (both qualitative and quantitative) that vary by technology area. An overview of Dataquest forecasting techniques can be found in the *Dataquest Research Methodology* document.

Dataquest's semiconductor forecast methodology leverages the resources of its parent, The Dun & Bradstreet Corporation, as well as the considerable internal resources of Dataquest.

Dun & Bradstreet Corporation information is used to develop the macroeconomic forecasts for the world's major economies. This forecast identifies trends in the economic health of the world's leading consumers and producers of electronic equipment. Using this forecast in conjunction with input from Dataquest's regional offices, Dataquest identifies the likelihood of whether a particular region or country will increase or decrease its consumption of electronic equipment.

Dataquest follows a four-step process to forecast the semiconductor market. First, Dataquest's Semiconductor Applications Market group, along with Dataquest's various electronics systems groups, provides a long-range outlook for the overall growth of the electronics equipment market. Semiconductor content ratios are developed by region to reflect the growing penetration of semiconductors into electronic equipment. This establishes a five-year trend growth path for total semiconductors for a five-year period from a demand-side perspective.

Second, Dataquest uses a decomposition time series model to generate forecasts of regional total semiconductor sales. The model assumes that sales are affected by factors such as long-run trends, short-run aggregate economic and industry-specific conditions, and seasonality. The forecast is made by using statistical methods to analyze each of the components separately, then combining them into a single aggregate. The model is especially useful for assessing market fluctuations about the trend growth path.

Third, Dataquest's worldwide semiconductor service and its Semiconductor Equipment, Materials, and Manufacturing service, in conjunction with its various regional offices, collaborate to formulate expectations of semiconductor market short-run fluctuations around the long-run trend. Tactical market issues and anticipated semiconductor materials demand significantly impact the forecast out to 12 months. Semiconductor equipment purchases and semiconductor device trends drive the forecast in the 12-month to 24-month time frame. Semiconductor fab facilities and long-run semiconductor device trends have the greatest impact on the forecast period covering two to five years.

The final step in the forecast process is to reconcile expected fluctuations in the electronics market and trends in the semiconductor industry so that the fluctuations do not inexplicably diverge from semiconductor industry trends. Dataquest anticipates that, in the absence of shocks to the market, market fluctuations converge toward the long-run trend.

Semiconductor Industry Assumptions

The North American semiconductor market continues to strengthen. Dataquest expects the North American market to grow 20.1 percent in 1993, up from a strong 18.8 percent in 1992. According to the latest WSTS statistics, total semiconductor bookings (three-month moving average) growth for the three months ended in January was 39.3 percent above year-earlier bookings, compared with 40.5 percent in December. Total semiconductor billings growth for the same period was 28.8 percent above year-earlier billings, compared with 31.0 percent in December.

Strength in the North American market can be attributed largely to the continuing strong recovery of the U.S. economy, and especially with respect to investment spending. The Dun & Bradstreet Corporation expects real (that is, inflation adjusted) business fixed investment on equipment to grow 13.1 percent in 1993, compared with 7.3 percent in 1992. In particular, chip demand stems from strong orders of portable PCs, client/server computers, and network hardware.

Dataquest expects the Japanese market to expand at a 6.9 percent dollar-based rate of growth (or 6.0 percent yen-based growth, assuming 0.8 percent depreciation of the U.S.$ against the yen) in 1993, after a 6.2 percent dollar-based (or 13.1 percent yen-based) contraction in 1992. The latest market statistics support this modest outlook. The dollar value of total semiconductor billings for the three months ended in December was 4.8 percent below year-earlier billings and decelerating. The bookings picture is a bit more hopeful: Total semiconductor bookings for the same period were 1.5 percent below year-earlier levels.

Japan's situation is due to more than just weakness in its European export market. Other factors include a heightened level of international competition in chips and systems, rising costs of capital in Japan, and a dearth of new, *high-volume, quick-adoption-rate* consumer electronics systems (for example, VCRs). Dataquest does not expect an improvement in Japan's export market to quickly and painlessly alleviate its structural problems in 1993.

Dataquest forecast the European market to expand at a 13.1 percent dollar-based rate of growth (or 25.8 percent ECU-based growth, assuming 11.2 percent appreciation of the U.S.$ against the ECU) in 1993, up from 12.0 percent dollar-based (or 3.5 percent ECU-based) expansion in 1992. Total semiconductor billings for the three months ended in January were 19.2 percent above year-earlier billings. Total semiconductor bookings for the same period were 36.1 percent above year-earlier levels. The second half of 1992 was characterized by a steep acceleration in billings and bookings growth, with actual growth significantly overshooting trend or equilibrium growth. Further, bookings and billings growth peaked at 48.5 percent and 25.5 percent, respectively, in the fourth quarter. Therefore, Dataquest expects the first half of 1993 to be characterized by robust but decelerating growth converging toward stability in the second half.

Recovery of the U.K. and French economies will help offset—but not completely—decelerating growth in Germany. PC manufacture in Ireland is strong, and much of the growth in the United Kingdom is related to multinational companies increasing their data processing and consumer equipment production. Investment in telecommunications infrastructure and the introduction of GSM mobile cellular phones also provide growth stimulus.

Dataquest forecasts the Asia/Pacific-ROW market to grow 27.6 percent in 1993, accelerating mildly from 26.6 percent growth in 1992. Again, the latest statistics support this outlook. Total semiconductor bookings growth for the three months ended in December was 46.3 percent above year-earlier bookings, compared with 49.7 percent in November. Similar to Europe, the second half of 1992 was characterized by a steep acceleration in bookings growth, with actual growth significantly overshooting trend or equilibrium growth. Therefore, the first half of 1993 likely will be a period of decelerating (but robust) growth converging toward equilibrium. Total semiconductor billings growth for December was 36.9 percent above year-earlier billings. Billings growth will probably peak in the late first-quarter/early-second-quarter period, and stabilize during the second half of 1993. Expansion continues to be driven by foreign and domestic investment and improvement in Western export market conditions.

Forecast Economic Assumptions

Dun & Bradstreet forecasts a mix of accelerating and decelerating positive growth in 1993 for the Group of Seven (G7) Countries.

The U.S., Canadian, Japanese, and U.K. economies are expected to grow at an accelerating pace in 1993. Though modest in comparison with historical rates of expansion during recovery periods, the benefit is that inflationary pressures likely will be held in check, thus helping sustain the expansion's duration. Growth rate forecasts, which assume constant prices and exchange rates, and local currencies, are as follows:

- U.S. real gross domestic product (GDP) is forecast to grow 2.7 percent in 1993, up from 1.9 percent in 1992; and to grow 2.7 percent in 1994.
- Canadian real GDP is forecast to grow 3.0 percent in 1993, up from 1.1 percent in 1992; and to grow 3.4 percent in 1994.

- Japanese real GDP is forecast to grow 2.3 percent in 1993, up from 1.8 percent in 1992; and to grow 3.4 percent in 1994.
- U.K. real GDP is forecast to grow 1.0 percent in 1993, up from a 0.8 percent contraction in 1992; and to grow 2.0 percent in 1994.

On the other hand, the German, French, and Italian economies are expected to experience decelerating growth in 1993. Chief among the moderating influences on growth prospects is the continuing cost burden of Germany's reunification. Forecasts for the German, French, and Italian economies are as follows:

- German real GDP is forecast to grow 0.5 percent in 1993, down from 0.8 percent in 1992; and to grow 2.5 percent in 1994.
- French real GDP is forecast to grow 1.3 percent in 1993, down from 2.0 percent in 1992; and to grow 2.5 percent in 1994.
- Italian real GDP is forecast to grow 0.9 percent in 1993, down from 1.1 percent in 1992; and to grow 1.6 percent in 1994.

Exchange Rates

Dataquest uses an average annual exchange rate in converting revenue to U.S. dollar values. Table 1 outlines these rates for 1992. These rates match the rates used in the 1992 preliminary market share project.

Table 1
Exchange Rates

	1992
Japan (Yen/U.S.$)	125.95
Europe (ECU/U.S.$)	0.749
France (Franc/U.S.$)	5.1433
Germany (Deutsche Mark/U.S.$)	1.5179
United Kingdom (U.S.$/Pound Sterling)	1.8481

Source: Dataquest (April 1993)

Table 2
Revenue from All Semiconductors Shipped to the World for Use in All Applications, 1988-1992 (Millions of U.S. Dollars)

	1988	1989	1990	1991	1992
Total Semiconductor (Monolithic + Hybrid)	50,859	54,339	54,545	59,694	65,264
Total Hybrid IC	1,462	1,368	1,289	1,395	1,381
Total Monolithic Semiconductor	49,397	52,971	53,256	58,299	63,883
Total IC	39,606	43,245	43,170	47,460	53,034
Bipolar Digital	5,200	4,314	4,173	3,628	3,295
Bipolar Memory	689	460	431	356	333
Bipolar Logic	4,511	3,854	3,742	3,272	2,962
MOS Digital	26,988	31,140	30,152	34,315	39,578
MOS Memory	11,692	15,405	12,128	12,841	15,305
MOS Microcomponent	7,144	7,808	9,584	11,774	14,012
MOS Logic	8,152	7,927	8,440	9,700	10,261
Monolithic Analog	7,418	7,791	8,845	9,517	10,161
Total Discrete	7,612	7,320	7,674	8,035	8,199
Total Optoelectronic	2,179	2,406	2,412	2,804	2,650

Source: Dataquest (April 1993)

Table 3
Revenue from All Semiconductors Shipped to the World for Use in All Applications, 1993-1997 (Millions of U.S. Dollars)

	1993	1994	1995	1996	1997
Total Semiconductor (Monolithic + Hybrid)	75,597	85,333	89,811	99,153	110,189
Total Hybrid IC	1,401	1,465	1,537	1,600	1,675
Total Monolithic Semiconductor	74,196	83,868	88,273	97,553	108,514
Total IC	62,489	71,319	74,904	83,270	93,224
Bipolar Digital	3,027	2,755	2,465	2,185	1,922
Bipolar Memory	287	248	220	194	174
Bipolar Logic	2,740	2,507	2,245	1,991	1,748
MOS Digital	48,041	55,685	58,160	65,335	73,950
MOS Memory	19,420	23,816	22,925	26,087	29,855
MOS Microcomponent	17,060	18,924	21,155	23,511	26,332
MOS Logic	11,561	12,945	14,080	15,737	17,763
Monolithic Analog	11,421	12,879	14,279	15,749	17,352
Total Discrete	8,849	9,500	10,160	10,867	11,668
Total Optoelectronic	2,858	3,049	3,209	3,416	3,622

Source: Dataquest (April 1993)

Table 4
Revenue Growth from All Semiconductors Shipped to the World for Use in All Applications, 1988-1992 (Percent Change)

	1988	1989	1990	1991	1992
Total Semiconductor (Monolithic + Hybrid)	33.0	6.8	0.4	9.4	9.3
Total Hybrid IC	14.4	-6.4	-5.8	8.2	-1.0
Total Monolithic Semiconductor	33.6	7.2	0.5	9.5	9.6
Total IC	38.4	9.2	-0.2	9.9	11.7
Bipolar Digital	9.2	-17.0	-3.3	-13.1	-9.2
Bipolar Memory	10.9	-33.2	-6.3	-17.4	-6.5
Bipolar Logic	9.0	-14.6	-2.9	-12.6	-9.5
MOS Digital	54.5	15.4	-3.2	13.8	15.3
MOS Memory	93.1	31.8	-21.3	5.9	19.2
MOS Microcomponent	39.9	9.3	22.7	22.9	19.0
MOS Logic	29.2	-2.8	6.5	14.9	5.8
Monolithic Analog	16.3	5.0	13.5	7.6	6.8
Total Discrete	14.4	-3.8	4.8	4.7	2.0
Total Optoelectronic	27.5	10.4	0.2	16.3	-5.5

Source: Dataquest (April 1993)

Table 5
Revenue Growth from All Semiconductors Shipped to the World for Use in All Applications, 1993-1997 (Percent Change)

	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
Total Semiconductor (Monolithic + Hybrid)	15.8	12.9	5.2	10.4	11.1	11.0
Total Hybrid IC	1.4	4.5	5.0	4.1	4.7	3.9
Total Monolithic Semiconductor	16.1	13.0	5.3	10.5	11.2	11.2
Total IC	17.8	14.1	5.0	11.2	12.0	11.9
Bipolar Digital	-8.1	-9.0	-10.5	-11.4	-12.0	-10.2
Bipolar Memory	-13.8	-13.6	-11.3	-11.8	-10.3	-12.2
Bipolar Logic	-7.5	-8.5	-10.4	-11.3	-12.2	-10.0
MOS Digital	21.4	15.9	4.4	12.3	13.2	13.3
MOS Memory	26.9	22.6	-3.7	13.8	14.4	14.3
MOS Microcomponent	21.8	10.9	11.8	11.1	12.0	13.4
MOS Logic	12.7	12.0	8.8	11.8	12.9	11.6
Monolithic Analog	12.4	12.8	10.9	10.3	10.2	11.3
Total Discrete	7.9	7.4	6.9	7.0	7.4	7.3
Total Optoelectronic	7.8	6.7	5.2	6.5	6.0	6.4

Source: Dataquest (April 1993)

Table 6
Revenue from All Semiconductors Shipped to North America for Use in All Applications, 1988-1992 (Millions of U.S. Dollars)

	1988	1989	1990	1991	1992
Total Semiconductor (Monolithic + Hybrid)	15,844	17,070	16,540	16,990	20,178
Total Hybrid IC	240	254	245	245	309
Total Monolithic Semiconductor	15,604	16,816	16,295	16,745	19,869
Total IC	13,575	14,848	14,371	15,024	17,943
Bipolar Digital	2,012	1,635	1,577	1,331	1,295
Bipolar Memory	235	180	160	131	144
Bipolar Logic	1,777	1,455	1,417	1,200	1,151
MOS Digital	9,606	10,988	10,390	11,296	13,995
MOS Memory	4,298	5,772	4,325	4,510	5,642
MOS Microcomponent	2,707	2,796	3,381	3,916	5,087
MOS Logic	2,601	2,420	2,684	2,870	3,266
Monolithic Analog	1,957	2,225	2,404	2,397	2,653
Total Discrete	1,676	1,639	1,611	1,389	1,588
Total Optoelectronic	353	329	313	332	338

Source: Dataquest (April 1993)

Table 7
Revenue from All Semiconductors Shipped to North America for Use in All Applications, 1993-1997 (Millions of U.S. Dollars)

	1993	1994	1995	1996	1997
Total Semiconductor (Monolithic + Hybrid)	24,233	27,885	28,404	31,093	34,889
Total Hybrid IC	300	270	260	240	240
Total Monolithic Semiconductor	23,933	27,615	28,144	30,853	34,649
Total IC	21,873	25,465	25,904	28,503	32,189
Bipolar Digital	1,195	1,074	960	843	734
Bipolar Memory	115	93	84	75	68
Bipolar Logic	1,080	981	876	768	666
MOS Digital	17,548	20,822	20,974	23,299	26,695
MOS Memory	7,580	9,945	8,962	9,905	11,391
MOS Microcomponent	6,197	6,584	7,269	8,091	9,338
MOS Logic	3,771	4,293	4,743	5,303	5,966
Monolithic Analog	3,130	3,570	3,970	4,360	4,760
Total Discrete	1,680	1,750	1,820	1,915	2,010
Total Optoelectronic	380	400	420	435	450

Source: Dataquest (April 1993)

Table 8
Revenue Growth from All Semiconductors Shipped to North America for Use in All Applications, 1988-1992 (Percent Change)

	1988	1989	1990	1991	1992
Total Semiconductor (Monolithic + Hybrid)	23.2	7.7	-3.1	2.7	18.8
Total Hybrid IC	22.4	5.8	-3.5	0	26.1
Total Monolithic Semiconductor	23.2	7.8	-3.1	2.8	18.7
Total IC	27.0	9.4	-3.2	4.5	19.4
Bipolar Digital	-4.1	-18.7	-3.6	-15.6	-2.7
Bipolar Memory	-13.3	-23.4	-11.1	-18.1	9.9
Bipolar Logic	-2.8	-18.1	-2.6	-15.3	-4.1
MOS Digital	42.6	14.4	-5.4	8.7	23.9
MOS Memory	72.1	34.3	-25.1	4.3	25.1
MOS Microcomponent	34.5	3.3	20.9	15.8	29.9
MOS Logic	16.7	-7.0	10.9	6.9	13.8
Monolithic Analog	5.6	13.7	8.0	-0.3	10.7
Total Discrete	2.1	-2.2	-1.7	-13.8	14.3
Total Optoelectronic	7.0	-6.8	-4.9	6.1	1.8

Source: Dataquest (April 1993)

Table 9
Revenue Growth from All Semiconductors Shipped to North America for Use in All Applications, 1993-1997 (Percent Change)

	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
Total Semiconductor (Monolithic + Hybrid)	20.1	15.1	1.9	9.5	12.2	11.6
Total Hybrid IC	-2.9	-10.0	-3.7	-7.7	0	-4.9
Total Monolithic Semiconductor	20.5	15.4	1.9	9.6	12.3	11.8
Total IC	21.9	16.4	1.7	10.0	12.9	12.4
Bipolar Digital	-7.7	-10.2	-10.6	-12.2	-12.9	- 10.7
Bipolar Memory	-20.1	-19.1	-9.7	-10.7	-9.3	-13.9
Bipolar Logic	-6.2	-9.2	-10.6	-12.3	-13.3	-10.4
MOS Digital	25.4	18.7	0.7	11.1	14.6	13.8
MOS Memory	34.3	31.2	-9.9	10.5	15.0	15.1
MOS Microcomponent	21.8	6.2	10.4	11.3	15.4	12.9
MOS Logic	15.4	13.9	10.5	11.8	12.5	12.8
Monolithic Analog	18.0	14.1	11.2	9.8	9.2	12.4
Total Discrete	5.8	4.2	4.0	5.2	5.0	4.8
Total Optoelectronic	12.4	5.3	5.0	3.6	3.4	5.9

Source: Dataquest (April 1993)

Table 10
Revenue from All Semiconductors Shipped to Japan for Use in All Applications, 1988-1992 (Millions of U.S. Dollars)

	1988	1989	1990	1991	1992
Total Semiconductor (Monolithic + Hybrid)	20,772	21,491	20,257	22,496	21,106
Total Hybrid IC	900	841	776	860	780
Total Monolithic Semiconductor	19,872	20,650	19,481	21,636	20,326
Total IC	15,227	16,019	15,018	16,417	15,581
Bipolar Digital	1,906	1,648	1,635	1,442	1,190
Bipolar Memory	348	191	194	165	144
Bipolar Logic	1,558	1,457	1,441	1,277	1,046
MOS Digital	10,501	11,636	10,660	11,881	11,430
MOS Memory	4,424	5,629	4,196	4,228	4,174
MOS Microcomponent	2,573	2,662	2,974	3,579	3,331
MOS Logic	3,504	3,345	3,490	4,074	3,925
Monolithic Analog	2,820	2,735	2,723	3,094	2,961
Total Discrete	3,282	3,080	2,969	3,432	3,138
Total Optoelectronic	1,363	1,551	1,494	1,787	1,607
Yen/U.S.$ Exchange Rate	130.00	138.00	144.00	136.00	125.95

Source: Dataquest (April 1993)

Table 11
Revenue from All Semiconductors Shipped to Japan for Use in All Applications, 1993-1997 (Millions of U.S. Dollars)

	1993	1994	1995	1996	1997
Total Semiconductor (Monolithic + Hybrid)	22,553	24,487	25,503	27,634	29,255
Total Hybrid IC	796	827	873	928	969
Total Monolithic Semiconductor	21,757	23,660	24,630	26,706	28,286
Total IC	16,709	18,328	19,111	20,929	22,221
Bipolar Digital	1,071	966	860	756	661
Bipolar Memory	128	116	103	91	82
Bipolar Logic	943	850	757	665	579
MOS Digital	12,496	14,009	14,696	16,397	17,614
MOS Memory	4,674	5,253	5,388	6,217	6,528
MOS Microcomponent	3,539	4,025	4,246	4,612	4,906
MOS Logic	4,283	4,731	5,062	5,568	6,180
Monolithic Analog	3,142	3,353	3,555	3,776	3,946
Total Discrete	3,347	3,534	3,686	3,849	4,041
Total Optoelectronic	1,701	1,798	1,833	1,928	2,024
Yen/U.S.$ Exchange Rate	124.96	124.96	124.96	124.96	124.96

Source: Dataquest (April 1993)

Table 12
Revenue Growth from All Semiconductors Shipped to Japan for Use in All Applications, 1988-1992 (U.S.$-Based Percent Change)

	1988	1989	1990	1991	1992
Total Semiconductor (Monolithic + Hybrid)	39.2	3.5	-5.7	11.1	-6.2
Total Hybrid IC	7.1	-6.6	-7.7	10.8	-9.3
Total Monolithic Semiconductor	41.1	3.9	-5.7	11.1	-6.1
Total IC	46.1	5.2	-6.2	9.3	-5.1
Bipolar Digital	25.1	-13.5	-0.8	-11.8	-17.5
Bipolar Memory	53.3	-45.1	1.6	-14.9	-12.7
Bipolar Logic	20.2	-6.5	-1.1	-11.4	-18.1
MOS Digital	63.5	10.8	-8.4	11.5	-3.8
MOS Memory	95.1	27.2	-25.5	0.8	-1.3
MOS Microcomponent	35.3	3.5	11.7	20.3	-6.9
MOS Logic	55.5	-4.5	4.3	16.7	-3.7
Monolithic Analog	13.9	-3.0	-0.4	13.6	-4.3
Total Discrete	21.9	-6.2	-3.6	15.6	-8.6
Total Optoelectronic	40.4	13.8	-3.7	19.6	-10.1
U.S.$ Appreciation versus Yen (%)	-9.7	6.2	4.3	-5.6	-7.4

Source: Dataquest (April 1993)

Table 13
Revenue Growth from All Semiconductors Shipped to Japan for Use in All Applications, 1993-1997 (U.S.$-Based Percent Change)

	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
Total Semiconductor (Monolithic + Hybrid)	6.9	8.6	4.1	8.4	5.9	6.7
Total Hybrid IC	2.1	3.9	5.6	6.3	4.4	4.4
Total Monolithic Semiconductor	7.0	8.7	4.1	8.4	5.9	6.8
Total IC	7.2	9.7	4.3	9.5	6.2	7.4
Bipolar Digital	-10.0	-9.8	-11.0	-12.1	-12.6	- 11.1
Bipolar Memory	-11.1	-9.4	-11.2	-11.7	-9.9	- 10.6
Bipolar Logic	-9.8	-9.9	-10.9	-12.2	-12.9	- 11.2
MOS Digital	9.3	12.1	4.9	11.6	7.4	9.0
MOS Memory	12.0	12.4	2.6	15.4	5.0	9.4
MOS Microcomponent	6.2	13.7	5.5	8.6	6.4	8.1
MOS Logic	9.1	10.5	7.0	10.0	11.0	9.5
Monolithic Analog	6.1	6.7	6.0	6.2	4.5	5.9
Total Discrete	6.7	5.6	4.3	4.4	5.0	5.2
Total Optoelectronic	5.8	5.7	1.9	5.2	5.0	4.7
U.S.$ Appreciation versus Yen (%)	-0.8	0	0	0	0	-0.2

Source: Dataquest (April 1993)

Table 14
Revenue from All Semiconductors Shipped to Japan for Use in All Applications, 1988-1992 (Billions of Yen)

	1988	1989	1990	1991	1992
Total Semiconductor (Monolithic + Hybrid)	2,700	2,966	2,917	3,059	2,658
Total Hybrid IC	117	116	112	117	98
Total Monolithic Semiconductor	2,583	2,850	2,805	2,942	2,560
Total IC	1,980	2,211	2,163	2,233	1,962
Bipolar Digital	248	227	235	196	150
Bipolar Memory	45	26	28	22	18
Bipolar Logic	203	201	208	174	132
MOS Digital	1,365	1,606	1,535	1,616	1,440
MOS Memory	575	777	604	575	526
MOS Microcomponent	334	367	428	487	420
MOS Logic	456	462	503	554	494
Monolithic Analog	367	377	392	421	373
Total Discrete	427	425	428	467	395
Total Optoelectronic	177	214	215	243	202
Yen/U.S.$ Exchange Rate	130.00	138.00	144.00	136.00	125.95

Source: Dataquest (April 1993)

Table 15
Revenue from All Semiconductors Shipped to Japan for Use in All Applications, 1993-1997 (Billions of Yen)

	1993	1994	1995	1996	1997
Total Semiconductor (Monolithic + Hybrid)	2,818	3,060	3,187	3,453	3,656
Total Hybrid IC	99	103	109	116	121
Total Monolithic Semiconductor	2,719	2,957	3,078	3,337	3,535
Total IC	2,088	2,290	2,388	2,615	2,777
Bipolar Digital	134	121	107	94	83
Bipolar Memory	16	14	13	11	10
Bipolar Logic	118	106	95	83	72
MOS Digital	1,562	1,751	1,836	2,049	2,201
MOS Memory	584	656	673	777	816
MOS Microcomponent	442	503	531	576	613
MOS Logic	535	591	633	696	772
Monolithic Analog	393	419	444	472	493
Total Discrete	418	442	461	481	505
Total Optoelectronic	213	225	229	241	253
Yen/U.S.$ Exchange Rate	124.96	124.96	124.96	124.96	124.96

Source: Dataquest (April 1993)

Table 16
Revenue Growth from All Semiconductors Shipped to Japan for Use in All Applications, 1988-1992 (Yen-Based Percent Change)

	1988	1989	1990	1991	1992
Total Semiconductor (Monolithic + Hybrid)	25.6	9.8	-1.6	4.9	-13.1
Total Hybrid IC	-3.3	-0.8	-3.7	4.7	-16.0
Total Monolithic Semiconductor	27.4	10.3	-1.6	4.9	-13.0
Total IC	31.9	11.7	-2.2	3.2	-12.1
Bipolar Digital	13.0	-8.2	3.5	-16.7	-23.6
Bipolar Memory	38.4	-41.7	6.0	-19.7	-19.2
Bipolar Logic	8.5	-0.7	3.2	-16.3	-24.1
MOS Digital	47.6	17.6	-4.4	5.3	-10.9
MOS Memory	76.1	35.1	-22.2	-4.8	-8.6
MOS Microcomponent	22.1	9.8	16.6	13.7	-13.8
MOS Logic	40.3	1.3	8.9	10.2	-10.8
Monolithic Analog	2.8	3.0	3.9	7.3	-11.4
Total Discrete	10.0	-0.4	0.6	9.2	-15.3
Total Optoelectronic	26.7	20.8	0.5	13.0	-16.7
U.S.$ Appreciation versus Yen (%)	-9.7	6.2	4.3	-5.6	-7.4

Source: Dataquest (April 1993)

Table 17
Revenue Growth from All Semiconductors Shipped to Japan for Use in All Applications, 1993-1997 (Yen-Based Percent Change)

	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
Total Semiconductor (Monolithic + Hybrid)	6.0	8.6	4.1	8.4	5.9	6.6
Total Hybrid IC	1.3	3.9	5.6	6.3	4.4	4.3
Total Monolithic Semiconductor	6.2	8.7	4.1	8.4	5.9	6.7
Total IC	6.4	9.7	4.3	9.5	6.2	7.2
Bipolar Digital	-10.7	-9.8	-11.0	-12.1	-12.6	- 11.2
Bipolar Memory	-11.8	-9.4	-11.2	-11.7	-9.9	-10.8
Bipolar Logic	-10.6	-9.9	-10.9	-12.2	-12.9	-11.3
MOS Digital	8.5	12.1	4.9	11.6	7.4	8.9
MOS Memory	11.1	12.4	2.6	15.4	5.0	9.2
MOS Microcomponent	5.4	13.7	5.5	8.6	6.4	7.9
MOS Logic	8.3	10.5	7.0	10.0	11.0	9.3
Monolithic Analog	5.3	6.7	6.0	6.2	4.5	5.7
Total Discrete	5.8	5.6	4.3	4.4	5.0	5.0
Total Optoelectronic	5.0	5.7	1.9	5.2	5.0	4.6
U.S.$ Appreciation versus Yen (%)	-0.8	0	0	0	0	-0.2

Source: Dataquest (April 1993)

Table 18
Revenue from All Semiconductors Shipped to Europe for Use in All Applications, 1988-1992 (Millions of U.S. Dollars)

	1988	1989	1990	1991	1992
Total Semiconductor (Monolithic + Hybrid)	8,491	9,498	10,415	11,014	12,338
Total Hybrid IC	117	136	157	178	169
Total Monolithic Semiconductor	8,374	9,362	10,258	10,836	12,169
Total IC	6,552	7,434	7,958	8,523	9,872
Bipolar Digital	772	627	565	486	427
Bipolar Memory	74	71	55	43	33
Bipolar Logic	698	556	510	443	394
MOS Digital	4,364	5,251	5,224	5,853	7,194
MOS Memory	1,797	2,417	2,050	2,129	2,642
MOS Microcomponent	1,212	1,442	1,802	2,082	2,819
MOS Logic	1,355	1,392	1,372	1,642	1,733
Monolithic Analog	1,416	1,556	2,169	2,184	2,251
Total Discrete	1,516	1,574	1,895	1,828	1,836
Total Optoelectronic	306	354	405	485	461
ECU/U.S.$ Exchange Rate	0.846	0.908	0.788	0.811	0.749

Source: Dataquest (April 1993)

Table 19
Revenue from All Semiconductors Shipped to Europe for Use in All Applications, 1993-1997 (Millions of U.S. Dollars)

	1993	1994	1995	1996	1997
Total Semiconductor (Monolithic + Hybrid)	13,954	15,474	16,527	18,339	20,550
Total Hybrid IC	165	197	210	218	232
Total Monolithic Semiconductor	13,789	15,277	16,317	18,121	20,318
Total IC	11,413	12,779	13,760	15,484	17,600
Bipolar Digital	371	330	280	249	228
Bipolar Memory	34	30	25	21	18
Bipolar Logic	337	300	255	228	210
MOS Digital	8,656	9,736	10,574	12,097	14,024
MOS Memory	3,212	3,679	3,794	4,605	5,772
MOS Microcomponent	3,541	3,984	4,582	5,055	5,549
MOS Logic	1,903	2,073	2,198	2,437	2,703
Monolithic Analog	2,386	2,713	2,906	3,138	3,348
Total Discrete	1,892	1,979	1,990	2,031	2,084
Total Optoelectronic	484	519	567	606	634
ECU/U.S.$ Exchange Rate	0.833	0.833	0.833	0.833	0.833

Source: Dataquest (April 1993)

Table 20
Revenue Growth from All Semiconductors Shipped to Europe for Use in All Applications, 1988-1992 (U.S.$-Based Percent Change)

	1988	1989	1990	1991	1992
Total Semiconductor (Monolithic + Hybrid)	30.7	11.9	9.7	5.8	12.0
Total Hybrid IC	18.2	16.2	15.4	13.4	-5.1
Total Monolithic Semiconductor	30.9	11.8	9.6	5.6	12.3
Total IC	38.2	13.5	7.0	7.1	15.8
Bipolar Digital	6.2	-18.8	-9.9	-14.0	-12.1
Bipolar Memory	-15.9	-4.1	-22.5	-21.8	-23.2
Bipolar Logic	9.2	-20.3	-8.3	-13.1	-11.1
MOS Digital	58.1	20.3	-0.5	12.0	22.9
MOS Memory	110.4	34.5	-15.2	3.9	24.1
MOS Microcomponent	50.6	19.0	25.0	15.5	35.4
MOS Logic	23.0	2.7	-1.4	19.7	5.5
Monolithic Analog	13.0	9.9	39.4	0.7	3.1
Total Discrete	10.1	3.8	20.4	-3.5	0.4
Total Optoelectronic	8.9	15.7	14.4	19.8	-4.9
U.S.$ Appreciation versus Ecu (%)	-2.5	7.3	-13.2	2.9	-7.6

Source: Dataquest (April 1993)

Table 21
Revenue Growth from All Semiconductors Shipped to Europe for Use in All Applications, 1993-1997 (U.S.$-Based Percent Change)

	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
Total Semiconductor (Monolithic + Hybrid)	13.1	10.9	6.8	11.0	12.1	10.7
Total Hybrid IC	-2.4	19.4	6.6	3.8	6.4	6.5
Total Monolithic Semiconductor	13.3	10.8	6.8	11.1	12.1	10.8
Total IC	15.6	12.0	7.7	12.5	13.7	12.3
Bipolar Digital	-13.1	-11.1	-15.2	-11.1	-8.4	-11.8
Bipolar Memory	3.0	-11.8	-16.7	-16.0	-14.3	-11.4
Bipolar Logic	-14.5	-11.0	-15.0	-10.6	-7.9	-11.8
MOS Digital	20.3	12.5	8.6	14.4	15.9	14.3
MOS Memory	21.6	14.5	3.1	21.4	25.3	16.9
MOS Microcomponent	25.6	12.5	15.0	10.3	9.8	14.5
MOS Logic	9.8	8.9	6.0	10.9	10.9	9.3
Monolithic Analog	6.0	13.7	7.1	8.0	6.7	8.3
Total Discrete	3.1	4.6	0.6	2.1	2.6	2.6
Total Optoelectronic	5.0	7.2	9.2	6.9	4.6	6.6
U.S.$ Appreciation versus ECU (%)	11.2	0	0	0	0	2.1

Source: Dataquest (April 1993)

Table 22
Revenue from All Semiconductors Shipped to Europe for Use in All Applications, 1988-1992 (Millions of ECU)

	1988	1989	1990	1991	1992
Total Semiconductor (Monolithic + Hybrid)	7,183	8,624	8,207	8,932	9,241
Total Hybrid IC	99	123	124	144	127
Total Monolithic Semiconductor	7,084	8,501	8,083	8,788	9,115
Total IC	5,543	6,750	6,271	6,912	7,394
Bipolar Digital	653	569	445	394	320
Bipolar Memory	63	64	43	35	25
Bipolar Logic	591	505	402	359	295
MOS Digital	3,692	4,768	4,117	4,747	5,388
MOS Memory	1,520	2,195	1,615	1,727	1,979
MOS Microcomponent	1,025	1,309	1,420	1,689	2,111
MOS Logic	1,146	1,264	1,081	1,332	1,298
Monolithic Analog	1,198	1,413	1,709	1,771	1,686
Total Discrete	1,283	1,429	1,493	1,483	1,375
Total Optoelectronic	259	321	319	393	345
ECU/U.S.$ Exchange Rate	0.846	0.908	0.788	0.811	0.749

Source: Dataquest (April 1993)

Table 23
Revenue from All Semiconductors Shipped to Europe for Use in All Applications, 1993-1997 (Millions of ECU)

	1993	1994	1995	1996	1997
Total Semiconductor (Monolithic + Hybrid)	11,624	12,890	13,767	15,276	17,118
Total Hybrid IC	137	164	175	182	193
Total Monolithic Semiconductor	11,486	12,726	13,592	15,095	16,925
Total IC	9,507	10,645	11,462	12,898	14,661
Bipolar Digital	309	275	233	207	190
Bipolar Memory	28	25	21	17	15
Bipolar Logic	281	250	212	190	175
MOS Digital	7,210	8,110	8,808	10,077	11,682
MOS Memory	2,676	3,065	3,160	3,836	4,808
MOS Microcomponent	2,950	3,319	3,817	4,211	4,622
MOS Logic	1,585	1,727	1,831	2,030	2,252
Monolithic Analog	1,988	2,260	2,421	2,614	2,789
Total Discrete	1,576	1,649	1,658	1,692	1,736
Total Optoelectronic	403	432	472	505	528
ECU/U.S.$ Exchange Rate	0.833	0.833	0.833	0.833	0.833

Source: Dataquest (April 1993)

Table 24
Revenue Growth from All Semiconductors Shipped to Europe for Use in All Applications, 1988-1992 (ECU-Based Percent Change)

	1988	1989	1990	1991	1992
Total Semiconductor (Monolithic + Hybrid)	27.4	20.1	-4.8	8.8	3.5
Total Hybrid IC	15.2	24.8	0.2	16.7	-12.3
Total Monolithic Semiconductor	27.5	20.0	-4.9	8.7	3.7
Total IC	34.7	21.8	-7.1	10.2	7.0
Bipolar Digital	3.5	-12.8	-21.8	-11.5	-18.9
Bipolar Memory	-18.0	3.0	-32.8	-19.5	-29.1
Bipolar Logic	6.5	-14.5	-20.4	-10.6	-17.9
MOS Digital	54.1	29.1	-13.7	15.3	13.5
MOS Memory	105.1	44.4	-26.4	6.9	14.6
MOS Microcomponent	46.7	27.7	8.5	18.9	25.0
MOS Logic	19.8	10.3	-14.5	23.2	-2.5
Monolithic Analog	10.1	17.9	21.0	3.6	-4.8
Total Discrete	7.3	11.4	4.5	-0.7	-7.2
Total Optoelectronic	6.1	24.2	-0.7	23.2	-12.2
U.S.$ Appreciation versus ECU (%)	-2.5	7.3	-13.2	2.9	-7.6

Source: Dataquest (April 1993)

Table 25
Revenue Growth from All Semiconductors Shipped to Europe for Use in All Applications, 1993-1997 (ECU-Based Percent Change)

	1993	1994	1995	1996	1997	1992-1997 CAGR (%)
Total Semiconductor (Monolithic + Hybrid)	25.8	10.9	6.8	11.0	12.1	13.1
Total Hybrid IC	8.6	19.4	6.6	3.8	6.4	8.8
Total Monolithic Semiconductor	26.0	10.8	6.8	11.1	12.1	13.2
Total IC	28.6	12.0	7.7	12.5	13.7	14.7
Bipolar Digital	-3.4	-11.1	-15.2	-11.1	-8.4	-9.9
Bipolar Memory	14.6	-11.8	-16.7	-16.0	-14.3	-9.5
Bipolar Logic	-4.9	-11.0	-15.0	-10.6	-7.9	-9.9
MOS Digital	33.8	12.5	8.6	14.4	15.9	16.7
MOS Memory	35.2	14.5	3.1	21.4	25.3	19.4
MOS Microcomponent	39.7	12.5	15.0	10.3	9.8	17.0
MOS Logic	22.1	8.9	6.0	10.9	10.9	11.6
Monolithic Analog	17.9	13.7	7.1	8.0	6.7	10.6
Total Discrete	14.6	4.6	0.6	2.1	2.6	4.8
Total Optoelectronic	16.8	7.2	9.2	6.9	4.6	8.9
U.S.$ Appreciation versus ECU (%)	11.2	0	0	0	0	2.1

Source: Dataquest (April 1993)

Table 26
Revenue from All Semiconductors Shipped to Asia/Pacific-Rest of World for Use in All Applications, 1988-1992 (Millions of U.S. Dollars)

	1988	1989	1990	1991	1992
Total Semiconductor (Monolithic + Hybrid)	5,752	6,280	7,333	9,194	11,642
Total Hybrid IC	205	137	111	112	123
Total Monolithic Semiconductor	5,547	6,143	7,222	9,082	11,519
Total IC	4,252	4,944	5,823	7,496	9,638
Bipolar Digital	510	404	396	369	383
Bipolar Memory	32	18	22	17	12
Bipolar Logic	478	386	374	352	371
MOS Digital	2,517	3,265	3,878	5,285	6,959
MOS Memory	1,173	1,587	1,557	1,974	2,847
MOS Microcomponent	652	908	1,427	2,197	2,775
MOS Logic	692	770	894	1,114	1,337
Monolithic Analog	1,225	1,275	1,549	1,842	2,296
Total Discrete	1,138	1,027	1,199	1,386	1,637
Total Optoelectronic	157	172	200	200	244

Source: Dataquest (April 1993)

Table 27
Revenue from All Semiconductors Shipped to Asia/Pacific-Rest of World for Use in All Applications, 1993-1997 (Millions of U.S. Dollars)

	1993	1994	1995	1996	1997
Total Semiconductor (Monolithic + Hybrid)	14,857	17,487	19,376	22,087	25,495
Total Hybrid IC	140	171	194	214	234
Total Monolithic Semiconductor	14,717	17,316	19,182	21,873	25,261
Total IC	12,494	14,747	16,129	18,354	21,214
Bipolar Digital	390	385	365	337	299
Bipolar Memory	10	9	8	7	6
Bipolar Logic	380	376	357	330	293
MOS Digital	9,341	11,119	11,916	13,542	15,617
MOS Memory	3,954	4,939	4,781	5,360	6,164
MOS Microcomponent	3,783	4,332	5,058	5,753	6,539
MOS Logic	1,604	1,848	2,077	2,429	2,914
Monolithic Analog	2,763	3,243	3,848	4,475	5,298
Total Discrete	1,930	2,237	2,664	3,072	3,533
Total Optoelectronic	293	332	389	447	514

Source: Dataquest (April 1993)

Table 28
Revenue Growth from All Semiconductors Shipped to Asia/Pacific-Rest of World for Use in All Applications, 1988-1992 (Percent Change)

	1988	1989	1990	1991	1992
Total Semiconductor (Monolithic + Hybrid)	45.0	9.2	16.8	25.4	26.6
Total Hybrid IC	43.4	-33.2	-19.0	0.9	9.8
Total Monolithic Semiconductor	45.0	10.7	17.6	25.8	26.8
Total IC	54.4	16.3	17.8	28.7	28.6
Bipolar Digital	24.1	-20.8	-2.0	-6.8	3.7
Bipolar Memory	-8.5	-43.8	22.2	-22.7	-29.4
Bipolar Logic	27.1	-19.2	-3.1	-5.9	5.3
MOS Digital	62.4	29.7	18.8	36.3	31.7
MOS Memory	168.4	35.3	-1.9	26.8	44.2
MOS Microcomponent	67.8	39.3	57.2	54.0	26.3
MOS Logic	-4.4	11.3	16.1	24.6	20.0
Monolithic Analog	54.3	4.1	21.5	18.9	24.6
Total Discrete	20.7	-9.8	16.7	15.6	18.1
Total Optoelectronic	23.6	9.6	16.3	0	22.0

Source: Dataquest (April 1993)

Table 29
Revenue Growth from All Semiconductors Shipped to Asia/Pacific-Rest of World for Use in All Applications, 1993-1997 (Percent Change)

	1993	1994	1995	1996	1997	1992-1997 CAGR (%)
Total Semiconductor (Monolithic + Hybrid)	27.6	17.7	10.8	14.0	15.4	17.0
Total Hybrid IC	13.8	21.9	13.9	10.1	9.3	13.7
Total Monolithic Semiconductor	27.8	17.7	10.8	14.0	15.5	17.0
Total IC	29.6	18.0	9.4	13.8	15.6	17.1
Bipolar Digital	1.9	-1.3	-5.2	-7.7	-11.3	-4.8
Bipolar Memory	-16.7	-10.0	-11.1	-12.5	-14.3	-12.9
Bipolar Logic	2.5	-1.1	-5.1	-7.6	-11.2	-4.6
MOS Digital	34.2	19.0	7.2	13.6	15.3	17.5
MOS Memory	38.9	24.9	-3.2	12.1	15.0	16.7
MOS Microcomponent	36.3	14.5	16.8	13.7	13.7	18.7
MOS Logic	20.0	15.2	12.4	16.9	20.0	16.9
Monolithic Analog	20.3	17.4	18.6	16.3	18.4	18.2
Total Discrete	17.9	15.9	19.1	15.3	15.0	16.6
Total Optoelectronic	20.1	13.3	17.2	14.9	15.0	16.1

Source: Dataquest (April 1993)

For More Information...

Terry Birkholz, Market Research Analyst................................(408) 437-8196
Via fax..(408) 437-0292

Dataquest®
a company of The Dun & Bradstreet Corporation

Dataquest®

a company of
The Dun & Bradstreet Corporation

Corporate Headquarters
Dataquest Incorporated
1290 Ridder Park Drive
San Jose, California 95131-2398
United States
Phone: 01-408-437-8000
Facsimile: 01-408-437-0292

Dataquest Incorporated
550 Cochituate Road
Framingham, Massachusetts 01701-9324
United States
Phone: 01-508-370-5555
Facsimile: 01-508-370-6262

Invitational Computer Conferences (ICC)
3990 Westerly Place, Suite 100
Newport Beach, California 92660
United States
Phone: (714) 476-9117
Facsimile: (714) 476-9969

Dataquest Japan Limited
Shinkawa Sanko Building
1-3-17, Shinkawa, Chuo-ku
Tokyo 104
Japan
Phone: 81-3-5566-0411
Facsimile: 81-3-5566-0425

Dataquest Korea
Dacheung Building, Room 1105
648-23 Yorksam-dong
Kangnam-gu, Seoul 135-080
Korea
Phone: 011-82-2-556-4166
Facsimile: 011-82-2-552-2661

European Headquarters
Dataquest Europe Limited
Roussel House, Broadwater Park
Denham, Uxbridge
Middlesex UB9 5HP
England
Phone: 44-895-835050
Facsimile: 44-895-835260/1

Dataquest GmbH
Kronstadter Strasse 9
8000 Munich 80
Germany
Phone: 011-49-89-930-9090
Facsimile: 011-49-89-930-3277

Dataquest Europe SA
Tour Gallieni 2
36, Avenue du General de Gaulle
93175 Bagnolet Cedex
France
Phone: 011-33-1-48-97-3100
Facsimile: 011-33-1-48-97-3400

Representative Agencies in
Bangkok, Hong Kong,
Kronberg, North Sydney,
Singapore, Taipei, and Tel Aviv

0014579

Dataquest®

Semiconductors

Worldwide MOS Memory Forecast

Market Statistics

1993 Fall Edition

Program: Memories Worldwide
Product Code: MMRY-WW-MS-9304
Publication Date: September 27, 1993

Dataquest®
Semiconductors

Worldwide MOS Memory Forecast

Market Statistics

1993 Fall Edition

Program: Memories Worldwide
Product Code: MMRY-WW-MS-9304
Publication Date: September 27, 1993

Table of Contents

Table of Contents (Continued)

List of Tables

Note: All tables show estimated data.

List of Tables (Continued)

Note: All tables show estimated data.

Chapter 1
Worldwide MOS Memory

Introduction

This document contains detailed information on Dataquest's current view of the MOS memory market. Included in this document is:

- 1993-1997 MOS memory forecast

Analyses of the MOS memory market provide insight into high-technology markets and reinforce estimates of consumption, production, and company revenue.

More detailed data on this market may be requested through our client inquiry service. Dataquest's qualitative analysis of this data can be found within the *Dataquest Perspectives* located within the binder of the same name.

Segmentation

This section defines the market segments that are specific to this document. For a complete description of all market segments tracked by Dataquest, please refer to Dataquest's *Semiconductor Market Definitions* guide.

Dataquest defines the MOS memory market as DRAM, SRAM, EPROM, ROM, EEPROM, flash memory, and other MOS memory (OMM). In this volume, Dataquest segments the MOS memory market by product type and density according to the following scheme:

- DRAM (densities from 64K through 64Mb)
- Fast SRAM (densities from 16K through 16Mb), separated into five speed categories
- Slow SRAM (densities from 16K through 16Mb), including conventional and pseudo SRAMs
- EPROM (densities from 16K through 8Mb)
- ROM (densities from 32K through 128Mb)
- EEPROM (densities from 256b through 4Mb)
- Flash memory (densities from 256K through 64Mb)
- Other MOS memory

Definitions

This section lists the definitions that are used by Dataquest to present the data in this document. Complete definitions for all Dataquest terms can be found in the Dataquest's *Semiconductor Market Definitions* document.

Product Definitions

DRAM: Includes dynamic RAM, multiport-DRAM (M-DRAM), and video-DRAM (VRAM). DRAMs have memory cells consisting of a single transistor, and require regular externally cycled memory cell refreshes. This category also includes new architecture DRAMs (NADs) such as rambus, cache, enhanced, and synchronous DRAMs. These are volatile memories and addressing is multiplexed.

SRAM: Includes static RAM, multiport-SRAM (M-SRAM), battery backed-up SRAM (BB-SRAM), and pseudo-SRAM (PSRAM). SRAMs have memory cells consisting of a minimum of four transistors, except a PSRAM, which has a memory cell consisting of a single transistor and is similar to a DRAM. SRAMs do not require externally cycled memory cell refreshes. These are volatile memories and addressing is not multiplexed (except in the case of PSRAM). Note that color palette DACs are included in the mixed-signal data converter category.

EPROM: Includes erasable programmable read-only memory. This product classification includes ultraviolet EPROM (UV EPROM) and one-time programmable read-only memory (OTP ROM). EPROMs have memory cells consisting of a single transistor and do not require any memory cell refreshes. These devices are nonvolatile memories.

Flash Memory: Includes nonvolatile products designed as flash EPROM/ EEPROM that incorporate either 5V or 12V programming supplies and one-transistor (1T) or two-transistor (2T) memory cells with electrical programming and fast bulk/chip erase. Flash memory can only erase data by bulk/chip, not by byte. These devices are nonvolatile memories.

Mask ROM: Includes mask-programmable read-only memory. Mask ROM is a form of memory that is programmed by the manufacturer to a user specification using a mask step. Mask ROM is programmed in hardware rather than software. These devices are nonvolatile memories.

EEPROM: Includes electronically erasable programmable read-only memory. Included are serial EEPROM (S-EEPROM), parallel EEPROM (P-EEPROM), and electronically alterable read-only memory (EAROM). EEPROMs have memory cells consisting of a minimum of two transistors and do not require memory cell refreshes. This product classification also includes nonvolatile RAM (NV-RAM), also known as shadow RAM. These latter semiconductor products are a combination of SRAM and EEPROM technologies in each memory cell. The EEPROM functions as a shadow backup for the SRAM when power is lost. These devices are nonvolatile memories.

Other MOS Memory: Includes all other MOS digital memory not already accounted for in the preceding categories. OMM includes MOS digital content addressable memory (CAM), MOS digital cache-tag RAM, MOS digital first-in/first-out memory (FIFO), MOS digital last-in/first-out memory (LIFO), and ferroelectric memory.

Line Item Definitions

Revenue: Revenue is calculated by multiplying a product's overall unit shipment total by the product's ASP.

Unit Shipments: All unit shipments, both merchant and captive, for memory suppliers selling to the merchant market; excludes totally captive suppliers, where devices are manufactured solely for the company's own use.

Average Selling Price (ASP): The average billing price per unit that is paid for a product when it leaves the factory; takes into account discounts given to the distribution channel and multiple-purchase discounts; prices are averaged over all companies, package types, lot sizes, and the entire speed mix, and they represent sales to both military and commercial accounts.

Number of Bits: Number of bits is calculated by multiplying a product's unit shipment total by the number of bits that a single unit of that product contains.

Price per Bit (PPB): PPB is calculated by dividing a product's ASP by the number of bits that a single unit of that product contains; this number is reported in microdollars; there are 1 million microdollars per U.S. dollar. For an overall product category (for example, DRAM), this metric is calculated by dividing the category's total revenue by its total number of bits.

Forecast Methodology

Dataquest publishes five-year unit shipments and factory revenue forecasts for the MOS memory market. In doing so, Dataquest utilizes a variety of forecasting techniques (both qualitative and quantitative) that vary by technology area. An overview of Dataquest forecasting techniques can be found in the *Dataquest Research Methodology* document.

MOS Memory Forecast Methodology

The following is Dataquest's MOS memory forecast methodology:

- Survey the leading memory vendors throughout the year for company expectations, as well as for their views of the markets that they participate in.
- Examine statistics provided by a number of industry organizations (such as WSTS and MITI) for up-to-date monthly trends.
- Perform time-series analysis.
- Research demand-side trends such as system sales, add-in demand, and application requirements.
- Monitor supply-side trends such as bit growth projections, new product developments, and general changes in the industry structure.

MOS Memory Forecast Assumptions

Review of 1993

Several unanticipated events impacted the MOS memory market in 1993. The strength of other trends also was not assessed accurately. The combination led to changes in Dataquest's outlook for MOS memories overall for 1993.

Yen Strength

It took ¥125 to buy a dollar in December 1992, and today it takes just ¥105. For all of 1993, we expect the exchange rate to be about ¥112 per dollar, a drop of more than 11 percent. This has important consequences in prices and units, because Japanese companies still had more than 52 percent share of the MOS memory market in 1992, and the vast majority of that was actually made in Japan (indeed, in 1992, still more than 50 percent of MOS memory was made in Japan, after an allowance for Texas Instruments' and Motorola's Japanese production is made).

It is not easy to quantify the impact of such an exchange rate change on MOS memory prices, which depend on the relative balance of supply and demand more than on the cost structures of the producers. But, coming as it did in the already undersupplied market, it certainly gave a strong rationale for Japanese companies to raise prices. It should be noted, though, that until the fourth quarter of 1993, the observed price rises in the marketplace were generally far less than the increased value of the yen, implying thinner margins for the Japanese producers despite a buoyant market. The market would not support a "pass-through" of increased costs that Japanese makers faced.

The strength of the yen has important consequences to Japanese MOS memory makers' profits, and, in turn, to their ability to invest in new facilities. See the "DRAM Forecast Assumptions" section for a fuller discussion.

Dataquest's policy is to assume that the exchange rates effective at the time of the forecast remain throughout the forecast period. Thus, we have assumed that the yen-to-dollar exchange rate will be about ¥105/U.S.$1 from the date of the forecast publication through the end of the forecast period in 1997.

Sumitomo Chemical Fire and Explosion

The wholly unanticipated fire at the Sumitomo Chemical plant caused panic and wild speculation in the already-nervous DRAM spot market for 5 to 6 weeks. As the extent of the impact of the explosion on the overall DRAM market became more clear, pricing sanity was restored at levels near what they had been before the explosion. The impact was almost entirely contained within the DRAM market, and other MOS memories felt no such anxiety attack as did the DRAM marketplace.

Dataquest expects this event to have only minor impact on the market during the next several quarters, and to certainly be a secondary influence on prices, compared to the rate at which supplies of DRAMs increase and the continued strength of PC-driven DRAM demand, the presence or absence of other DRAM market destabilizers (as aggressive pricing was in 1992), or even IBM's future role in the DRAM marketplace.

PC Demand Persistence

The bubble of PC demand first witnessed in late 1992 and the first quarter of 1993 has yet to subside, at least in terms of PC makers' sales forecasts and their DRAM bookings. We had anticipated a slowdown, and for stagnation to first appear in the summer quarter. This has yet to take shape. For more information on this matter see the DRAM discussion in the "DRAM Forecast Assumptions" section.

Sour Economies

Though the link between the overall economies of the major MOS memory consumers and memory demand is often weak, certainly no one anticipated the steady downward revisions of GDP/GNP growth for Europe (especially Germany), Japan (which may be headed into yet another relapse of recession), and the United States. We entered 1992 full of hope that it was onward and upward, but have met with only disappointment and economic stagnation. Still, semiconductors have looked good throughout.

There are several matters of considerable contention: whether the PC market can continue to blossom in the backdrop of a no-growth economy, whether this cycle is truly different, and whether we are now finally beginning to see the payoff for electronics in improved productivity that has been noticeably absent for the past decade. Are we seeing that the pervasiveness of electronics has now made growth of the semiconductor industry, through increased penetration in all products, so great as to overcome any modest shrinkage in the total GNP into which electronics products sell? What is the consequence of a 1 percent smaller market when the penetration rate is increasing 10 percent per year? Is it all the better when the economies do turn around?

Changes to the 1993 Outlook

In 1993, prices were more firm than we anticipated in our 1993 preliminary *Worldwide MOS Memory Forecast* published March 22, 1993 (MMRY-WW-MS-9301) for almost all products. This firmness was led by DRAMs, and followed last by SRAMs, which continued to be an oversupplied market until the summer quarter.

This impacted both unit price and market size. For 1993, we raised our estimated MOS memory market size by 8.6 percent, to about $21.0 billion, mainly on price increases. About 65 percent of the revenue increase was in the DRAM market, which was revised from $12.1 billion to $13.1 billion, or 8.3 percent. (DRAMs' share of all MOS memory revenue, in 1993 and 1994, will be a historic high of about 63 to

64 percent, having risen from less than 54 percent in 1990. DRAMs' share of MOS memory revenue has also shown a decidedly cyclical trend, but also a steadily increasing component.)

Some of this rise in forecast market size remained throughout the forecast period.

Changes to the Long-Term Outlook

The market size for 1997 was raised just 1.3 percent, implying that the revenue gains that we expect to be made in 1993 will, for the most part, be given back in future years.

Because the MOS memory market has not experienced the profit bubble that ordinarily may have been expected, investment increases have been modest so far, implying a slower rate of capacity expansion and a greater period of supply-demand near balance in the market. This may mean reduced price volatility for the short term.

This profit and investment picture is constrained by several factors: the relatively stable prices, the strong yen, a relatively short period of profitability, restrained investment among the Japanese (because of major unresolved corporate strategic issues and a changed business environment after the bubble burst), and low profitability in 1992, as the DRAM market expanded to absorb all available capacity without providing the funds for additional expansion.

The poor worldwide economic outlook for the remainder of 1993 and into 1994 also affected out changed view of the future.

Though our compound annual growth rate (CAGR) from 1992 to 1997 remains almost unchanged at 15.9 percent, the distribution of revenue along the in-between years favors the early years more than the latter. The year 1995 will have a less abrupt contraction, but this depends critically on the aforementioned investment profile for the coming years, as well as the continued favorable development of major demand elements such as PCs, notebooks, memory-hungry software, the PCMCIA card market development, and steady price reductions. Historically, one cycle's price reductions have fueled the next cycle's expansion, but the market has seen rather unusual price stability for six quarters, with two to four more to come.

Exchange Rates

Dataquest utilizes an average annual exchange rate in converting revenue to U.S. dollar amounts. Table 1-1 shows these rates for 1990 through 1992.

Table 1-1
Exchange Rates

	1990	1991	1992
Japan (Yen/U.S.$)	144.00	135.00	126.45
France (Franc/U.S.$)	5.44	5.64	5.14
Germany (Deutsche Mark/U.S.$)	1.62	1.66	1.52
United Kingdom (U.S.$/Pound Sterling)	1.79	1.77	1.85

Source: Dataquest (September 1993)

Notes to Forecast Tables

Readers should keep the following notes in mind about the tables in this document:

1. In 1991, Dataquest began to subdivide its existing classification of SRAMs. SRAMs are divided into five speed categories: 0 to 9ns; 10 to 19ns; 20 to 44ns; 45 to 70ns; and more than 70ns. For this forecast, slow SRAMs are defined as having access speeds of 45ns and more. The remaining speed categories are considered fast SRAMs.

2. All tables contain rounded data. As a result, some data points will be displayed in a manner that obscures the underlying data. For instance, data points shown as being zero in revenue tables, which are denominated in millions of dollars, may actually contain $400,000 that has been rounded to zero to conform with the table's metrics.

Table 1-2
Factory Revenue from Shipments of Semiconductor Memory to the World, 1990-1997 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
DRAM	6,436	6,905	8,521	13,161	15,656	14,889	14,543	18,234	16.4
SRAM	2,434	2,569	2,990	3,865	4,426	4,339	5,139	6,063	15.2
EPROM	1,446	1,362	1,226	1,249	1,283	1,207	1,178	996	-4.1
FLASH	35	120	257	651	1,418	2,023	2,559	2,971	63.2
ROM	1,132	1,198	1,445	1,479	1,649	1,463	1,918	2,202	8.8
EEPROM	292	326	369	408	481	534	578	640	11.7
OMM	174	212	187	228	241	247	258	271	7.7
Total	11,949	12,692	14,995	21,042	25,155	24,702	26,174	31,376	15.9
Percent Change (%)	-20.2	6.2	18.1	40.3	19.5	-1.8	6.0	19.9	

Source: Dataquest (September 1993)

Table 1-3
Shipments of Semiconductor Memory to the World, 1990-1997 (Millions of Units)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
DRAM	1,336	1,286	1,474	1,498	1,462	1,301	1,249	1,291	-2.6
SRAM	620	704	842	946	888	756	829	1,003	3.6
EPROM	424	476	424	433	438	396	382	336	-4.6
FLASH	3	12	28	76	141	235	333	461	75.0
ROM	315	383	418	434	457	402	439	482	2.9
EEPROM	127	213	300	384	457	548	600	685	17.9
OMM	27	32	33	39	41	43	43	45	6.2
Total	2,852	3,105	3,520	3,810	3,883	3,680	3,875	4,304	4.1
Percent Change (%)	4.7	8.9	13.3	8.2	1.9	-5.2	5.3	11.1	

Source: Dataquest (September 1993)

Table 1-4
Average Selling Price for Shipments of Semiconductor Memory to the World, 1990-1997 (U.S. Dollars)

	1990	1991	1992	1993	1994	1995	1996	1997
DRAM	4.82	5.37	5.78	8.79	10.71	11.44	11.64	14.12
SRAM	3.92	3.65	3.55	4.08	4.99	5.74	6.20	6.04
EPROM	3.41	2.86	2.89	2.89	2.93	3.05	3.08	2.96
FLASH	13.23	10.13	9.14	8.59	10.08	8.61	7.69	6.44
ROM	3.59	3.12	3.46	3.41	3.61	3.64	4.37	4.56
EEPROM	2.30	1.53	1.23	1.06	1.05	0.98	0.96	0.93
OMM	6.55	6.70	5.65	5.85	5.90	5.80	5.95	6.05
Average	4.19	4.09	4.26	5.52	6.48	6.71	6.75	7.29
Percent Change (%)	-23.8	-2.4	4.2	29.6	17.3	3.6	0.6	7.9

Source: Dataquest (September 1993)

Table 1-5
Bits from Shipments of Semiconductor Memory to the World, 1990-1997 (Trillions of Bits)*

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
DRAM	964	1,535	2,828	4,297	6,488	9,022	13,197	18,642	45.8
SRAM	91	127	186	369	598	776	1,281	2,269	64.8
EPROM	182	221	253	288	352	387	420	414	10.4
FLASH	2	10	29	93	376	768	1,650	2,932	150.9
ROM	682	955	1,592	2,759	4,831	5,712	8,592	13,227	52.7
EEPROM	1	2	3	4	5	6	8	11	30.2
OMM	0	0	0	0	0	0	0	0	13.2
Total	1,922	2,850	4,892	7,810	12,649	16,670	25,148	37,495	50.3
Percent Change (%)	50.9	48.3	71.6	59.6	62.0	31.8	50.9	49.1	

*Trillion = 1.0×10^{12}

Source: Dataquest (September 1993)

Table 1-6
Price per Bit for Shipments of Semiconductor Memory to the World, 1990-1997 (Microdollars)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
DRAM	6.7	4.5	3.0	3.1	2.4	1.7	1.1	1.0	-20.1
SRAM	26.9	20.2	16.0	10.5	7.4	5.6	4.0	2.7	-30.1
EPROM	7.9	6.2	4.9	4.3	3.6	3.1	2.8	2.4	-13.1
FLASH	21.0	11.5	8.7	7.0	3.8	2.6	1.6	1.0	-35.0
ROM	1.7	1.3	0.9	0.5	0.3	0.3	0.2	0.2	-28.8
EEPROM	224.0	153.8	126.1	112.6	98.5	85.7	69.1	58.4	-14.3
OMM	1,169.6	1,155.2	911.3	914.1	842.9	773.3	743.8	711.8	-4.8
Average	6.2	4.5	3.1	2.7	2.0	1.5	1.0	0.8	-22.9
Percent Change (%)	-47.1	-28.4	-31.2	-12.1	-26.2	-25.5	-29.8	-19.6	

Source: Dataquest (September 1993)

Chapter 2
DRAM Forecast Assumptions

Changes to the 1993 Outlook

Several factors affecting the MOS memory market as a whole are discussed earlier in this document and will be mentioned only briefly here.

The Sumitomo panic of 1993 impacted DRAMs more than any other product, and there is expected to be a slight residual impact on prices for the reminder of the year, but small compared to other factors.

The rising yen has been presented by Japanese DRAM makers in their spring and fall price offensives as a rationale for higher prices. But we believe that the overall supply and demand balance (which remains tight) is the major factor driving higher prices, not the exchange rate. (Prices plummeted in tandem with the exchange rate in 1985 and were a proximate cause of the trade dispute that resulted in the Semiconductor Trade Agreement in 1986.) To Dataquest, it is questionable whether the Japanese can make their $12.50 price quotes for 4Mb DRAMs for the fourth quarter stick throughout the quarter.

The PC market, and its insatiable demand for DRAMs, has remained stronger than anticipated in our earlier forecast. We expected European PC demand to slow this summer, which it did only to the slightest degree; it has come back in the past few weeks of September. Although we still believe that a significant slowdown in PC-driven DRAM demand is coming, apparently it has been pushed back more than a quarter.

Each of these factors has led to higher prices than anticipated. Our unit demand by density remains almost unchanged since our March forecast.

1994 Outlook

For 1994, though we expect to be entering the year somewhat stronger, we are less optimistic for the year as a whole because of the indications that the systems business demand growth has peaked, and the fact that the economies of the major PC consumers are stagnant and show as many signs of death as of life. Only the slowish investment in capacity will keep supply and demand balanced into 1994. Therefore we expect a softer landing in the second half of 1994, but still a depressed market in 1995.

Though prices have risen since the first quarter, we expect a turnaround brought about by a softening of demand for PCs, followed a few months later by weaker DRAM demand. At the same time, capacity has slowly been put in place, and an increasing fraction of the 4Mb output is being run on first-generation 16Mb processes, 0.55 to 0.65µm, that yield upward of 280 to 330 gross die per 150mm wafer.

Fundamental Assumptions for the DRAM Forecast

The basic assumptions surrounding supply and demand development in the DRAM market forecast are discussed in the following paragraphs.

Market Status: An Expansion Now Past Its Prime

In the end-systems market, we are beginning to see the end of the bubble. Several indicators show that we are past the booking peak and that some systems inventories are building up. Seasonal weakness in the market will likely give way to a reduced rate of overall growth as we move into the fall and winter quarters. For DRAMs, the market turn will lag to a degree dependent on how well PC makers have forecast their collective demand. We expect DRAM price declines at about year-end or in the first part of 1994. The declines probably will not be precipitous, for reasons discussed in the following section.

Implications of Depressed Profitability

Maybe Not as Much Profit to Reinvest

Profits have improved for all products, but for the Japanese, with the strong yen, export prices have not increased enough to match the rise in the yen value. Therefore, yen income, which is needed to pay costs of production, is flattish. In the native currency, yen prices are flat and profits have risen less than for those companies whose costs are denominated in the depreciated currencies.

A more modest profit opportunity for Japan, coupled with the major structural problems brought about by the bursting bubble, will make it tough for Japan to invest from profits to add capacity as it did in 1983 to 1985 and 1988 to 1990. We do not expect that Japanese supply will expand at the rate that it has during earlier cycles, thereby the time when supply would otherwise race past demand will be postponed and the result will be price erosion.

More on Profits and Supply Expansion

The important role of profits in funding semiconductor growth and capital spending is underscored by the dilemma faced by the Japanese DRAM makers, who still control about 50 percent of DRAM production. Historically, DRAM profit bubbles of 18 to 24 months' duration have provided the fuel for the next wave of capacity expansions, indeed, often to an excess. This time promises to be different. In addition to the shorter period of lower profitability, Japanese parent companies face strategic choices that will certainly inhibit the flow of investment capital into the kinds of semiconductor capacity expansion we have seen in the past cycles. This would point to either an increased rate of loss of DRAM market share to Koreans and others, a reduced rate of price erosion (until profit growth makes further investment possible), or both.

Implications of Competitive Supply Development

We expect supply to speed past demand and prices to drop rapidly in the coming 2 to 3 years. We expect a prolonged period of steady profitability, because of capacity generally running behind demand, for up to a few years, as Japanese companies recover from a yen shock that promises to be with us for some time. Further, at the factories of many DRAM makers, wafer start allocations are based on revenue per wafers, and there is increased product interchangeability compared to earlier years, reducing the "DRAMs or die" dilemma that makers faced before. The Koreans, with 75 percent of their revenue in DRAMs, are clearly a factor for constant profit-killing price pressure, but, because of their "mere" 25 percent DRAM market share and 17 percent MOS memory market share cannot hope to make up for slower Japanese investment increases.

Underinvestment in the Past Will Slow Supply Expansion

There is other important evidence that there has been a significant underinvestment from 1989 to 1993 to support the kinds of growth that appear to lie just ahead: namely, 1992 was truly a remarkable year in MOS memory (80 percent-plus DRAM bit growth), but price pressure by Koreans prevented any semblance of profitability in spite of a pending capacity shortfall that developed in 1993. The capacity expansion for 1993 is to a large degree picking the low-hanging fruit: equipping preexisting shells for high return on investment. (For example, at NEC's Roseville, California plant, the first $400 million got the shell plus 10,000 150mm starts per month. The next $250 million will get 20,000 starts more, about a 4:1 return on investment ratio. Similar events are taking place at Mitsubishi, Toshiba, and Hitachi.)

But such practices can go on for only so long before the shells are filled, and new brink and mortar must be added, which takes a long time to bring online. Also, the ramp rate of 4Mb for 1993 appears to be about 60 percent of the rate of leading-edge product in earlier cycles.

Supply-Side Conclusion

Supply is coming, but it will increase more slowly for several reasons, thereby postponing the day of reckoning when supply speeds past demand and prices drop rapidly.

Still, in DRAMs in particular, the rate at which Korea expands its capacity during the next 12 months could tell a lot about the market for 1994 to 1997. The present market conditions, price, and profit scenarios could spell a major market share opportunity for the Korean DRAM makers, and also an opportunity to expand further into SRAMs and flash memories.

Several important questions remain unresolved: Is there enough profit outside of Japan, and enough desire to spend it on DRAM capacity, to quickly turn a measured price decline in 1994 into a rout? Or are we smarter than that? Or will Japanese DRAM makers prevail in their own corporate boardrooms, and gain the funds necessary to expand, despite whatever lack of profitability their semiconductor groups have experienced, and despite their parent companies' financial problems?

Longer-Term Outlook for DRAM Demand

The euphoria of 9 months ago has not dissipated yet. And we believe that there is an element of truth that the 1990s are the golden age of electronics productivity (as some have said, in defending the proposition that today's boom was somehow different and would go on for 2 more years).

We also are seeing hard copy for multimedia and Windows NT (or Chicago, or Windows 4.0, or Cairo) promising to move us all to the next stage of user-friendly software, and 16MB (or more) per PC. Also, workstations are reaching back into the PC realm, and there has emerged a memory aftermarket that now makes up about 15 to 20 percent of DRAM demand. Flash memory cards, server memory for workgroup computing, notebooks, and PDAs all have voracious appetites for memory.

Several recent ventures that may enable the bona fide convergence of consumer and computer technologies and markets are evidence that the many technology "concepts" are now clear enough that the big money from technology companies, media companies, and a host of interested parties is now ready to stake its claims in what these companies believe will be the key market drivers of the late 1990s. Clearly, the longer-term outlook for demand is good, and DRAM makers appear to have more faith in the longer-term future than at any point in recent history. While the path to 1996 to 1998 may be uncertain, few doubt that major demand elements and markets for DRAMs are coming into focus, and present unparalleled opportunities for market growth and profits.

What about flash, and its impact on DRAMs? Today, flash memories are still in their infancy, and it remains uncertain whether they can reach the price points that their followers claim. Within a few years, however, we will be able to ascertain more clearly the relative strength of DRAM, flash, or mask ROM in serving the known silicon operating system market on the desktop and in portables.

Table 2-1
Factory Revenue from Shipments of DRAMs to the World, 1990-1997
(Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
64K STAND	38	20	11	7	0	0	0	0	NM
256K STAND	1,135	457	189	120	90	50	24	2	-62.0
256K VRAM	188	163	156	120	93	46	20	14	-38.3
1Mb STAND	3,981	3,424	2,392	1,485	914	578	170	124	-44.7
1Mb VRAM	250	408	527	624	374	217	140	80	-31.4
2Mb VRAM	0	0	5	117	184	150	142	91	76.8
4Mb STAND	844	2,400	5,031	9,085	8,256	4,286	2,420	1,541	-21.1
4Mb VRAM	0	0	1	28	120	225	290	368	254.1
16Mb STAND	0	33	208	1,575	5,626	9,282	10,888	12,615	127.4
64Mb STAND	0	0	0	0	0	55	450	3,400	NM
Total	6,436	6,905	8,521	13,161	15,656	14,889	14,543	18,234	16.4
Percent Change (%)	-22.7	7.3	23.4	54.5	19.0	-4.9	-2.3	25.4	

NM = Not meaningful
Source: Dataquest (September 1993)

Table 2-2
Shipments of DRAMs to the World, 1990-1997
(Millions of Units)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
64K STAND	26	14	8	5	0	0	0	0	NM
256K STAND	565	254	135	80	56	31	15	1	-62.5
256K VRAM	55	45	59	43	32	17	10	7	-34.6
1Mb STAND	644	788	743	450	277	175	50	36	-45.4
1Mb VRAM	21	47	79	99	68	50	35	20	-23.9
2Mb VRAM	0	0	0	9	18	21	21	14	109.9
4Mb STAND	24	138	449	790	860	635	440	268	-9.8
4Mb VRAM	0	0	0	1	6	15	25	35	401.8
16Mb STAND	0	0	2	21	145	357	650	870	243.9
64Mb STAND	0	0	0	0	0	0	3	40	NM
Total	1,336	1,286	1,474	1,498	1,462	1,301	1,249	1,291	-2.6
Percent Change (%)	6.5	-3.7	14.6	1.6	-2.4	-11.0	-4.0	3.4	

NM = Not meaningful
Source: Dataquest (September 1993)

Table 2-3
Average Selling Price for Shipments of DRAMs to the World, 1990-1997 (U.S. Dollars)

	1990	1991	1992	1993	1994	1995	1996	1997
64K STAND	1.48	1.48	1.34	1.40	-	-	-	-
256K STAND	2.01	1.80	1.40	1.50	1.60	1.60	1.60	1.50
256K VRAM	3.41	3.60	2.67	2.80	2.90	2.70	2.00	2.00
1Mb STAND	6.18	4.34	3.22	3.30	3.30	3.30	3.40	3.45
1Mb VRAM	11.78	8.62	6.71	6.30	5.50	4.35	4.00	4.00
2Mb VRAM	-	-	15.30	13.00	10.20	7.15	6.75	6.50
4Mb STAND	34.59	17.43	11.20	11.50	9.60	6.75	5.50	5.75
4Mb VRAM	-	-	60.00	28.00	20.00	15.00	11.60	10.50
16Mb STAND	-	246.60	114.85	75.00	38.80	26.00	16.75	14.50
64Mb STAND	-	-	-	-	-	275.00	150.00	85.00
Average	4.82	5.37	5.78	8.79	10.71	11.44	11.64	14.12
Percent Change (%)	-27.4	11.4	7.6	52.0	21.9	6.9	1.8	21.3

Source: Dataquest (September 1993)

Table 2-4
Bits from Shipments of DRAMs to the World, 1990-1997 (Trillions of Bits)*

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
64K STAND	2	1	1	0	0	0	0	0	NM
256K STAND	148	67	35	21	15	8	4	0	-62.5
256K VRAM	14	12	15	11	8	4	3	2	-34.6
1Mb STAND	675	826	779	472	290	184	52	38	-45.4
1Mb VRAM	22	50	82	104	71	52	37	21	-23.9
2Mb VRAM	0	0	1	19	38	44	44	29	109.9
4Mb STAND	102	577	1,885	3,314	3,607	2,663	1,845	1,124	-9.8
4Mb VRAM	0	0	0	4	25	63	105	147	401.8
16Mb STAND	0	2	30	352	2,433	5,989	10,905	14,596	243.9
64Mb STAND	0	0	0	0	0	13	201	2,684	NM
Total	964	1,535	2,828	4,297	6,488	9,022	13,197	18,642	45.8
Percent Change (%)	50.2	59.2	84.2	51.9	51.0	39.1	46.3	41.3	

*Trillion = 1.0×10^{12}

NM = Not meaningful

Source: Dataquest (September 1993)

Table 2-5
Price per Bit for Shipments of DRAMs to the World, 1990-1997
(Microdollars)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
64K STAND	22.6	22.5	20.5	21.4	-	-	-	-	NM
256K STAND	7.7	6.9	5.4	5.7	6.1	6.1	6.1	5.7	1.3
256K VRAM	13.0	13.7	10.2	10.7	11.1	10.3	7.6	7.6	-5.6
1Mb STAND	5.9	4.1	3.1	3.1	3.1	3.1	3.2	3.3	1.4
1Mb VRAM	11.2	8.2	6.4	6.0	5.2	4.1	3.8	3.8	-9.8
2Mb VRAM	-	-	7.3	6.2	4.9	3.4	3.2	3.1	-15.7
4Mb STAND	8.2	4.2	2.7	2.7	2.3	1.6	1.3	1.4	-12.5
4Mb VRAM	-	-	14.3	6.7	4.8	3.6	2.8	2.5	-29.4
16Mb STAND	-	14.7	6.8	4.5	2.3	1.5	1.0	0.9	-33.9
64Mb STAND	-	-	-	-	-	4.1	2.2	1.3	NM
Average	6.7	4.5	3.0	3.1	2.4	1.7	1.1	1.0	-20.1
Percent Change (%)	-48.5	-32.6	-33.0	1.7	-21.2	-31.6	-33.2	-11.2	

NM = Not meaningful

Source: Dataquest (September 1993)

Chapter 3
SRAM Forecast Assumptions

Changes to the 1993 Outlook

Dataquest made an effort to understand differences between our market totals and makeup and the data published from WSTS. In SRAMs, this is often difficult, because many SRAM makers' shipments are estimated in the WSTS data on a constant-share-of-market-method, and even the base estimates may be inaccurate. In a changing market, as occurred in 1992 and 1993, these deviations can be substantial. Further, a major restatement of the year totals was made in the final 1992 WSTS data—after Dataquest had finalized its own SRAM forecast. In early 1993, the WSTS SRAM unit shipment data, which heavily influenced Dataquest's preliminary 1993 SRAM forecast, was revised significantly downward for the last 6 months of the year. The estimated quarterly unit shipments collected by Dataquest in late 1992 and early 1993 were, in fact, much more consistent with the restated WSTS data. In this forecast, we revised our initial forecast to match more closely both the original Dataquest market data and the restated WSTS 1992 data.

The correction we expected in 1993 also is not now expected to occur. In this correction, we expected the life cycles of the 64K and 256K devices to fall into line with historical end-of-life trends. During the course of the year, however, Japan-based consumer electronics manufacturers did not convert their designs to the 1Mb SRAM as was indicated by the preliminary 1992 WSTS SRAM unit shipment figures.

Changes to Long-Term Outlook

Aside from the aforementioned 64K and 256Kb life cycles, there were no major changes in the forecast from the March edition to the present one. Market size, prices, and prices per bit for the SRAM market as a whole remain about as they were forecast before.

Fundamental Assumptions for the SRAM Forecast

Following are the fundamental assumptions for the SRAM forecast:

- Three different markets exist: slow, which begins at the present time at about 45ns; fast, which is anything not slow or pseudo-SRAM; and pseudo.
- Pseudo-SRAMs are not forecast to be made obsolete by self-refreshed byte-wide DRAMs, although this is likely to happen at a time that cannot be determined. These devices are equivalent except for their pin rotation. Limited acceptance is expected for pseudo-SRAMs for the long term.
- Cache memories built from discrete SRAMs will continue to find a home in most computer systems, despite competition from processors with built-in cache, DRAMs with built-in cache, chipsets, and other cache controllers with built-in cache, and exotic, high-speed DRAM

interface mechanisms. There are several reasons for this, stemming from basic computer architecture through price-per-bit of integrated versus discrete SRAM, and simple market differentiation through cache as an option. This will be the most important driver of fast SRAM growth.

- Slow SRAMs will move along the same path as has been followed since their inception: to serve as inexpensive storage in an enormous variety of applications, with the lower densities being absorbed into application-specific controllers, ASICs, and microcontrollers. For the purposes of the forecast, slow SRAMs comprise both the old "slow" category of devices slower than 70ns, and the 45, 55, 70ns category.
- Markets for slow SRAMs comprise consumer goods (video games, camcorders), office equipment (fax machines, autodialers), telecommunications (pagers, central office switches), instrumentation (bar code readers, heart rate monitors), data processing equipment (hard disk drives, modems) and a wide variety of other applications. All of these markets have improved on a worldwide basis in 1993, providing a positive impact upon the slow SRAM market. This trend is expected to continue until the Japanese economy restabilizes (near mid-1994), after which the market for slow SRAMs will become supply-limited until the expected cyclical slump of 1995.
- Overall bit growth will loosely parallel that of DRAMs, as has happened in the past decade.
- Although there have been samples of 4Mb SRAMs for more than 2 years now, production of these devices is ramping up very slowly. Demand is strong, and shipments are severely supply-limited. Dataquest has subsequently pushed out our expectations for peak shipments of these devices.

Table 3-1
Factory Revenue from Shipments of SRAMs to the World, 1990-1997
(Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
16K 10-19ns	0	5	6	3	2	1	1	0	-40.1
16K 20-44ns	0	33	35	10	6	4	2	1	-49.0
16K 44-70ns	0	13	9	3	2	1	1	1	-43.5
16K <70ns	77	0	0	0	0	0	0	0	NM
16K >70ns	117	63	77	12	7	5	5	4	-45.5
64K 0-9ns	0	0	3	30	26	14	3	2	-7.4
64K 10-19ns	0	42	40	20	16	13	5	4	-37.7
64K 20-44ns	0	235	190	79	57	43	16	12	-42.5
64K 44-70ns	0	63	50	30	22	19	7	5	-36.0
64K <70ns	380	0	0	0	0	0	0	0	NM
64K >70ns	368	317	380	165	44	22	15	11	-51.2
64K >70ns PSRAM	3	6	7	3	1	0	0	0	NM
256K 0-9ns	0	0	4	122	157	162	107	62	72.6
256K 10-19ns	0	46	66	93	150	162	119	102	9.3
256K 20-44ns	0	273	395	344	383	395	260	237	-9.7
256K 44-70ns	0	58	90	122	137	147	98	87	-0.8
256K <70ns	341	0	0	0	0	0	0	0	NM
256K >70ns	703	718	706	1,247	632	148	152	129	-28.8
256K >70ns PSRAM	97	162	139	131	97	57	19	34	-24.5
1Mb 0-9ns	0	0	52	68	184	236	492	418	51.8
1Mb 10-19ns	0	110	149	74	152	253	430	377	20.3
1Mb 20-44ns	0	45	93	143	321	573	818	701	49.7
1Mb 44-70ns	0	59	86	114	191	278	315	295	27.8
1Mb <70ns	69	0	0	0	0	0	0	0	NM
1Mb >70ns	191	244	313	776	1,009	583	697	377	3.8
1Mb >70ns PSRAM	87	61	52	86	78	85	99	85	10.4
4Mb 0-9ns	0	0	0	0	0	8	21	47	NM
4Mb 10-19ns	0	0	0	0	21	39	126	205	NM
4Mb 20-44ns	0	0	0	3	33	36	66	138	NM
4Mb 44-70ns	0	0	0	9	84	71	82	198	NM
4Mb >70ns	0	0	2	89	446	803	792	880	242.8
4Mb >70ns PSRAM	0	14	45	92	158	137	170	149	27.0
16Mb 0-9ns	0	0	0	0	0	0	1	53	NM
16Mb 10-19ns	0	0	0	0	0	0	18	290	NM
16Mb 20-44ns	0	0	0	0	0	0	9	147	NM
16Mb 44-70ns	0	0	0	0	0	0	8	178	NM

(Continued)

Table 3-1 (Continued)
Factory Revenue from Shipments of SRAMs to the World, 1990-1997
(Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
16Mb >70ns	0	0	0	0	0	4	115	691	NM
16Mb >70ns PSRAM	0	0	0	0	11	41	67	142	NM
Total	2,434	2,569	2,990	3,865	4,426	4,339	5,139	6,063	15.2
Percent Change (%)	-26.9	5.6	16.4	29.3	14.5	-2.0	18.5	18.0	

NM = Not meaningful
Source: Dataquest (September 1993)

Table 3-2
Shipments of SRAMs to the World, 1990-1997
(Millions of Units)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
16K 10-19ns	0	2	2	1	1	1	0	0	-33.0
16K 20-44ns	0	14	13	5	4	3	2	1	-40.6
16K 44-70ns	0	10	6	2	2	1	1	0	-41.6
16K <70ns	32	0	0	0	0	0	0	0	NM
16K >70ns	91	90	87	12	7	3	2	1	-55.7
64K 0-9ns	0	0	0	2	3	3	1	1	33.0
64K 10-19ns	0	10	10	7	6	5	2	2	-30.7
64K 20-44ns	0	65	77	40	30	23	9	6	-39.1
64K 44-70ns	0	30	27	18	13	10	4	3	-35.8
64K <70ns	69	0	0	0	0	0	0	0	NM
64K >70ns	200	186	213	127	28	13	9	6	-51.3
64K >70ns PSRAM	2	4	4	2	1	0	0	0	NM
256K 0-9ns	0	0	0	3	10	16	13	10	223.2
256K 10-19ns	0	2	4	12	23	32	24	19	36.6
256K 20-44ns	0	28	57	96	128	132	68	53	-1.5
256K 44-70ns	0	11	23	35	48	51	28	22	-1.4
256K <70ns	21	0	0	0	0	0	0	0	NM
256K >70ns	168	180	199	356	222	51	43	37	-28.6
256K >70ns PSRAM	23	41	59	65	56	33	11	17	-22.1
1Mb 0-9ns	0	0	0	1	4	12	29	42	237.9
1Mb 10-19ns	0	1	1	4	11	25	52	75	142.2
1Mb 20-44ns	0	1	3	12	38	84	145	209	131.8
1Mb 44-70ns	0	2	7	14	29	47	64	92	69.9
1Mb <70ns	1	0	0	0	0	0	0	0	NM
1Mb >70ns	6	18	31	97	155	99	141	120	31.1
1Mb >70ns PSRAM	7	9	12	25	28	28	27	21	11.4
4Mb 0-9ns	0	0	0	0	0	0	0	1	NM
4Mb 10-19ns	0	0	0	0	0	1	5	14	NM
4Mb 20-44ns	0	0	0	0	1	2	7	19	NM
4Mb 44-70ns	0	0	0	0	3	4	10	28	NM
4Mb >70ns	0	0	0	1	16	50	92	124	503.7
4Mb >70ns PSRAM	0	1	4	10	23	23	33	37	57.0
16Mb 0-9ns	0	0	0	0	0	0	0	0	NM
16Mb 10-19ns	0	0	0	0	0	0	0	2	NM
16Mb 20-44ns	0	0	0	0	0	0	0	3	NM
16Mb 44-70ns	0	0	0	0	0	0	0	4	NM

(Continued)

Table 3-2 (Continued)
Shipments of SRAMs to the World, 1990-1997
(Millions of Units)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
16Mb >70ns	0	0	0	0	0	0	1	17	NM
16Mb >70ns PSRAM	0	0	0	0	0	2	7	16	NM
Total	620	704	842	946	888	756	829	1,003	3.6
Percent Change (%)	-1.6	13.4	19.7	12.4	-6.2	-14.9	9.7	21.0	

NM = Not meaningful
Source: Dataquest (September 1993)

Table 3-3
Average Selling Price for Shipments of SRAMs to the World, 1990-1997
(U.S. Dollars)

	1990	1991	1992	1993	1994	1995	1996	1997
16K 10-19ns	-	3.30	3.50	2.50	2.25	2.10	2.00	2.00
16K 20-44ns	-	2.40	2.67	2.00	1.60	1.40	1.25	1.25
16K 44-70ns	-	1.25	1.48	1.25	1.25	1.25	1.25	1.25
16K <70ns	2.44	-	-	-	-	-	-	-
16K >70ns	1.28	0.70	0.88	1.00	1.00	1.50	2.50	2.50
64K 0-9ns	-	-	17.12	15.00	10.00	4.75	2.80	2.80
64K 10-19ns	-	4.18	3.84	2.75	2.50	2.50	2.25	2.25
64K 20-44ns	-	3.63	2.46	2.00	1.90	1.90	1.85	1.85
64K 44-70ns	-	2.11	1.84	1.65	1.70	1.80	1.80	1.80
64K <70ns	5.49	-	-	-	-	-	-	-
64K >70ns	1.84	1.70	1.78	1.30	1.60	1.70	1.80	1.80
64K >70ns PSRAM	1.88	1.72	1.50	1.30	1.20	1.30	-	-
256K 0-9ns	-	-	138.12	42.00	15.00	10.00	8.00	6.00
256K 10-19ns	-	24.31	16.75	8.00	6.50	5.00	4.95	5.50
256K 20-44ns	-	9.71	6.93	3.60	3.00	3.00	3.80	4.50
256K 44-70ns	-	5.33	3.88	3.50	2.85	2.90	3.50	4.00
256K <70ns	15.94	-	-	-	-	-	-	-
256K >70ns	4.18	4.00	3.54	3.50	2.85	2.90	3.50	3.50
256K >70ns PSRAM	4.19	4.00	2.34	2.00	1.75	1.70	1.80	2.00
1Mb 0-9ns	-	-	546.42	110.00	45.00	20.00	17.00	10.00
1Mb 10-19ns	-	200.00	165.01	20.00	14.35	10.00	8.25	5.00
1Mb 20-44ns	-	46.94	29.79	11.50	8.55	6.80	5.65	3.35
1Mb 44-70ns	-	25.47	13.27	8.00	6.50	5.90	4.95	3.20
1Mb <70ns	68.78	-	-	-	-	-	-	-
1Mb >70ns	30.76	13.39	10.15	8.00	6.50	5.90	4.95	3.15
1Mb >70ns PSRAM	12.29	6.50	4.18	3.50	2.80	3.00	3.70	4.00
4Mb 0-9ns	-	-	-	-	-	100.00	50.00	38.00
4Mb 10-19ns	-	-	-	-	67.00	34.00	27.00	15.00
4Mb 20-44ns	-	-	-	200.00	30.00	18.00	10.00	7.20
4Mb 44-70ns	-	-	-	100.00	28.00	16.00	8.60	7.08
4Mb >70ns	-	-	120.00	100.00	28.00	16.00	8.60	7.08
4Mb >70ns PSRAM	-	13.54	11.54	9.00	7.00	6.00	5.20	4.00
16Mb 0-9ns	-	-	-	-	-	-	300.00	300.00
16Mb 10-19ns	-	-	-	-	-	-	400.00	150.00
16Mb 20-44ns	-	-	-	-	-	-	150.00	54.00
16Mb 44-70ns	-	-	-	-	-	-	85.00	45.00

(Continued)

Table 3-3 (Continued)
Average Selling Price for Shipments of SRAMs to the World, 1990-1997
(U.S. Dollars)

	1990	1991	1992	1993	1994	1995	1996	1997
16Mb >70ns	-	-	-	-	-	180.00	85.00	40.00
16Mb >70ns PSRAM	-	-	-	-	26.10	17.15	10.00	9.00
Average	3.92	3.65	3.55	4.08	4.99	5.74	6.20	6.04
Percent Change (%)	-25.7	-6.9	-2.7	15.0	22.0	15.1	8.0	-2.5

Source: Dataquest (September 1993)

Table 3-4
Bits from Shipments of SRAMs to the World, 1990-1997
(Trillions of Bits)*

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
16K 10-19ns	0	0	0	0	0	0	0	0	-33.0
16K 20-44ns	0	0	0	0	0	0	0	0	-40.6
16K 44-70ns	0	0	0	0	0	0	0	0	-41.6
16K <70ns	1	0	0	0	0	0	0	0	NM
16K >70ns	1	1	1	0	0	0	0	0	-55.7
64K 0-9ns	0	0	0	0	0	0	0	0	33.0
64K 10-19ns	0	1	1	0	0	0	0	0	-30.7
64K 20-44ns	0	4	5	3	2	1	1	0	-39.1
64K 44-70ns	0	2	2	1	1	1	0	0	-35.8
64K <70ns	5	0	0	0	0	0	0	0	NM
64K >70ns	13	12	14	8	2	1	1	0	-51.3
64K >70ns PSRAM	0	0	0	0	0	0	0	0	NM
256K 0-9ns	0	0	0	1	3	4	4	3	223.2
256K 10-19ns	0	1	1	3	6	8	6	5	36.6
256K 20-44ns	0	7	15	25	33	34	18	14	-1.5
256K 44-70ns	0	3	6	9	13	13	7	6	-1.4
256K <70ns	6	0	0	0	0	0	0	0	NM
256K >70ns	44	47	52	93	58	13	11	10	-28.6
256K >70ns PSRAM	6	11	16	17	15	9	3	4	-22.1
1Mb 0-9ns	0	0	0	1	4	12	30	44	237.9
1Mb 10-19ns	0	1	1	4	11	27	55	79	142.2
1Mb 20-44ns	0	1	3	13	39	88	152	219	131.8
1Mb 44-70ns	0	2	7	15	31	49	67	97	69.9
1Mb <70ns	1	0	0	0	0	0	0	0	NM
1Mb >70ns	7	19	32	102	163	104	148	126	31.1
1Mb >70ns PSRAM	7	10	13	26	29	30	28	22	11.4
4Mb 0-9ns	0	0	0	0	0	0	2	5	NM
4Mb 10-19ns	0	0	0	0	1	5	20	57	NM
4Mb 20-44ns	0	0	0	0	5	8	28	81	NM
4Mb 44-70ns	0	0	0	0	13	19	40	117	NM
4Mb >70ns	0	0	0	4	67	211	386	521	503.7
4Mb >70ns PSRAM	0	4	16	43	95	96	137	157	57.0
16Mb 0-9ns	0	0	0	0	0	0	0	3	NM
16Mb 10-19ns	0	0	0	0	0	0	1	32	NM
16Mb 20-44ns	0	0	0	0	0	0	1	46	NM
16Mb 44-70ns	0	0	0	0	0	0	2	66	NM

(Continued)

Table 3-4 (Continued)
Bits from Shipments of SRAMs to the World, 1990-1997
(Trillions of Bits)*

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
16Mb >70ns	0	0	0	0	0	0	23	290	NM
16Mb >70ns PSRAM	0	0	0	0	7	40	112	264	NM
Total	91	127	186	369	598	776	1,281	2,269	64.8
Percent Change (%)	24.9	40.3	46.8	97.6	62.2	29.8	65.1	77.1	

NM = Not meaningful

*Trillion = 1.0×10^{12}

Source: Dataquest (September 1993)

Table 3-5
Price per Bit for Shipments of SRAMs to the World, 1990-1997
(Microdollars)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
16K 10-19ns	-	201.4	213.6	152.6	137.3	128.2	122.1	122.1	-10.6
16K 20-44ns	-	146.5	162.7	122.1	97.7	85.4	76.3	76.3	-14.1
16K 44-70ns	-	76.3	90.4	76.3	76.3	76.3	76.3	76.3	-3.3
16K <70ns	148.9	-	-	-	-	-	-	-	NM
16K >70ns	78.4	42.7	53.7	61.0	61.0	91.6	152.6	152.6	23.2
64K 0-9ns	-	-	261.2	228.9	152.6	72.5	42.7	42.7	-30.4
64K 10-19ns	-	63.7	58.5	42.0	38.1	38.1	34.3	34.3	-10.1
64K 20-44ns	-	55.3	37.6	30.5	29.0	29.0	28.2	28.2	-5.6
64K 44-70ns	-	32.3	28.0	25.2	25.9	27.5	27.5	27.5	-0.4
64K <70ns	83.8	-	-	-	-	-	-	-	NM
64K >70ns	28.1	26.0	27.1	19.8	24.4	25.9	27.5	27.5	0.2
64K >70ns PSRAM	28.6	26.2	22.9	19.8	18.3	19.8	-	-	NM
256K 0-9ns	-	-	526.9	160.2	57.2	38.1	30.5	22.9	-46.6
256K 10-19ns	-	92.7	63.9	30.5	24.8	19.1	18.9	21.0	-20.0
256K 20-44ns	-	37.1	26.4	13.7	11.4	11.4	14.5	17.2	-8.3
256K 44-70ns	-	20.3	14.8	13.4	10.9	11.1	13.4	15.3	0.6
256K <70ns	60.8	-	-	-	-	-	-	-	NM
256K >70ns	15.9	15.3	13.5	13.4	10.9	11.1	13.4	13.4	-0.3
256K >70ns PSRAM	16.0	15.3	8.9	7.6	6.7	6.5	6.9	7.6	-3.1
1Mb 0-9ns	-	-	521.1	104.9	42.9	19.1	16.2	9.5	-55.1
1Mb 10-19ns	-	190.7	157.4	19.1	13.7	9.5	7.9	4.8	-50.3
1Mb 20-44ns	-	44.8	28.4	11.0	8.2	6.5	5.4	3.2	-35.4
1Mb 44-70ns	-	24.3	12.7	7.6	6.2	5.6	4.7	3.1	-24.8
1Mb <70ns	65.6	-	-	-	-	-	-	-	NM
1Mb >70ns	29.3	12.8	9.7	7.6	6.2	5.6	4.7	3.0	-20.9
1Mb >70ns PSRAM	11.7	6.2	4.0	3.3	2.7	2.9	3.5	3.8	-0.9
4Mb 0-9ns	-	-	-	-	-	23.8	11.9	9.1	NM
4Mb 10-19ns	-	-	-	-	16.0	8.1	6.4	3.6	NM
4Mb 20-44ns	-	-	-	47.7	7.2	4.3	2.4	1.7	NM
4Mb 44-70ns	-	-	-	23.8	6.7	3.8	2.1	1.7	NM
4Mb >70ns	-	-	28.6	23.8	6.7	3.8	2.1	1.7	-43.2
4Mb >70ns PSRAM	-	3.2	2.8	2.1	1.7	1.4	1.2	1.0	-19.1
16Mb 0-9ns	-	-	-	-	-	-	17.9	17.9	NM
16Mb 10-19ns	-	-	-	-	-	-	23.8	8.9	NM
16Mb 20-44ns	-	-	-	-	-	-	8.9	3.2	NM
16Mb 44-70ns	-	-	-	-	-	-	5.1	2.7	NM

(Continued)

Table 3-5 (Continued)
Price per Bit for Shipments of SRAMs to the World, 1990-1997
(Microdollars)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
16Mb >70ns	-	-	-	-	-	10.7	5.1	2.4	NM
16Mb >70ns PSRAM	-	-	-	-	1.6	1.0	0.6	0.5	NM
Average	26.9	20.2	16.0	10.5	7.4	5.6	4.0	2.7	-30.1
Percent Change (%)	-41.5	-24.7	-20.7	-34.6	-29.4	-24.4	-28.3	-33.4	

NM = Not meaningful
Source: Dataquest (September 1993)

Chapter 4
Nonvolatile Memory Forecast Assumptions

EPROM Forecast Assumptions

EPROM prices remained relatively stable, as flash memory remained in short supply for most of 1993. Both the demand for EPROMs and the available wafer fab capacity stayed at prior levels. Advanced Micro Devices, the No. 1 player in 1992, has shifted EPROM production to foundries to free up capacity for flash. This is indicative of the current thinking, and we do not expect fab capacity turning back to EPROM. SGS-Thomson, TI, and National Semiconductor are expected to keep their EPROM lines running for as long as they deem them to be profitable. And clearly there is some profit to be made by the remaining vendors. However, more and more applications are switching to flash, including telecom (driven by cellular), networking, PC BIOS, and automotive. The future of high-density devices (for example, 8Mb and 16Mb) is still questionable, threatened by the arch-rival technology of flash. The EPROM market is expected to decline slowly. We do not expect ASPs to drop dramatically as the number of suppliers and available products decline.

Flash Memory Forecast Assumptions

The most significant recent development is that the production problems Intel has experienced in the recent past appear to be over. This "expectation" was a built-in assumption in our prior forecast, and as a result minor forecast changes were made, reflecting a greater degree of confidence that this market will develop as expected. Limited production of flash effectively kept prices stable in 1992 and 1993. Average selling prices will resume their downward trend in 1994, as more players come on-board. We also expect to see significant additional capacity online in 1994 from many entrenched and "new" players.

Both Intel and AMD have now committed significant wafer fab capacity to flash memory, in Intel's case by bringing on-board additional capacity in New Mexico, accelerating production from Sharp in Japan, and the return of full production at NMBS, which was acquired by Nippon Steel Semiconductor. AMD, the No. 2 player, in an alliance with Fujitsu plans to bring on-board significant new fab capacity by 1995. Mitsubishi, Toshiba, Hitachi, National Semiconductor, TI, SGS-Thomson, Fujitsu, Matsushita, and Samsung are expected to increase their presence in this market. The 16Mb flash memory is expected to be the battlefield for companies that have not been significant players so far. Overall flash memory will be the fastest-growing segment of all semiconductor memories, approaching $3 billion by 1997. The market drivers are EPROM replacement and new applications in portable computing, telecommunications, automotive, and solid-state storage.

ROM Forecast Assumptions

Changes to the 1993 Outlook

No major changes were made in our 1993 forecast for the ROM market, except that prices did not decline as much as anticipated earlier, leading to a larger overall market size. The ROM market has been subject to many of the same unanticipated influences that all MOS memories have been for 1993: continued weakness in the Japanese market, increasing strength of the yen, and lackluster economic performance of the U.S. and European economies. The ROM market appears to not have been impacted by the Sumitomo explosion in July.

Changes to Long-Term Outlook

Since our March forecast, we have slowed the rapid advance of ROMs to higher densities, while preserving the anticipated revenue growth rate. This has slowed the excessive rate of decline of ROM PPB from 1992 to 1997, which we had forecast earlier, and raised the forecast units shipments by density for the intervening years.

Fundamental Assumptions for the ROM Forecast

The mask ROM market is a custom market, and therefore it suffers from those negative factors unique to markets for custom products, as follows:

- Manufacturers that can use the same line to manufacture either mask ROMs or a standard product are more inclined to manufacture the standard product, especially in times of tight capacity, such as 1993 has been.
- Because the mask programmed onto the ROM causes working devices to be usable to only a single customer, special screens are only offered in the most limited sense.
- No manufacturer, with the possible exception of Sharp, uses ROMs as a process driver.
- ROM densities are comparable to those of DRAMs but do not lead those of DRAMs.

For the past several years, the ROM market has undergone a surge, mainly because of the overwhelming popularity of the video game market. This market has driven the peak demand years for the three most recent generations of ROM (4Mb, 8Mb, and 16Mb) but may run out of steam as ROMs compete against DRAM for fab space, and it will hit a physical density limit as available densities follow the standard increases of all other memory technologies.

The effect of CD-ROMs on the mask ROM market will continue to be negligible through the life of the forecast, simply because of the high cost of the CD-ROM player required to use such a medium.

Personal digital assistants (PDAs), while becoming an important market for mask ROMs, will not displace video games as the major ROM application within the life of the forecast.

Other nonvolatile technologies will never be able to match the low PPB of the mask ROM at high unit volumes. At lower volumes, one-time charges will cause the alternative technologies to be more cost-effective. The decision point is forced by an equation of fixed costs versus variable costs. In the outer years of this forecast, flash memories may be a viable, cost-effective alternative to ROMs in applications where reprogrammability is an asset, at densities of 64Mb and beyond.

The density of the densest manufacturable ROM doubles about every 18 months.

The introduction of HP's Omnibook, with operating system and application software embedded in mask ROM, reopens an important potential high-volume market for high-density ROMs. The performance improvement of ROM versus disk-to-DRAM schemes for operating system store and retrieval are substantial, and the Omnibook has economically put MS-DOS, Excel, Word, and Windows all in ROM in a machine costing less than $2,000.

Dataquest made an effort to understand differences between our market sizing, prices, and market composition and those of WSTS. Almost all ROMs are produced by companies that submit their data into the WSTS market statistics data, although there remain some uncertainties with regard to reporting of multichip ROMs being sold into the games cartridge industry. We believe that the unit shipment and price data reported in this forecast is the most accurate measure of that data and, indeed, tracks the WSTS data closely.

EEPROM Forecast Assumptions

From a unit volume standpoint, the low-density serial EEPROMs will grow the most. In terms of revenue the EEPROM market offers no surprises, growing at a respectable rate, but nonetheless is indicative of a mature market. The 1Kb and 2Kb devices will be the unit volume leaders within the forecast horizon, with a gradual shift to 4Kb. The majority of 64K EEPROMs are parallel devices; however, the drive to reduce the cost of consumer products is enabling 32K and 64K serial EEPROMs densities. Hand-held telephones are one example of a system that can benefit from a lower pin-count (8-pin versus 28-pin), and therefore can be less expensive devices that also occupy less board space.

The high-density EEPROMs were helped by the temporary production problems flash experienced, as vendors re-evaluated the wisdom of designing EEPROM out in favor of flash. We expect the military market to continue to absorb the lion's share of high-density EEPROMs, even as the military budgets decline. A 4Mb device is expected to be introduced by 1995; expect volumes to be very low. The 4Mb EEPROM is targeted at applications that must have high-density EEPROM, military for the most part, replacing multichip EEPROM modules.

Table 4-1
Factory Revenue from Shipments of EPROMs to the World, 1990-1997 (Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
16K	13	12	12	10	9	8	7	4	-21.3
32K	18	25	23	17	16	13	10	7	-22.1
64K	88	100	71	62	58	48	36	18	-23.7
128K	103	75	44	38	34	30	21	21	-14.0
256K	361	450	331	291	273	226	205	178	-11.7
512K	279	205	226	281	234	140	132	103	-14.5
1Mb	480	299	229	265	287	337	356	298	5.5
2Mb	70	100	111	124	182	197	176	138	4.4
4Mb	35	97	178	157	184	181	214	204	2.8
8Mb	0	0	0	3	7	29	23	25	NM
Total	1,446	1,362	1,226	1,249	1,283	1,207	1,178	996	-4.1
Percent Change (%)	-20.1	-5.8	-10.0	1.9	2.7	-6.0	-2.3	-15.5	

NM = Not meaningful

Source: Dataquest (September 1993)

Table 4-2
Shipments of EPROMs to the World, 1990-1997 (Millions of Units)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
16K	6	5	6	5	4	4	3	2	-23.3
32K	8	11	10	7	7	5	4	3	-23.9
64K	39	57	42	36	32	25	18	9	-26.5
128K	46	42	29	23	20	18	12	12	-17.1
256K	158	205	157	138	130	105	93	79	-12.9
512K	98	72	85	112	98	60	55	43	-12.7
1Mb	64	66	65	75	91	112	125	117	12.5
2Mb	5	12	16	23	36	41	39	35	16.4
4Mb	1	6	14	15	21	25	31	34	19.8
8Mb	0	0	0	0	0	2	3	4	NM
Total	424	476	424	433	438	396	382	336	-4.6
Percent Change (%)	5.5	12.3	-10.9	2.1	1.2	-9.7	-3.4	-12.1	

NM = Not meaningful

Source: Dataquest (September 1993)

Table 4-3
Average Selling Price for Shipments of EPROMs to the World, 1990-1997
(U.S. Dollars)

	1990	1991	1992	1993	1994	1995	1996	1997
16K	2.15	2.24	2.20	2.30	2.35	2.35	2.40	2.50
32K	2.24	2.33	2.30	2.45	2.50	2.50	2.55	2.60
64K	2.25	1.74	1.70	1.72	1.80	1.90	2.00	2.05
128K	2.27	1.79	1.50	1.70	1.70	1.70	1.75	1.80
256K	2.29	2.20	2.11	2.10	2.10	2.15	2.20	2.25
512K	2.84	2.85	2.66	2.50	2.40	2.35	2.40	2.40
1Mb	7.52	4.51	3.52	3.55	3.15	3.00	2.85	2.55
2Mb	15.25	8.37	6.80	5.50	5.05	4.80	4.50	3.95
4Mb	35.16	15.99	13.02	10.85	8.75	7.25	6.90	6.05
8Mb	-	-	-	29.00	23.00	15.00	9.00	6.75
Average	3.41	2.86	2.89	2.89	2.93	3.05	3.08	2.96
Percent Change (%)	-24.2	-16.1	1.0	-0.2	1.5	4.2	1.1	-3.8

Source: Dataquest (September 1993)

Table 4-4
Bits from Shipments of EPROMs to the World, 1990-1997
(Trillions of Bits)*

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
16K	0	0	0	0	0	0	0	0	-23.3
32K	0	0	0	0	0	0	0	0	-23.9
64K	3	4	3	2	2	2	1	1	-26.5
128K	6	5	4	3	3	2	2	2	-17.1
256K	41	54	41	36	34	28	24	21	-12.9
512K	52	38	45	59	51	31	29	23	-12.7
1Mb	67	70	68	78	95	118	131	123	12.5
2Mb	10	25	34	47	75	86	82	73	16.4
4Mb	4	25	57	61	88	105	130	141	19.8
8Mb	0	0	0	1	3	16	21	31	NM
Total	182	221	253	288	352	387	420	414	10.4
Percent Change (%)	37.5	21.2	14.3	14.1	22.0	10.1	8.4	-1.4	

NM = Not meaningful

*Trillion = 1.0×10^{12}

Source: Dataquest (September 1993)

Table 4-5
Price per Bit for Shipments of EPROMs to the World, 1990-1997
(Microdollars)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
16K	131.0	136.4	134.3	140.4	143.4	143.4	146.5	152.6	2.6
32K	68.5	71.2	70.2	74.8	76.3	76.3	77.8	79.3	2.5
64K	34.4	26.6	25.9	26.2	27.5	29.0	30.5	31.3	3.8
128K	17.3	13.7	11.4	13.0	13.0	13.0	13.4	13.7	3.7
256K	8.7	8.4	8.0	8.0	8.0	8.2	8.4	8.6	1.3
512K	5.4	5.4	5.1	4.8	4.6	4.5	4.6	4.6	-2.1
1Mb	7.2	4.3	3.4	3.4	3.0	2.9	2.7	2.4	-6.3
2Mb	7.3	4.0	3.2	2.6	2.4	2.3	2.1	1.9	-10.3
4Mb	8.4	3.8	3.1	2.6	2.1	1.7	1.6	1.4	-14.2
8Mb	-	-	-	3.5	2.7	1.8	1.1	0.8	NM
Average	7.9	6.2	4.9	4.3	3.6	3.1	2.8	2.4	-13.1
Percent Change (%)	-41.9	-22.2	-21.3	-10.7	-15.8	-14.6	-9.9	-14.3	

NM = Not meaningful
Source: Dataquest (September 1993)

Table 4-6
Factory Revenue from Shipments of Flash Memory to the World, 1990-1997
(Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
256K	10	17	26	74	90	74	49	40	9.1
512K	2	18	28	80	104	108	80	63	18.0
1Mb	22	51	117	203	193	377	414	424	29.3
2Mb	1	34	76	184	180	250	259	312	32.8
4Mb	0	0	4	58	251	313	416	465	158.8
8Mb	0	0	6	36	392	408	486	620	149.6
16Mb	0	0	0	17	209	493	840	911	NM
32Mb	0	0	0	0	0	0	7	58	NM
64Mb	0	0	0	0	0	0	8	78	NM
Total	35	120	257	651	1,418	2,023	2,559	2,971	63.2
Percent Change (%)	218.4	238.9	114.5	153.8	117.8	42.6	26.5	16.1	

NM = Not meaningful
Source: Dataquest (September 1993)

Table 4-7
Shipments of Flash Memory to the World, 1990-1997 (Millions of Units)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
256K	1	3	5	17	26	24	18	16	26.4
512K	0	2	4	15	26	30	25	23	41.0
1Mb	1	5	15	28	35	77	92	110	49.6
2Mb	0	2	4	13	18	39	48	63	73.6
4Mb	0	0	0	2	15	25	57	75	252.4
8Mb	0	0	0	1	16	23	45	79	230.6
16Mb	0	0	0	0	5	17	48	92	NM
32Mb	0	0	0	0	0	0	0	2	NM
64Mb	0	0	0	0	0	0	0	1	NM
Total	3	12	28	76	141	235	333	461	75.0
Percent Change (%)	314.3	342.4	137.9	169.9	85.6	67.0	41.6	38.6	

NM = Not meaningful
Source: Dataquest (September 1993)

Table 4-8
Average Selling Price for Shipments of Flash Memory to the World, 1990-1997 (U.S. Dollars)

	1990	1991	1992	1993	1994	1995	1996	1997
256K	7.58	5.62	5.22	4.50	3.50	3.10	2.80	2.50
512K	13.10	7.59	6.69	5.30	4.00	3.60	3.20	2.75
1Mb	19.54	10.49	7.99	7.25	5.50	4.90	4.50	3.85
2Mb	31.63	21.50	18.90	14.75	10.00	6.40	5.40	4.95
4Mb	-	-	29.00	25.00	16.75	12.50	7.30	6.20
8Mb	-	-	32.00	30.00	24.50	17.75	10.80	7.85
16Mb	-	-	-	55.00	41.75	29.00	17.50	9.90
32Mb	-	-	-	-	-	-	36.00	29.00
64Mb	-	-	-	-	-	-	75.00	65.00
Average	13.23	10.13	9.14	8.59	10.08	8.61	7.69	6.44
Percent Change (%)	-23.1	-23.4	-9.8	-6.0	17.4	-14.6	-10.7	-16.2

Source: Dataquest (September 1993)

Table 4-9
Bits from Shipments of Flash Memory to the World, 1990-1997 (Trillions of Bits)*

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
256K	0	1	1	4	7	6	5	4	26.4
512K	0	1	2	8	14	16	13	12	41.0
1Mb	1	5	15	29	37	81	96	115	49.6
2Mb	0	3	8	26	38	82	101	132	73.6
4Mb	0	0	1	10	63	105	239	315	252.4
8Mb	0	0	2	10	134	193	377	663	230.6
16Mb	0	0	0	5	84	285	805	1,544	NM
32Mb	0	0	0	0	0	0	7	67	NM
64Mb	0	0	0	0	0	0	7	81	NM
Total	2	10	29	93	376	768	1,650	2,932	150.9
Percent Change (%)	505.0	519.5	182.8	213.8	306.3	104.2	115.0	77.7	

NM = Not meaningful
*Trillion = 1.0×10^{12}
Source: Dataquest (September 1993)

Table 4-10
Price per Bit for Shipments of Flash Memory to the World, 1990-1997 (Microdollars)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
256K	28.9	21.5	19.9	17.2	13.4	11.8	10.7	9.5	-13.7
512K	25.0	14.5	12.8	10.1	7.6	6.9	6.1	5.2	-16.3
1Mb	18.6	10.0	7.6	6.9	5.2	4.7	4.3	3.7	-13.6
2Mb	15.1	10.3	9.0	7.0	4.8	3.1	2.6	2.4	-23.5
4Mb	-	-	6.9	6.0	4.0	3.0	1.7	1.5	-26.5
8Mb	-	-	3.8	3.6	2.9	2.1	1.3	0.9	-24.5
16Mb	-	-	-	3.3	2.5	1.7	1.0	0.6	NM
32Mb	-	-	-	-	-	-	1.1	0.9	NM
64Mb	-	-	-	-	-	-	1.1	1.0	NM
Average	21.0	11.5	8.7	7.0	3.8	2.6	1.6	1.0	-35.0
Percent Change (%)	-47.4	-45.3	-24.2	-19.1	-46.4	-30.2	-41.2	-34.7	

NM = Not meaningful
Source: Dataquest (September 1993)

Table 4-11
Factory Revenue from Shipments of ROMs to the World, 1990-1997
(Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
32K	1	1	0	0	0	0	0	0	NM
64K	12	9	4	2	0	0	0	0	NM
128K	8	13	4	2	1	0	0	0	NM
256K	53	67	42	23	12	3	0	0	NM
512K	63	53	36	21	7	2	0	0	NM
1Mb	285	334	237	117	82	30	12	9	-48.1
2Mb	200	179	157	125	82	29	15	10	-42.8
4Mb	386	306	350	471	306	204	193	137	-17.0
8Mb	92	214	433	199	135	88	71	55	-33.7
16Mb	31	21	182	519	709	654	521	395	16.7
32Mb	0	0	0	0	316	333	553	645	NM
64Mb	0	0	0	0	0	120	333	690	NM
128Mb	0	0	0	0	0	0	219	260	NM
Total	1,132	1,198	1,445	1,479	1,649	1,463	1,918	2,202	8.8
Percent Change (%)	5.8	5.8	20.7	2.3	11.5	-11.3	31.0	14.8	

NM = Not meaningful

Source: Dataquest (September 1993)

Table 4-12
Shipments of ROMs to the World, 1990-1997
(Millions of Units)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
32K	0	0	0	0	0	0	0	0	NM
64K	7	5	2	1	0	0	0	0	NM
128K	5	9	3	2	1	0	0	0	NM
256K	32	38	28	17	9	2	0	0	NM
512K	27	27	19	11	4	1	0	0	NM
1Mb	104	131	113	60	40	16	7	5	-46.8
2Mb	53	58	59	48	31	12	7	5	-39.4
4Mb	74	77	102	157	133	100	96	72	-6.5
8Mb	12	37	77	44	35	28	26	24	-20.7
16Mb	2	3	16	93	177	195	193	188	64.5
32Mb	0	0	0	0	27	44	88	121	NM
64Mb	0	0	0	0	0	4	18	53	NM
128Mb	0	0	0	0	0	0	4	14	NM
Total	315	383	418	434	457	402	439	482	2.9
Percent Change (%)	5.4	21.5	9.1	3.7	5.4	-12.1	9.2	10.0	

NM = Not meaningful

Source: Dataquest (September 1993)

Table 4-13
Average Selling Price for Shipments of ROMs to the World, 1990-1997
(U.S. Dollars)

	1990	1991	1992	1993	1994	1995	1996	1997
32K	1.60	2.29	-	-	-	-	-	-
64K	1.60	1.65	1.55	1.55	-	-	-	-
128K	1.65	1.51	1.45	1.20	1.12	-	-	-
256K	1.68	1.77	1.50	1.35	1.30	1.25	-	-
512K	2.35	1.99	1.95	1.90	1.85	1.80	-	-
1Mb	2.75	2.55	2.10	1.93	2.05	1.90	1.85	1.85
2Mb	3.80	3.10	2.66	2.59	2.65	2.45	2.35	2.00
4Mb	5.20	4.00	3.45	3.00	2.30	2.05	2.00	1.90
8Mb	7.75	5.84	5.64	4.50	3.80	3.15	2.70	2.30
16Mb	19.00	8.32	11.66	5.60	4.00	3.35	2.70	2.10
32Mb	-	-	-	-	11.90	7.60	6.30	5.35
64Mb	-	-	-	-	-	30.00	19.00	13.00
128Mb	-	-	-	-	-	-	50.00	18.00
Average	3.59	3.12	3.46	3.41	3.61	3.64	4.37	4.56
Percent Change (%)	0.5	-12.9	10.7	-1.4	5.9	0.9	20.0	4.4

Source: Dataquest (September 1993)

Table 4-14
Bits from Shipments of ROMs to the World, 1990-1997
(Trillions of Bits)*

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
32K	0	0	0	0	0	0	0	0	NM
64K	0	0	0	0	0	0	0	0	NM
128K	1	1	0	0	0	0	0	0	NM
256K	8	10	7	4	2	1	0	0	NM
512K	14	14	10	6	2	1	0	0	NM
1Mb	109	137	119	63	42	17	7	5	-46.8
2Mb	110	121	124	101	65	25	14	10	-39.4
4Mb	311	321	426	659	557	418	405	303	-6.5
8Mb	100	307	644	372	297	234	221	202	-20.7
16Mb	28	42	262	1,554	2,973	3,277	3,237	3,156	64.5
32Mb	0	0	0	0	892	1,472	2,943	4,047	NM
64Mb	0	0	0	0	0	268	1,177	3,561	NM
128Mb	0	0	0	0	0	0	589	1,942	NM
Total	682	955	1,592	2,759	4,831	5,712	8,592	13,227	52.7
Percent Change (%)	60.2	40.1	66.8	73.3	75.1	18.2	50.4	53.9	

NM = Not meaningful

*Trillion = 1.0×10^{12}

Source: Dataquest (September 1993)

Table 4-15
Price per Bit for Shipments of ROMs to the World, 1990-1997
(Microdollars)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
32K	48.8	70.0	-	-	-	-	-	-	NM
64K	24.4	25.2	23.7	23.7	-	-	-	-	NM
128K	12.6	11.5	11.1	9.2	8.5	-	-	-	NM
256K	6.4	6.8	5.7	5.1	5.0	4.8	-	-	NM
512K	4.5	3.8	3.7	3.6	3.5	3.4	-	-	NM
1Mb	2.6	2.4	2.0	1.8	2.0	1.8	1.8	1.8	-2.5
2Mb	1.8	1.5	1.3	1.2	1.3	1.2	1.1	1.0	-5.5
4Mb	1.2	1.0	0.8	0.7	0.5	0.5	0.5	0.5	-11.2
8Mb	0.9	0.7	0.7	0.5	0.5	0.4	0.3	0.3	-16.4
16Mb	1.1	0.5	0.7	0.3	0.2	0.2	0.2	0.1	-29.0
32Mb	-	-	-	-	0.4	0.2	0.2	0.2	NM
64Mb	-	-	-	-	-	0.4	0.3	0.2	NM
128Mb	-	-	-	-	-	-	0.4	0.1	NM
Average	1.7	1.3	0.9	0.5	0.3	0.3	0.2	0.2	-28.8
Percent Change (%)	-33.9	-24.5	-27.6	-41.0	-36.3	-25.0	-12.9	-25.4	

NM = Not meaningful
Source: Dataquest (September 1993)

Table 4-16
Factory Revenue from Shipments of EEPROMs to the World, 1990-1997
(Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
256b	17	18	23	33	35	34	27	23	0.2
512b	0	6	7	8	8	9	10	11	7.5
1K	49	62	69	67	72	63	49	45	-8.3
2K	38	52	41	49	47	56	59	60	8.2
4K	54	28	41	48	62	77	80	94	17.8
8K	0	0	4	6	8	12	12	14	30.0
16K	27	32	33	38	46	63	78	89	21.7
64K	59	74	81	77	88	87	103	124	8.7
256K	45	48	61	57	60	36	23	19	-20.4
512K	0	1	1	4	7	7	11	12	85.9
1Mb	3	5	8	23	48	78	96	105	69.0
4Mb	0	0	0	0	0	14	33	45	NM
Total	292	326	369	408	481	534	578	640	11.7
Percent Change (%)	-8.6	11.7	13.0	10.7	18.0	10.9	8.3	10.6	

NM = Not meaningful

Source: Dataquest (September 1993)

Table 4-17
Shipments of EEPROMs to the World, 1990-1997
(Millions of Units)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
256b	23	25	40	55	63	75	69	66	10.4
512b	0	7	10	12	14	17	19	23	18.0
1K	49	100	144	167	180	179	168	160	2.2
2K	17	39	47	65	79	112	130	155	27.0
4K	20	13	21	38	59	85	106	138	45.1
8K	0	0	2	4	5	8	10	12	49.8
16K	7	11	15	19	26	37	52	71	37.0
64K	10	15	18	21	25	30	41	55	25.7
256K	1	2	4	4	5	4	3	3	-9.2
512K	0	0	0	0	0	0	0	1	104.4
1Mb	0	0	0	0	1	1	2	2	80.9
4Mb	0	0	0	0	0	0	0	1	NM
Total	127	213	300	384	457	548	600	685	17.9
Percent Change (%)	7.4	67.5	41.0	28.0	18.9	19.9	9.5	14.3	

NM = Not meaningful
Source: Dataquest (September 1993)

Table 4-18
Average Selling Price for Shipments of EEPROMs to the World, 1990-1997
(U.S. Dollars)

	1990	1991	1992	1993	1994	1995	1996	1997
256b	0.75	0.72	0.57	0.60	0.56	0.45	0.39	0.35
512b	-	0.82	0.75	0.70	0.60	0.55	0.50	0.47
1K	1.00	0.62	0.48	0.40	0.40	0.35	0.29	0.28
2K	2.20	1.33	0.87	0.75	0.60	0.50	0.45	0.39
4K	2.75	2.11	1.93	1.25	1.05	0.90	0.75	0.68
8K	-	2.51	2.24	1.60	1.55	1.50	1.25	1.10
16K	3.73	2.82	2.26	2.05	1.79	1.70	1.50	1.25
64K	5.75	5.01	4.64	3.75	3.50	2.90	2.50	2.25
256K	38.19	19.46	14.99	13.50	11.80	9.25	8.50	7.75
512K	-	44.88	38.61	40.00	37.00	35.00	27.00	24.00
1Mb	100.00	92.56	77.38	75.00	68.00	65.00	60.00	55.00
4Mb	-	-	-	-	-	135.00	110.00	90.00
Average	2.30	1.53	1.23	1.06	1.05	0.98	0.96	0.93
Percent Change (%)	-14.9	-33.4	-19.9	-13.5	-0.8	-7.5	-1.1	-3.2

Source: Dataquest (September 1993)

Table 4-19
Bits from Shipments of EEPROMs to the World, 1990-1997
(Trillions of Bits)*

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
256b	0	0	0	0	0	0	0	0	10.4
512b	0	0	0	0	0	0	0	0	18.0
1K	0	0	0	0	0	0	0	0	2.2
2K	0	0	0	0	0	0	0	0	27.0
4K	0	0	0	0	0	0	0	1	45.1
8K	0	0	0	0	0	0	0	0	49.8
16K	0	0	0	0	0	1	1	1	37.0
64K	1	1	1	1	2	2	3	4	25.7
256K	0	1	1	1	1	1	1	1	-9.2
512K	0	0	0	0	0	0	0	0	104.4
1Mb	0	0	0	0	1	1	2	2	80.9
4Mb	0	0	0	0	0	0	1	2	NM
Total	1	2	3	4	5	6	8	11	30.2
Percent Change (%)	27.2	62.6	37.8	24.0	34.8	27.5	34.4	30.8	

NM = Not meaningful
*Trillion = 1.0×10^{12}
Source: Dataquest (September 1993)

Table 4-20
Price per Bit for Shipments of EEPROMs to the World, 1990-1997 (Microdollars)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
256b	2,929.7	2,796.3	2,226.7	2,343.8	2,187.5	1,757.8	1,523.4	1,367.2	-9.3
512b	-	1,598.3	1,464.4	1,367.2	1,171.9	1,074.2	976.6	918.0	-8.9
1K	976.6	605.5	470.1	390.6	390.6	341.8	283.2	273.4	-10.3
2K	1,074.2	650.6	423.5	366.2	293.0	244.1	219.7	190.4	-14.8
4K	671.4	514.8	470.1	305.2	256.3	219.7	183.1	166.0	-18.8
8K	-	306.4	273.1	195.3	189.2	183.1	152.6	134.3	-13.2
16K	227.7	172.0	137.7	125.1	109.3	103.8	91.6	76.3	-11.1
64K	87.8	76.5	70.8	57.2	53.4	44.3	38.1	34.3	-13.5
256K	145.7	74.2	57.2	51.5	45.0	35.3	32.4	29.6	-12.4
512K	-	85.6	73.6	76.3	70.6	66.8	51.5	45.8	-9.1
1Mb	95.4	88.3	73.8	71.5	64.8	62.0	57.2	52.5	-6.6
4Mb	-	-	-	-	-	32.2	26.2	21.5	NM
Average	224.0	153.8	126.1	112.6	98.5	85.7	69.1	58.4	-14.3
Percent Change (%)	-28.1	-31.3	-18.0	-10.7	-12.5	-13.0	-19.4	-15.4	

NM = Not meaningful

Source: Dataquest (September 1993)

For More Information...

Lane Mason, Director/Principal Analyst ....(408) 437-8120
Via fax ....(408) 437-0292

Dataqu

Dataquest®

a company of
The Dun & Bradstreet Corporation

Dataquest Incorporated
1290 Ridder Park Drive
San Jose, California 95131-2398
United States
Phone: 01-408-437-8000
Facsimile: 01-408-437-0292

Dataquest Incorporated
550 Cochituate Road
Framingham, Massachusetts 01701-9324
United States
Phone: 01-508-370-5555
Facsimile: 01-508-370-6262

Invitational Computer Conferences (ICC)
3990 Westerly Place, Suite 100
Newport Beach, California 92660
United States
Phone: (714) 476-9117
Facsimile: (714) 476-9969

Dataquest Japan Limited
Shinkawa Sanko Building
1-3-17, Shinkawa, Chuo-ku
Tokyo 104
Japan
Phone: 81-3-5566-0411
Facsimile: 81-3-5566-0425

Dataquest Korea
Trade Tower, Suite 3806
159 Samsung-dong
Kangnam-gu, Seoul 135-729
Korea
Phone: 011-82-2-551-1331
Facsimile: 011-82-2-551-1330

European Headquarters
Dataquest Europe Limited
Roussel House, Broadwater Park
Denham, Uxbridge
Middlesex UB9 5HP
England
Phone: 44-895-835050
Facsimile: 44-895-835260/1

Dataquest GmbH
Kronstadter Strasse 9
8000 Munich 80
Germany
Phone: 011-49-89-930-9090
Facsimile: 011-49-89-930-3277

Dataquest Europe SA
Tour Gallieni 2
36, Avenue du General de Gaulle
93175 Bagnolet Cedex
France
Phone: 011-33-1-48-97-3100
Facsimile: 011-33-1-48-97-3400

Representative Agencies in
Bangkok, Hong Kong,
Kronberg, North Sydney,
Singapore, Taipei, and Tel Aviv

0015271

Dataquest®

Semiconductors

Semiconductor Consumption Forecast

Market Statistics

1993 Final

Program: Semiconductors
Product Code: SCND-WW-MS-9302
Publication Date: October 18, 1993

Dataquest®

Semiconductors

Semiconductor Consumption Forecast

Market Statistics

1993 Final

Program: Semiconductors
Product Code: SCND-WW-MS-9302
Publication Date: October 18, 1993

Table of Contents

Table of Contents (Continued)

Table of Contents

Note: All tables show estimated data.

Table of Contents (Continued)

Note: All tables show estimated data.

Semiconductor Consumption Forecast

Introduction

This document contains detailed information on Dataquest's view of the semiconductor device market. Included in this document are the following:

- 1988-1992 historical data
- 1993-1997 forecast data

Worldwide market revenue estimates combine data from many countries, each of which has a different and fluctuating exchange rate. Estimates of non-U.S. market revenue are based on the average exchange rate for the given year. Refer to the section entitled "Exchange Rates" for more information regarding these average rates. As a rule, Dataquest's estimates are calculated in local currencies and then converted to U.S. dollars.

Dataquest does not forecast exchange rates per se; however, we do forecast semiconductor markets in several regions of the world, and we use the U.S. dollar as a common currency for intermarket comparisons and aggregation. In general, in the forecast period Dataquest assumes that the actual exchange rate of the full month prior to the month in which the forecast-input assumptions are set will apply throughout all future months of the forecast interval. For the current iteration of the semiconductor consumption forecast, please note the following:

- Actual monthly exchange rates are used for all months in the historical interval through July 1993.
- The July 1993 exchange rate is assumed to hold for all months in the August to December 1993 period, and throughout all future years (1994 to 1997).

Quarterly or annual exchange rates (over either the historical or forecast interval) are calculated as the simple arithmetic mean of the appropriate 3 or 12 monthly rates, respectively.

More detailed data on this market may be requested through Dataquest's client inquiry service.

Segmentation

This section outlines the market segments specific to this document. Dataquest's objective is to provide data along the lines of segmentation that are logical, appropriate to the industry in question, and immediately useful to clients.

For a detailed explanation of Dataquest's market segmentation, refer to the *Dataquest Research Methodology* document.

Dataquest defines the semiconductor industry as the group of competing companies primarily engaged in manufacturing semiconductors and related solid-state devices. Important products of the semiconductor industry include integrated circuits, discrete devices, and optoelectronic devices.

For forecasting purposes, Dataquest defines the semiconductor market according to the following functional segmentation scheme:

- Total Semiconductor (including Hybrids)
- Hybrid ICs
- Total Semiconductor (excluding Hybrids)
  - Total IC
    - Bipolar Digital
      - Bipolar Memory
      - Bipolar Logic
    - MOS Digital
      - MOS Memory
      - MOS Microcomponent
      - MOS Logic
    - Monolithic Analog
  - Total Discrete
  - Total Optoelectronic

Definitions

This section lists the definitions used by Dataquest to present the data in this document. Definitions for semiconductor devices can be found in the *Dataquest Semiconductor Market Definitions Guide.*

Total Semiconductor, including Hybrid Integrated Circuits (Total Semiconductor, excluding Hybrid Integrated Circuits, + Hybrid Integrated Circuits). Defined as any active semiconductor product that contains semiconducting material (such as silicon, germanium, or gallium arsenide, but excluding ceramics) and reacts dynamically to an input signal, whether by modifying its shape or adding energy to it. This definition excludes standalone passive components such as capacitors, resistors, inductors, oscillators, crystals, transformers, and relays.

Total Hybrid Integrated Circuit. Defined as a semiconductor product consisting of more than one die contained in a single package. A hybrid IC may perform 100 percent linear, 100 percent digital, or mixed-signal (both linear and digital) functions. Includes hybrid implementation of all monolithic IC functions described in the following categories. Includes all hybrid ICs manufactured using bipolar, MOS, or BiCMOS technologies.

Total Semiconductor, excluding Hybrid Integrated Circuits (Total Integrated Circuit + Total Discrete + Total Optoelectronic). Defined as any active semiconductor product that contains semiconducting material (such as silicon, germanium, or gallium arsenide, but excluding ceramics) and reacts dynamically to an input signal, whether by modifying its shape or adding energy to it. Includes monolithic IC only. This definition excludes standalone passive components such as capacitors, resistors, inductors, oscillators, crystals, transformers, and relays.

Total Integrated Circuit (Digital Monolithic Bipolar IC + Digital Monolithic MOS IC + Monolithic Analog IC). A monolithic IC is defined as a large number of passive and/or active discrete semiconductor circuits integrated onto a single die and contained in a single package.

Bipolar Digital IC (Bipolar Digital Memory IC + Bipolar Logic IC). A bipolar digital IC is defined as a monolithic semiconductor product in which 100 percent of the die area performs digital functions, and concurrently, 100 percent of the die area is manufactured using bipolar semiconductor technology. A digital function is one in which data-carrying signals vary in discrete values.

Bipolar Digital Memory. Defined as a bipolar digital product in which binary data is stored and electronically retrieved. Includes ECL random-access memory (RAM), read-only memory (ROM), programmable ROM (PROM), last-in/first-out (LIFO) memory, and first-in/first-out (FIFO) memory. Not included are products made with mixed bipolar CMOS (that is, BiCMOS) with TTL or ECL outputs, which are classified as MOS.

Bipolar Digital Logic IC (Bipolar Digital Logic Application-Specific IC + Standard Logic IC + Other Bipolar Digital Logic). Defined as a bipolar digital IC product in which more than 50 percent of the die area performs logic functions. Includes bipolar digital microcomponent ICs.

MOS Digital IC (MOS Digital Memory IC + MOS Digital Microcomponent IC + MOS Digital Logic IC). A MOS digital IC is defined as a monolithic semiconductor product in which 100 percent of the die area performs digital functions, and concurrently, any portion of the die area that is manufactured using metal-oxide semiconductor (MOS) technology. A digital function is one in which data-carrying signals vary in discrete values. Includes mixed technology manufacturing, such as BiMOS and BiCMOS, where some MOS technology is employed.

MOS Digital Memory IC (DRAM + SRAM + EPROM + EEPROM + Flash Memory + Mask ROM + Other MOS Digital Memory IC). Defined as a MOS digital IC in which binary data is stored and electronically retrieved.

MOS Digital Microcomponent IC (MOS Digital Microprocessor + MOS Digital Microcontroller + MOS Digital Microperipheral + Programmable Digital Signal Processor). Defined as a MOS digital IC that contains a data processing unit or serves as an interface to such a unit. Includes both complex-instruction-set computing (CISC) and reduced-instruction-set computing (RISC) architectures.

MOS Digital Logic IC (MOS Digital Application-Specific IC + MOS Digital Standard Logic IC + Other MOS Digital Logic). Defined as a MOS digital IC product in which more than 50 percent of the die area performs logic functions. Excludes MOS digital microcomponent ICs.

Monolithic Analog IC (Amplifier/Comparator IC + Voltage Regulator/Reference IC + Data Convertor/Switch/Multiplexer IC + Interface IC + Telecom IC + Disk Drive IC + Other Special Function IC + Linear Array/ASIC + Mixed-Signal ASIC + Total Special Consumer IC + Special Automotive IC + Smart Power IC). A monolithic analog IC is a semiconductor that deals in the realm of electrical signal processing, power control, or electrical drive capability. It is one in which some of the inputs or outputs can be defined in terms of continuously or linearly variable voltages, currents, or frequencies. Includes all monolithic analog ICs manufactured using bipolar, MOS, or BiCMOS technologies.

Total Discrete (Transistor + Diode + Thyristor + Other Discrete). A discrete semiconductor is defined as a unit building block performing a fundamental semiconductor function.

Total Optoelectronic (LED Lamp/Display + Optocoupler + CCD + Laser Diode + Photosensor + Other Optoelectronic). Defined as a semiconductor product in which photons induce the flow of electrons, or vice versa. Other functions may also be integrated onto the product. This category does not include LCD, incandescent displays, fluorescent displays, cathode ray tubes (CRTs), or plasma displays.

Regional Definitions

North America: Includes Canada, Mexico, and the United States (50 states).

Japan: Japan is the only single-country region.

Europe: Western Europe includes Austria, Belgium, Denmark, Eire, Finland, France, Germany (including former East Germany), Greece, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, and Rest of Western Europe (Cyprus, Iceland, Malta, Turkey, and others). Eastern Europe includes Albania, Bulgaria, the Czech and Slovak republics, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, the Republics of the former USSR (including Belorussia, Russia, and Ukraine), and others.

Asia/Pacific: Includes Asia/Pacific's newly industrialized economies (NIEs) and the Rest of Asia/Pacific regions. NIEs include Hong Kong, Singapore, South Korea, and Taiwan. The Rest of Asia/Pacific region includes Australia, Burma, Cambodia, China, India, Indonesia, Laos, Malaysia, Maldives, Myanmar, Nepal, New Zealand, the Philippines, Thailand, and Vietnam.

Rest of World: Includes Africa, the Caribbean, Central America, the Middle East, Oceania, and South America.

Line Item Definitions

Factory revenue is defined as the money value received by a semiconductor manufacturer for its products. Dataquest includes all revenue, both merchant and captive, for semiconductor suppliers selling to the merchant market. The data excludes completely captive suppliers where devices are manufactured solely for the company's own use. A product that is used internally is valued at the market price rather than at the transfer or factory price.

Forecast Methodology

Dataquest publishes five-year revenue forecasts for the semiconductor market during the first and third quarters of each year. In doing so, Dataquest uses a variety of forecasting techniques (both qualitative and quantitative) that vary by technology area. An overview of Dataquest forecasting techniques can be found in the *Dataquest Research Methodology* document.

Dataquest's semiconductor forecast methodology leverages the resources of its parent, The Dun & Bradstreet Corporation, as well as the considerable internal resources of Dataquest.

Dun & Bradstreet Corporation information is used to develop the macroeconomic forecasts for the world's major economies. This forecast identifies trends in the economic health of the world's leading consuming and producing nations of electronic equipment. Using this forecast in conjunction with input from Dataquest's regional offices, Dataquest identifies the likelihood of whether a particular region or country will increase or decrease its consumption of electronic equipment.

Dataquest follows a four-step process to forecast the semiconductor market. First, Dataquest's Semiconductor Applications Market group, along with Dataquest's various electronics systems groups, provides a long-range outlook for the overall growth of the electronics equipment market. Semiconductor content ratios are developed by region to reflect the growing penetration of semiconductors into electronic equipment. This establishes a trend growth path for total semiconductors for a five-year period from a demand-side perspective.

Second, Dataquest uses a decomposition time series model to generate forecasts of regional total semiconductor sales. The model assumes that sales are affected by factors such as long-run trends, short-run aggregate economic and industry-specific conditions, and seasonality. The forecast is made by using statistical methods to analyze each of the components separately, then combining them into a single aggregate. The model is especially useful for assessing near-term market fluctuations about the trend growth path.

Third, Dataquest's worldwide semiconductor service and its Semiconductor Equipment, Materials, and Manufacturing service, in conjunction with its various regional offices, collaborate to formulate expectations of semiconductor market short-run fluctuations around the long-run trend. Tactical market issues and anticipated semiconductor materials demand significantly impact the forecast out to 12 months. Semiconductor equipment purchases and semiconductor device trends drive the forecast in the 12-month to 24-month time frame. Semiconductor fab facilities and long-run semiconductor device trends have the greatest impact on the forecast period covering two to five years.

The final step in the forecast process is to reconcile expected fluctuations in the electronics market and trends in the semiconductor industry so that the fluctuations do not inexplicably diverge from semiconductor industry trends. Dataquest anticipates that, in the absence of shocks to the market, market fluctuations converge toward the long-run trend.

Forecast Summary and Assumptions

Dataquest forecasts the worldwide semiconductor market growth to peak at 24.2 percent in 1993, accelerating sharply from 9.3 percent growth in 1992; and to decelerate to 9.8 percent growth in 1994. In general, market expansion is being driven by the broad-based growth in personal computers, spurred by the recent bout of price erosion. According to the latest WSTS statistics, worldwide total semiconductor billings (three-month moving average) growth for the three months ended in July is 32.8 percent above year-earlier billings, compared with 33.1 percent in June. Total semiconductor bookings growth for the same period was 35.4 percent above year-earlier bookings, compared with 35.0 percent in June.

The North American semiconductor market continues to strengthen. Dataquest expects the North American market to grow 32.7 percent in 1993, up from a strong 20.2 percent in 1992, and to decelerate to 19.0 percent growth in 1994. According to the latest WSTS statistics, total semiconductor bookings (three-month moving average) growth for the three months ended in August was 37.0 percent above year-earlier bookings, compared with 43.9 percent in July. Total semiconductor billings growth for the same period was 38.6 percent above year-earlier billings, compared with 38.4 percent in July.

Strength in the North American market can be attributed largely to the continuing recovery of the U.S. economy, especially with respect to investment spending. Dun & Bradstreet expects real (that is, inflation-adjusted) business fixed investment on equipment to grow 14.4 percent in 1993, compared with 10.5 percent in 1992; and to decelerate to 11.7 percent growth in 1994. In particular, chip demand stems from strong orders of portable PCs, client/server computers, and network hardware.

Dataquest expects the Japanese market to expand at a 13.1 percent dollar-based rate of growth (or decline at a 1.5 percent yen-based rate of contraction, assuming a 12.4 percent depreciation of the U.S. dollar against the yen) in 1993, after an 8.5 percent dollar-based (or 14.9 percent yen-based) contraction in 1992. The outlook for 1994 calls for 8.8 percent dollar-based growth (or 4.8 percent yen-based growth, assuming a 4.2 percent depreciation of the U.S. dollar against the yen). The latest market statistics support this modest outlook. The dollar value of total semiconductor billings for the three months ended in July was 26.7 percent above year-earlier billings. The bookings picture is equally buoyant: Total semiconductor bookings for the same period were 26.5 percent above year-earlier levels.

The depth and duration of Japan's economic recession, in general, is proving to be the chief obstacle to Japan's near-term growth prospects. Also, appreciation of the yen against major world currencies hit just when the economy was beginning to show some signs of recovery. In the long run, the strengthening yen will further shift investment to non-Japan Asia, resulting in marginal declines in chip consumption in the domestic market.

Dataquest forecasts the European market to expand at a 23.5 percent dollar-based rate of growth (or 37.9 percent ECU-based growth, assuming 11.7 percent appreciation of the U.S. dollar against the ECU) in 1993; up from 10.9 percent dollar-based (or 5.4 percent ECU-based) expansion in 1992. The outlook for 1994 calls for 13.4 percent dollar-based growth (or 17.2 percent ECU-based growth, assuming a 3.3 percent depreciation of the U.S. dollar against the ECU). Total semiconductor billings for the three months ended in August were 28.9 percent above year-earlier billings. Total semiconductor bookings for the same period were 31.0 percent above year-earlier levels.

Memory and microprocessor growth is driving the European market. Short-term growth is also being boosted by a shortage of some components (and rising prices), especially small outline logic products. Telecom investment will provide a broad base for long-term growth potential.

Dataquest forecasts the Asia/Pacific-ROW market to grow 29.5 percent in 1993, decelerating only slightly from 30.9 percent growth in 1992. Dataquest expects the Asia/Pacific region to further decelerate to 20.0 percent growth in 1994. Again, the latest statistics support this outlook. Total semiconductor bookings growth for the three months ended in July was 44.2 percent above year-earlier bookings, compared with 46.8 percent growth in June and 59.7 percent growth in May. Total semiconductor billings growth for July was 34.9 percent above year-earlier billings, compared with 34.5 percent growth in June, and 37.1 percent growth in May.

Asia/Pacific-ROW growth benefits from two built-in factors. First is the relative immaturity of their economies vis-a-vis the economies of the more developed industrial nations. Asia's indigenous demand will continue to make up one of the fastest growing markets for the 1990s. Second is the strong yen. Dataquest believes that Japan will increasingly use non-Japan Asia for assembly of system-level products.

Forecast Assumptions: Economics

Dun & Bradstreet forecasts real gross domestic product (GDP) growth among the Group of Seven (G7) countries to be mixed in 1993 and 1994. Countries' economies are becoming increasingly integrated through expanded trade flows. Therefore, continued improvement of U.S. business conditions will be critically important to expected improvement in short run economic activity in the major European and East Asian economies. Growth rate forecasts are as follows:

- U.S. real GDP growth is expected to accelerate from 2.1 percent in 1992 to 2.6 percent in 1993; and to further accelerate to 2.9 percent in 1994.
- Canadian real GDP growth is expected to accelerate from 0.7 percent in 1992 to 3.1 percent in 1993; and to further accelerate to 3.8 percent in 1994.
- U.K. real GDP is expected to grow 1.7 percent in 1993, following a 0.5 percent contraction in 1992; and to further accelerate to 2.7 percent growth in 1994.
- Japanese real GDP growth is expected to decelerate from 1.5 percent in 1992 to 1.3 percent in 1993; and to accelerate to 2.7 percent in 1994.
- Italian real GDP growth is expected to decelerate from 0.9 in 1992 to 0.3 percent in 1993; and to accelerate to 1.5 percent in 1994.
- German real GDP growth is expected to contract 1.5 percent in 1993 following 1.4 percent growth in 1992; and to recover and expand 1.2 percent in 1994.
- French real GDP growth is expected to contract 1.0 percent in 1993 following 1.1 percent growth in 1992; and to recover and expand 1.3 percent in 1994.

Forecast Assumptions: Personal Computer Market

The major influences on the PC market are as follows:

- 486 MPUs are becoming the processor of choice to run new Windows applications on low-priced PCs.
- Upgrading from 286/386-based PCs to low-priced 486 PCs is fueling replacements. Replaced units are going into education markets, and duplicate systems into one-person offices, ROW, and the scrap heap.
- The shift from IBM-compatible to Microsoft-compatible opens the door for non-Intel architectures such as Alpha and PowerPC that could have a potential impact beginning in mid-1994 or earlier.
- Initial Pentium PCs will be absorbed by network server databases, engineering, and financial applications. The Pentium 486 pin-compatible overdrive strategy will quicken users' purchase of PCs that can be upgraded to Pentium.
- Growth in Asia/Pacific and ROW is driving 386 and 486 PC demand.

The following factors contribute significantly to the uncertainty of the PC forecast:

- A potential renewed price war could develop based on Advanced Micro Devices and Cyrix 486 pricing. Intel could radically drop Pentium prices if a 486- or RISC-based PC price war develops.
- Docking stations to be used with notebooks and subnotebooks are being offered by many manufacturers. Better integration of the DOS/ Windows feature will cause docking stations to impact desktop unit sales.

The following is a summary of Dataquest's PC forecast:

- Worldwide unit shipments growth is expected to decelerate to 16.9 percent in 1993, following 18.9 percent growth in 1992; and to further decelerate to 16.2 percent growth in 1994.
- Worldwide factory revenue growth is expected to accelerate to 11.1 percent in 1993, following 10.7 percent growth in 1992; and to further accelerate to 14.7 percent growth in 1994.
- Worldwide prices are expected to depreciate 5.1 percent in 1993, from an average selling price (ASP) of $1,760 in 1992 to $1,670 in 1993; and to further depreciate 1.2 percent in 1994 to $1,650.

Forecast Assumptions: Electronic Equipment Markets

The demand for semiconductors is derived from the underlying demand for the electronic systems responsible for their use. Therefore, inclusion of the electronic systems outlook is critical to ensuring the consistency of the semiconductor forecast. The electronic equipment market outlook is summarized in the following paragraphs.

Data processing production will continue to strengthen in 1993, growing 6.3 percent, up from a 5.5 percent growth rate in 1992, and will further accelerate to 7.1 percent growth in 1994. In North America, expansion is expected to accelerate to 4.6 percent growth in 1993—compared with the 3.9 percent growth rate registered in 1992—as the investment climate continues to improve and stabilize; and to decelerate slightly to 4.3 percent growth in 1994. Japanese production growth is expected to be a moderate 2.5 percent in 1993—albeit a significant improvement over the 2.1 percent contraction in 1992; and to accelerate to 3.9 percent growth in 1994, as businesses relax budget constraints in response to improving economic and business conditions. European production growth is forecast to decelerate dramatically to 1.8 percent growth in 1993 from 8.7 percent growth in 1992, but to improve sharply in 1994, growing 7.2 percent. European production of finished data processing systems will be lackluster as a result of Germany's retrenchment, and the overall sluggish European economic and business conditions. The board business remains one of the few bright spots in the European market. Asia/ Pacific-ROW production prospects remain upbeat as it increasingly becomes the region of choice for mass manufacturing of established technologies. Expect growth of 19.5 percent in 1993, up from 17.1 percent in 1992, and decelerating to 15.4 percent growth in 1994.

Growth of communications production—the most stable-growing of the application markets, owing to its heterogeneous composition of personal wireless communications, premise voice and data products, and large-scale, long-life investment in public telecommunications infrastructure—will accelerate slightly in 1993 to 7.4 percent from 7.2 percent in 1992. Dataquest expects growth to decelerate slightly to 7.1 percent in 1994. Investment in networking the existing and growing stock of data processing equipment will help drive communications hardware growth through 1997.

Production of industrial and consumer equipment bore the brunt of the recent downturn in worldwide business conditions: growth was 0.4 and 1.4 percent, respectively, in 1992. Dataquest expects these markets to grow 5.7 and 8.1 percent, respectively, in 1993; and to grow 7.0 percent and 6.9 percent, respectively, in 1994.

Military/civil aerospace electronics production will continue to be hit hard by Western nations' defense budget cuts in 1993, declining 1.1 percent worldwide on the heels of a 1.5 percent contraction in 1992. Few positive opportunities remain for all but the most specialized niche players participating in simulation systems, dedicated military computer systems, and civil space projects. Civil aerospace electronics production will remain the bright spot in this application market, fueled by replacement of aging jet airliners and upgrades of the worldwide air traffic control system.

Transportation electronics production is expected to grow 7.6 percent in 1993, and to accelerate to 8.3 percent in 1994. Production was hurt by the recession, but growth prospects are relatively upbeat because of increased household spending, combined with an increasing share of electronic systems' added value to new vehicles.

Forecast Assumptions: Semiconductor Devices

The following is a summary of assumptions that underlie the individual device forecasts.

Bipolar Logic

The surge in the PC market in Asia/Pacific-ROW has given a boost to standard logic and other bipolar logic devices. North American and Japanese high-end computer markets are declining at a rapid rate. However, because of the unexpectedly steep depreciation of the U.S. dollar against the yen this year to date, the Japanese market's dollar-denominated decline is shallower than previously expected.

North American growth is mainly coming from the data processing market. High-end computers (mainframe and midrange) are being replaced by smaller PCs and workstations, thus there is a shift from ECL to CMOS, which is causing the bipolar logic market to fall. In general growth is negative; bipolar technology is being replaced by CMOS.

Devices pulling down overall bipolar logic growth are standard logic, PLDs, gate arrays, and CBICs.

MOS Memories

An Expansion Past Its Prime

We are beginning to see the end of the cyclical bubble. Several indicators show we are past the booking peak, and there is some inventory building. Seasonal weakness in the market will likely give way to a reduced rate of overall growth. Dataquest expects price declines about year-end, but probably not precipitous declines.

Thinner Profits to Reinvest

Profits have improved for all products, but for the Japanese, with the strong yen, export prices have not increased enough to match the rise in the yen value. Therefore, yen-based income, which is needed to pay costs of production, is relatively flat. In the local currency (yen), where most of the production takes place, device prices are flat, and profits have risen less than for those companies whose costs are denominated in the depreciated currencies.

A more modest profit opportunity for Japan, coupled with the major structural problems brought about by the bursting bubble, will make it tough for Japan to invest from profits to add capacity as it did in the 1983 to 1985 and the 1988 to 1990 periods. Therefore, Dataquest does not expect that Japanese supply will expand at the rate that it has during earlier cycles, thereby prolonging the period of profitability.

More on Profits and Supply Expansion

The important role of profits in funding semiconductor growth and capital spending is underscored by the dilemma faced by the Japanese DRAM makers that still control about 50 percent of DRAM production. Historically, DRAM profit bubbles of 18 to 24 months have provided the internal financing necessary to fund the succeeding wave of capacity expansions, indeed, often to an excess. This time promises to be different. In addition to the shorter period of lower profitability, Japanese parent companies face strategic choices that will certainly inhibit the flow of investment capital into the kinds of semiconductor capacity expansion we have seen in past cycles. This would point to either an increased rate of loss of DRAM market share to Korean manufacturers and others, a reduced rate of price erosion (until widened profit margins made further investment possible), or both.

Dataquest expects both in the coming two to three years. We expect a prolonged period of steady profitability because capacity will generally run behind demand for up to a few years as Japanese companies recover from a yen shock that promises to be with us for some time. Further, at the factories of many DRAM makers, wafer start allocations are based on revenue per wafer. There is increased product interchangeability compared to earlier years, reducing the "DRAMs or die" dilemma that manufacturers faced in prior years. The Korean manufacturers, with 75 percent of their revenue originating from DRAMs, are clearly a factor for constant profit-killing price pressure. But, because of their "mere" 25 percent DRAM market share and 15 percent MOS memory market share, the Koreans cannot hope to make up for the slower rate of Japanese investment. Still, in DRAMs in particular, the rate at which Korean manufacturers expand capacity during the next 12 months could tell a lot about the market for 1994 to 1997. Given present market conditions, price and profit scenarios could spell a major market share opportunity for the Korean DRAM manufacturers, and also an opportunity to expand further into SRAMs and flash memories.

Slow Investment Today Will Slow Tomorrow's Capacity Expansion

There is other evidence that there has been a significant underinvestment from 1989 to 1993 to support the kinds of growth that appear to lie just ahead. Namely, 1992 was truly a remarkable year in MOS memory (80 percent-plus DRAM bit growth), but price pressure by Korean manufacturers prevented any semblance of profitability in spite of a pending capacity shortfall that developed in 1993. The capacity expansion for 1993 is, to a large extent, picking the low-hanging fruit—equipping pre-existing shells for high return on investment. But such an investment strategy can go on for only so long before the shells are filled, and new foundations must be laid and brick and mortar added. This sort of investment takes a long time to bring online. Also, the ramp rate of 4Mb for 1993 appears to be about 60 percent of the rate of leading-edge products in earlier cycles.

Dataquest Conclusion

Supply is coming, but will increase more slowly for several reasons, thereby postponing the day of reckoning when supply speeds past demand and prices drop severely.

Demand

Multimedia and Windows NT promise to move us to the next stage of user-friendly software requiring 16MB (or more) per PC. Also, workstations are reaching back into the PC realm, and there has emerged a memory aftermarket that now makes up about 15 to 20 percent of DRAM demand. The future also calls for flash memory cards, server memory for workgroup computing, notebooks, and PDAs, all with voracious appetites for memory.

Several recent ventures that may enable the bona fide convergence of consumer and computer technologies and markets are evidence that the many technology "concepts" are now clear enough that the big-money technology companies, media companies, and a host of interested parties are now ready to stake their claims in what they believe will be the key application market drivers of the late 1990s. Clearly, the longer-term outlook for demand is good, and memory makers appear to have more faith in the longer-term future than at any point in recent history. Although the path to 1996 to 1998 may be uncertain, few doubt that major demand elements and markets for MOS memories are coming into focus and present unparalleled opportunities for market growth and profits.

Outlook for 1994

Though prices have risen since the first quarter, we expect a turnaround brought about by some softening of demand for PCs, followed a few months later by weaker DRAM demand. At the same time, capacity has slowly been put in place, and an increasing fraction of the 4Mb output is being run on first-generation 16Mb, 0.55- to 0.65-micron processes, with yields upwards of 280 to 330 gross die per 150mm wafer.

MOS Memory Regional Comments

North America

The United States has done well in 1992 to 1993 as a consumer of MOS memory. The present PC (desktop and notebook) boom is driven by U.S.-based companies such as Apple, IBM, Compaq, Gateway 2000, and Dell. PDAs are North American, as are workstations, the SIMM aftermarket, large computers, and multimedia. Dataquest does not anticipate this winning streak to go on forever, and the U.S. share of MOS memory consumption is expected to decline to near its 1989 to 1990 levels. Also, U.S. companies are adept at moving to low-cost regions at the drop of a price, which will also push MOS memory consumption into Asia.

Japan

From 1988 to 1992, the Japanese semiconductor market showed no net growth, and actually declined 5.7 percent in MOS memory. From the last cyclical peak in 1989, Japan's market size has dropped (in dollar terms) more than 25 percent for MOS memory; and its share of the world MOS memory consumption has declined from 37.8 percent to 27.3 percent. Is the decline permanent, or will Japan work through its problems and again strike fear into the hearts and souls of electronics producers around the world? The high yen will not help in that it raises the cost of anyone doing business in Japan, including the Japanese. It makes imported MOS memory cheaper in Japan (on a yen base), but it makes all of its electronics exports more expensive to consumers in its export-oriented economy. To an extent, and as in the past, Japanese manufacturers will likely substitute capital for labor, automate their operations, and keep the jobs at home. But over the long haul, Japan will necessarily become more open to investing in foreign places and moving production offshore. In stages, Japanese companies will take further steps off the island. With an exchange rate of ¥100/U.S.$1 in sight, and diminishing homespun profit prospects, they have no choice.

Therefore, Dataquest expects Japan to recover some fraction of its former glory (as electronics producer, and share of DRAM consumption) as well as move more operations into Asia.

Europe

Europe has surprised us by its strength in the past 12 to 18 months on the upside by its semiconductor (and MOS memory) consumption, and on the downside on the overall weakness of the larger European economies. Dataquest believes European manufacturers will have a tough time sustaining their share of demand in light of their relatively high wage levels over the long term.

Asia/Pacific-ROW

In the long run, the Asia/Pacific-ROW region gains on two counts. The first is the immature developing economies that have been the drivers for the past several years. The indigenous demand from Asia will continue to make up one of the fastest growing markets for the 1990s. The second reason is the strong yen; we believe that Japan will increasingly use Asia outside of Japan for assembly of system-level products, and thus as the consuming region for DRAMs.

Microcomponents

Microprocessors

Highlights of the microprocessor market are as follows:

- Increasing demands in performance, addressability, and use of high-level languages has pushed virtually all the growth to 32-bit architectures, while 8-bit MPUs (still in high volume) are only slightly growing and 16-bit MPUs will steadily decline.
- Overall ASPs have steadily increased during the last five years by 25 to 45 percent per year and are expected to continue increasing throughout this forecast period. The MPU market is dominated (with more than 65 percent revenue share) by Intel, which is positioned to continue its dominance for the next few years.
- The x86 family, representing well more than 80 percent of MPU revenue, is tied directly to the PC market, which is expected to double its volume in the next five years while microprocessor ASPs continue to grow.
- The 68K family controlled by Motorola will grow moderately in both volume and ASP as a result of a shift to embedded applications.
- The open system RISC microprocessor is projected to achieve the highest growth during this period primarily because of the PowerPC making its way into volume systems, initially through Apple's Macintosh (1994 volume), followed by IBM's Power Personal Systems division (1996 volume).
- The embedded system-focused microprocessors, led completely by RISC microprocessors, will show moderate growth during the next five years as unit volumes drive upward, increasing in the 1995 to 1997 period because of hand-held devices. However, ASPs will decline during this same period.

Microcontrollers

Highlights of the microcontroller market are as follows:

- Microcontroller growth in 1993, while quite strong, has definitely been capacity limited. This growth has been exceptionally strong in the transportation, communications, and data processing markets.
- The electronic content in automobiles is increasing. 8-bit MCUs are used in a variety of automotive applications, including entertainment systems, seats, windows/sunroofs, security, and air bags. 16-bit MCUs are primarily used in antiskid braking systems. 32-bit controllers are

beginning to be used for powertrain management and control in addition to their use in dynamic suspension control.

- The communications market has a voracious demand for 8- and 16-bit MCUs in pagers, cellular telephones, wireless telephones, and smart-wired handsets.
- The data processing market is increasing its use of all MCU word-widths. 8-bit devices are used heavily in keyboards and pointing devices (mice, track balls and electronic pens). 16-bit devices have found a home in hard disk drives at about the 125MB density and greater.
- Consumer items ranging from camcorders to universal remote control devices to tennis shoes are making use of 8-bit microcontrollers.
- The industrial market has long been a home for MCUs with its wide variety of applications. Recently, 16-bit MCUs have been used extensively in motor control applications, particularly for air conditioning units.
- The current boom in MCU consumption has occurred despite the general economic slump that has hit Japan, historically the largest consumer of microcontrollers. When the Japanese market recovers, the capacity available for the current supply-constrained market will be taxed to the breaking point. It is imperative that additional MCU capacity be added before the Japanese economy begins its recovery.

Microperipherals

Highlights of the microperipherals market are as follows:

- Nearly all microperipherals categories have increased their unit volumes in direct proportion to the increase in PC demand.
- PC logic chipsets will be recapturing volume as some large PC vendors (IBM and Apple) move from captive/ASIC system designs to using standard microperipherals. ASPs will slightly increase because of feature integration (cache TAGs, keyboard controller, floppy controller, and PCMCIA controller).
- Graphics chip volumes have increased dramatically along with PC unit demand, while ASPs have also increased as GUI accelerators have appeared.
- The emergence of video codecs (compression/decompression) and audio control ICs has spurred entirely new growth that transcends the PC market and will move high volumes into consumer products.
- Communications controllers will exhibit good growth because prices have already bottomed on many components and penetration into the PC market and other equipment is steadily increasing.
- Math coprocessors have virtually dissipated their revenue streams and will have little effect as we move forward.
- Mass storage controller growth is slowing because of slowed growth in SCSI penetration as well as integration of controllers into PC core logic.

Programmable Digital Signal Processing (pDSP)

Highlights of the pDSP market are as follows:

- The high growth in the pDSP market is continuing and appears to be a long-term phenomenon. High-speed data communications applications such as modems are still a major element of this strong growth.
- Other communications applications such as cellular telephones are also responsible for accelerating this growth pattern.
- Audio processing and video compression/decompression algorithms are beginning to drive the need for DSP in general, and the programmable variety is capturing many of the early design wins.

Microcomponents Regional Comments

Regional comments regarding the microcomponent market are as follows:

- North American regional consumption of microcomponents has been making a comeback during the last two years, capturing an increasing share of the total market. This is primarily the result of an increase in the portion of microprocessor purchasing (mainly 386/486) in the region of consumption rather than the region of subsystem manufacturing. Though this increase is expected to subside in two years, the addition of onshore manufacturing for future products such as handheld electronic devices and digital video/video products will sustain regional consumption.
- European regional consumption assumes that the continuing trend of Asian companies shipping boards to Europe without MPUs will continue, which results in an increase of microcomponent purchases. This trend, along with strong telecommunications and automotive electronics growth in Europe, will cause European microcomponent consumption to temporarily surpass that of the Asia/Pacific region. As the European PC market saturates, we expect Asia/Pacific growth to quickly pass up Europe in terms of microcomponent consumption.
- Japan has been on a downward trend in its share of the microcomponent market and will at long last begin a recovery in 1996 fueled by telecom, multimedia, and PDAs. Its economic recovery, projected to start next year, also will fuel a regrowth of its domestic consumer market.
- Asia/Pacific-ROW has been steadily increasing its share of microcomponent consumption during the last five years and is projected to continue its growth as a center of manufacturing for electronic systems as well as a region of increasing end-equipment consumption. Key areas of expansion include China and Latin America.

MOS Logic

Highlights of the MOS logic market are as follows:

- Since the previous forecast, the short-term outlook has improved primarily because of the increased value of the yen. Also, the North American market (primarily the computer market) has been stronger than expected.

- North American growth is mainly coming from the data processing market. High-end computers (mainframe and midrange) are being replaced by smaller PCs and workstations, thus there is a shift from ECL to CMOS, which is fueling growth of the MOS logic market. ASIC pricing per gate continues to fall at the same rapid rate as experienced in the past, spurring demand. ASSPs and chipsets continue to negatively impact the ASIC growth rates. Positive market growth in MOS logic is being driven from a variety of sources, including portable computers and workstations; 2.5- and 1.8- inch disk drives; video compression and decompression; digital video (color space conversion and image digitizing); T1 multiplexing, ISDN, and encryption; and 3V and mixed 3/5V systems.
- Devices pulling down overall MOS logic growth are standard logic and full-custom ICs.
- Devices pushing up overall MOS logic growth are FPGAs, gate arrays, and CBICs.

Analog

Highlights of the analog market are as follows:

- Expect a moderate recovery in the consumer market in 1993, with growth mostly going to Asia/Pacific. Japanese dollar growth is largely because of the appreciating yen.
- The strong market in North America for analog ICs is partly because of continuing growth in computers. Growth in most other nonmilitary markets has been good, with telecom and automotive adding considerably to the growth.
- Analog functions such as amplifiers and interface ICs are showing a return to growth as noncomputer markets show more strength.
- Telecom-specific and mass storage-specific ICs are tied to the strength in their respective markets.
- The five-year forecast continues to change in product mix from linear to mixed analog/digital ICs, and the change in regional consumption as nonconsumer equipment becomes of greater importance to the analog market.

Discrete

Highlights of the discrete market are as follows:

- Single-digit growth is because many categories have little growth potential.
- A strong power transistor market, especially, for power MOSFETs and IGBTs, will provide the major growth driver in discrete.

Optoelectronic

Highlights of the optoelectronic market are as follows:

- Optoelectronics is largely consumed by Japanese consumer equipment manufacturers. The result is limited growth in 1993 because of dollar depreciation.

- Increased use of optoelectronic devices in the computer market, such as CD-ROMs and scanners, will help to spur growth and reduce dependency on consumer market toward the outlying years of the forecast interval.

Exchange Rates

Dataquest uses an average annual exchange rate in converting revenue to U.S. dollar values. Table 1 outlines these rates.

Table 1
Exchange Rates

	1992	1993	1994-1997
Japan (Yen/U.S.$)	126.45	110.72	106.07
Europe (ECU/U.S.$)	0.770	0.860	0.889
France (Franc/U.S.$)	4.4507	5.6628	5.8441
Germany (Deutsche Mark/U.S.$)	1.5554	1.6686	1.7172
United Kingdom (U.S.$/Pound Sterling)	1.7694	1.5040	1.5004

Source: Dataquest (October 1993)

Table 2
Revenue from All Semiconductors Shipped to the World for Use in All Applications, 1988-1992 (Millions of U.S. Dollars)

	1988	1989	1990	1991	1992
Total Semiconductor (Including Hybrid ICs)	50,859	54,339	54,545	59,694	65,261
Hybrid ICs	1,462	1,368	1,289	1,395	1,335
Total Semiconductor (Excluding Hybrid ICs)	49,397	52,971	53,256	58,299	63,926
Total IC	39,606	43,245	43,170	47,460	53,083
Bipolar Digital	5,200	4,314	4,173	3,628	3,193
Bipolar Memory	689	460	431	356	318
Bipolar Logic	4,511	3,854	3,742	3,272	2,875
MOS Digital	26,988	31,140	30,152	34,315	39,710
MOS Memory	11,692	15,405	12,128	12,841	15,308
MOS Microcomponent	7,144	7,808	9,584	11,774	14,359
MOS Logic	8,152	7,927	8,440	9,700	10,043
Monolithic Analog	7,418	7,791	8,845	9,517	10,180
Total Discrete	7,612	7,320	7,674	8,035	8,155
Total Optoelectronic	2,179	2,406	2,412	2,804	2,688

Source: Dataquest (October 1993)

Table 3
Revenue from All Semiconductors Shipped to the World for Use in All Applications, 1993-1997 (Millions of U.S. Dollars)

	1993	1994	1995	1996	1997
Total Semiconductor (Including Hybrid ICs)	81,069	93,423	102,608	114,491	133,778
Hybrid ICs	1,438	1,506	1,583	1,747	1,828
Total Semiconductor (Excluding Hybrid ICs)	79,631	91,916	101,024	112,744	131,950
Total IC	67,909	79,266	87,485	98,246	116,285
Bipolar Digital	3,052	2,745	2,455	2,162	1,881
Bipolar Memory	308	239	209	179	146
Bipolar Logic	2,744	2,506	2,246	1,983	1,735
MOS Digital	52,835	63,260	70,357	79,745	96,193
MOS Memory	21,042	25,155	24,702	26,173	31,376
MOS Microcomponent	19,635	24,285	30,665	36,870	45,900
MOS Logic	12,158	13,820	14,990	16,702	18,917
Monolithic Analog	12,022	13,261	14,672	16,339	18,211
Total Discrete	8,910	9,650	10,414	11,169	12,125
Total Optoelectronic	2,813	3,000	3,125	3,329	3,540

Source: Dataquest (October 1993)

Table 4
Revenue Growth from All Semiconductors Shipped to the World for Use in All Applications, 1988-1992 (Percent Change)

	1988	1989	1990	1991	1992
Total Semiconductor (Including Hybrid ICs)	33.0	6.8	0.4	9.4	9.3
Hybrid ICs	14.4	-6.4	-5.8	8.2	-4.3
Total Semiconductor (Excluding Hybrid ICs)	33.6	7.2	0.5	9.5	9.7
Total IC	38.4	9.2	-0.2	9.9	11.8
Bipolar Digital	9.2	-17.0	-3.3	-13.1	-12.0
Bipolar Memory	10.9	-33.2	-6.3	-17.4	-10.7
Bipolar Logic	9.0	-14.6	-2.9	-12.6	-12.1
MOS Digital	54.5	15.4	-3.2	13.8	15.7
MOS Memory	93.1	31.8	-21.3	5.9	19.2
MOS Microcomponent	39.9	9.3	22.7	22.9	22.0
MOS Logic	29.2	-2.8	6.5	14.9	3.5
Monolithic Analog	16.3	5.0	13.5	7.6	7.0
Total Discrete	14.4	-3.8	4.8	4.7	1.5
Total Optoelectronic	27.5	10.4	0.2	16.3	-4.1

Source: Dataquest (October 1993)

Table 5
Revenue Growth from All Semiconductors Shipped to the World for Use in All Applications, 1993-1997 (Percent Change)

	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
Total Semiconductor (Including Hybrid ICs)	24.2	15.2	9.8	11.6	16.8	15.4
Hybrid ICs	7.7	4.8	5.1	10.3	4.6	6.5
Total Semiconductor (Excluding Hybrid ICs)	24.6	15.4	9.9	11.6	17.0	15.6
Total IC	27.9	16.7	10.4	12.3	18.4	17.0
Bipolar Digital	-4.4	-10.1	-10.5	-11.9	-13.0	-10.0
Bipolar Memory	-3.1	-22.4	-12.6	-14.4	-18.4	-14.4
Bipolar Logic	-4.5	-8.7	-10.4	-11.7	-12.5	-9.6
MOS Digital	33.1	19.7	11.2	13.3	20.6	19.4
MOS Memory	37.5	19.5	-1.8	6.0	19.9	15.4
MOS Microcomponent	36.7	23.7	26.3	20.2	24.5	26.2
MOS Logic	21.1	13.7	8.5	11.4	13.3	13.5
Monolithic Analog	18.1	10.3	10.6	11.4	11.5	12.3
Total Discrete	9.3	8.3	7.9	7.2	8.6	8.3
Total Optoelectronic	4.6	6.6	4.2	6.5	6.3	5.7

Source: Dataquest (October 1993)

Table 6
Revenue from All Semiconductors Shipped to North America for Use in All Applications, 1988-1992 (Millions of U.S. Dollars)

	1988	1989	1990	1991	1992
Total Semiconductor (Including Hybrid ICs)	15,844	17,070	16,540	16,990	20,430
Hybrid ICs	240	254	245	245	309
Total Semiconductor (Excluding Hybrid ICs)	15,604	16,816	16,295	16,745	20,121
Total IC	13,575	14,848	14,371	15,024	18,095
Bipolar Digital	2,012	1,635	1,577	1,331	1,232
Bipolar Memory	235	180	160	131	130
Bipolar Logic	1,777	1,455	1,417	1,200	1,102
MOS Digital	9,606	10,988	10,390	11,296	14,174
MOS Memory	4,298	5,772	4,325	4,510	5,707
MOS Microcomponent	2,707	2,796	3,381	3,916	5,282
MOS Logic	2,601	2,420	2,684	2,870	3,185
Monolithic Analog	1,957	2,225	2,404	2,397	2,689
Total Discrete	1,676	1,639	1,611	1,389	1,603
Total Optoelectronic	353	329	313	332	423

Source: Dataquest (October 1993)

Table 7
Revenue from All Semiconductors Shipped to North America for Use in All Applications, 1993-1997 (Millions of U.S. Dollars)

	1993	1994	1995	1996	1997
Total Semiconductor (Including Hybrid ICs)	27,108	32,269	36,273	40,494	49,722
Hybrid ICs	300	270	260	240	240
Total Semiconductor (Excluding Hybrid ICs)	26,808	31,999	36,013	40,254	49,482
Total IC	24,492	29,499	33,393	37,494	46,542
Bipolar Digital	1,165	1,044	932	813	700
Bipolar Memory	122	106	94	78	63
Bipolar Logic	1,043	938	838	735	637
MOS Digital	20,027	24,771	28,362	32,082	40,542
MOS Memory	8,338	10,214	9,731	9,625	12,403
MOS Microcomponent	7,805	10,050	13,750	17,000	22,000
MOS Logic	3,884	4,507	4,881	5,457	6,139
Monolithic Analog	3,300	3,685	4,100	4,600	5,300
Total Discrete	1,881	2,050	2,150	2,250	2,400
Total Optoelectronic	435	450	470	510	540

Source: Dataquest (October 1993)

Table 8
Revenue Growth from All Semiconductors Shipped to North America for Use in All Applications, 1988-1992 (Percent Change)

	1988	1989	1990	1991	1992
Total Semiconductor (Including Hybrid ICs)	23.2	7.7	-3.1	2.7	20.2
Hybrid ICs	22.4	5.8	-3.5	0	26.1
Total Semiconductor (Excluding Hybrid ICs)	23.2	7.8	-3.1	2.8	20.2
Total IC	27.0	9.4	-3.2	4.5	20.4
Bipolar Digital	-4.1	-18.7	-3.6	-15.6	-7.4
Bipolar Memory	-13.3	-23.4	-11.1	-18.1	-0.8
Bipolar Logic	-2.8	-18.1	-2.6	-15.3	-8.2
MOS Digital	42.6	14.4	-5.4	8.7	25.5
MOS Memory	72.1	34.3	-25.1	4.3	26.5
MOS Microcomponent	34.5	3.3	20.9	15.8	34.9
MOS Logic	16.7	-7.0	10.9	6.9	11.0
Monolithic Analog	5.6	13.7	8.0	-0.3	12.2
Total Discrete	2.1	-2.2	-1.7	-13.8	15.4
Total Optoelectronic	7.0	-6.8	-4.9	6.1	27.4

Source: Dataquest (October 1993)

Table 9
Revenue Growth from All Semiconductors Shipped to North America for Use in All Applications, 1993-1997 (Percent Change)

	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
Total Semiconductor (Including Hybrid ICs)	32.7	19.0	12.4	11.6	22.8	19.5
Hybrid ICs	-2.9	-10.0	-3.7	-7.7	0	-4.9
Total Semiconductor (Excluding Hybrid ICs)	33.2	19.4	12.5	11.8	22.9	19.7
Total IC	35.4	20.4	13.2	12.3	24.1	20.8
Bipolar Digital	-5.4	-10.4	-10.7	-12.8	-13.9	-10.7
Bipolar Memory	-6.2	-13.1	-11.3	-17.0	-19.2	-13.5
Bipolar Logic	-5.3	-10.1	-10.6	-12.3	-13.3	-10.4
MOS Digital	41.3	23.7	14.5	13.1	26.4	23.4
MOS Memory	46.1	22.5	-4.7	-1.1	28.9	16.8
MOS Microcomponent	47.8	28.8	36.8	23.6	29.4	33.0
MOS Logic	21.9	16.0	8.3	11.8	12.5	14.0
Monolithic Analog	22.7	11.7	11.3	12.2	15.2	14.5
Total Discrete	17.3	9.0	4.9	4.7	6.7	8.4
Total Optoelectronic	2.8	3.4	4.4	8.5	5.9	5.0

Source: Dataquest (October 1993)

Table 10
Revenue from All Semiconductors Shipped to Japan for Use in All Applications, 1988-1992 (Millions of U.S. Dollars)

	1988	1989	1990	1991	1992
Total Semiconductor (Including Hybrid ICs)	20,772	21,491	20,257	22,496	20,579
Hybrid ICs	900	841	776	860	750
Total Semiconductor (Excluding Hybrid ICs)	19,872	20,650	19,481	21,636	19,829
Total IC	15,227	16,019	15,018	16,417	15,196
Bipolar Digital	1,906	1,648	1,635	1,442	1,154
Bipolar Memory	348	191	194	165	138
Bipolar Logic	1,558	1,457	1,441	1,277	1,016
MOS Digital	10,501	11,636	10,660	11,881	11,139
MOS Memory	4,424	5,629	4,196	4,228	4,037
MOS Microcomponent	2,573	2,662	2,974	3,579	3,269
MOS Logic	3,504	3,345	3,490	4,074	3,833
Monolithic Analog	2,820	2,735	2,723	3,094	2,903
Total Discrete	3,282	3,080	2,969	3,432	3,077
Total Optoelectronic	1,363	1,551	1,494	1,787	1,556
Yen/U.S.$ Exchange Rate	130.00	138.00	144.00	136.00	126.45

Source: Dataquest (October 1993)

Table 11
Revenue from All Semiconductors Shipped to Japan for Use in All Applications, 1993-1997 (Millions of U.S. Dollars)

	1993	1994	1995	1996	1997
Total Semiconductor (Including Hybrid ICs)	23,284	25,332	26,730	29,671	32,581
Hybrid ICs	833	868	919	1,075	1,122
Total Semiconductor (Excluding Hybrid ICs)	22,452	24,463	25,810	28,596	31,459
Total IC	17,554	19,320	20,484	23,024	25,605
Bipolar Digital	1,108	975	866	762	660
Bipolar Memory	139	95	82	73	60
Bipolar Logic	969	880	784	689	600
MOS Digital	13,358	15,049	16,130	18,547	21,061
MOS Memory	4,939	5,618	5,767	6,655	6,988
MOS Microcomponent	3,800	4,350	4,875	5,800	7,250
MOS Logic	4,619	5,081	5,488	6,092	6,823
Monolithic Analog	3,088	3,295	3,488	3,715	3,884
Total Discrete	3,270	3,423	3,573	3,729	3,917
Total Optoelectronic	1,628	1,721	1,754	1,844	1,937
Yen/U.S.$ Exchange Rate	110.72	106.07	106.07	106.07	106.07

Source: Dataquest (October 1993)

Table 12
Revenue Growth from All Semiconductors Shipped to Japan for Use in All Applications, 1988-1992 (U.S.$-Based Percent Change)

	1988	1989	1990	1991	1992
Total Semiconductor (Including Hybrid ICs)	39.2	3.5	-5.7	11.1	-8.5
Hybrid ICs	7.1	-6.6	-7.7	10.8	-12.8
Total Semiconductor (Excluding Hybrid ICs)	41.1	3.9	-5.7	11.1	-8.4
Total IC	46.1	5.2	-6.2	9.3	-7.4
Bipolar Digital	25.1	-13.5	-0.8	-11.8	-20.0
Bipolar Memory	53.3	-45.1	1.6	-14.9	-16.4
Bipolar Logic	20.2	-6.5	-1.1	-11.4	-20.4
MOS Digital	63.5	10.8	-8.4	11.5	-6.2
MOS Memory	95.1	27.2	-25.5	0.8	-4.5
MOS Microcomponent	35.3	3.5	11.7	20.3	-8.7
MOS Logic	55.5	-4.5	4.3	16.7	-5.9
Monolithic Analog	13.9	-3.0	-0.4	13.6	-6.2
Total Discrete	21.9	-6.2	-3.6	15.6	-10.3
Total Optoelectronic	40.4	13.8	-3.7	19.6	-12.9
U.S.$ Appreciation versus Yen (%)	-9.7	6.2	4.3	-5.6	-7.0

Source: Dataquest (October 1993)

Table 13
Revenue Growth from All Semiconductors Shipped to Japan for Use in All Applications, 1993-1997 (U.S.$-Based Percent Change)

	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
Total Semiconductor (Including Hybrid ICs)	13.1	8.8	5.5	11.0	9.8	9.6
Hybrid ICs	11.0	4.3	5.9	16.9	4.4	8.4
Total Semiconductor (Excluding Hybrid ICs)	13.2	9.0	5.5	10.8	10.0	9.7
Total IC	15.5	10.1	6.0	12.4	11.2	11.0
Bipolar Digital	-4.0	-12.0	-11.3	-11.9	-13.5	-10.6
Bipolar Memory	0.7	-31.7	-13.7	-11.0	-17.8	-15.3
Bipolar Logic	-4.6	-9.2	-11.0	-12.0	-13.0	-10.0
MOS Digital	19.9	12.7	7.2	15.0	13.6	13.6
MOS Memory	22.3	13.7	2.7	15.4	5.0	11.6
MOS Microcomponent	16.2	14.5	12.1	19.0	25.0	17.3
MOS Logic	20.5	10.0	8.0	11.0	12.0	12.2
Monolithic Analog	6.4	6.7	5.9	6.5	4.6	6.0
Total Discrete	6.3	4.7	4.4	4.4	5.1	4.9
Total Optoelectronic	4.6	5.7	1.9	5.2	5.1	4.5
U.S. $ Appreciation versus Yen (%)	-12.4	0	0	0	0	-3.5

Source: Dataquest (October 1993)

Table 14
Revenue from All Semiconductors Shipped to Japan for Use in All Applications, 1988-1992 (Billions of Yen)

	1988	1989	1990	1991	1992
Total Semiconductor (Including Hybrid ICs)	2,700	2,966	2,917	3,059	2,602
Hybrid ICs	117	116	112	117	95
Total Semiconductor (Excluding Hybrid ICs)	2,583	2,850	2,805	2,942	2,507
Total IC	1,980	2,211	2,163	2,233	1,922
Bipolar Digital	248	227	235	196	146
Bipolar Memory	45	26	28	22	17
Bipolar Logic	203	201	208	174	128
MOS Digital	1,365	1,606	1,535	1,616	1,409
MOS Memory	575	777	604	575	510
MOS Microcomponent	334	367	428	487	413
MOS Logic	456	462	503	554	485
Monolithic Analog	367	377	392	421	367
Total Discrete	427	425	428	467	389
Total Optoelectronic	177	214	215	243	197
Yen/U.S.$ Exchange Rate	130.00	138.00	144.00	136.00	126.45

Source: Dataquest (October 1993)

Table 15
Revenue from All Semiconductors Shipped to Japan for Use in All Applications, 1993-1997 (Billions of Yen)

	1993	1994	1995	1996	1997
Total Semiconductor (Including Hybrid ICs)	2,565	2,687	2,835	3,147	3,456
Hybrid ICs	92	92	98	114	119
Total Semiconductor (Excluding Hybrid ICs)	2,473	2,595	2,738	3,033	3,337
Total IC	1,933	2,049	2,173	2,442	2,716
Bipolar Digital	122	103	92	81	70
Bipolar Memory	15	10	9	8	6
Bipolar Logic	107	93	83	73	64
MOS Digital	1,471	1,596	1,711	1,967	2,234
MOS Memory	543	596	612	706	741
MOS Microcomponent	419	461	517	615	769
MOS Logic	509	539	582	646	724
Monolithic Analog	341	350	370	394	412
Total Discrete	361	363	379	396	416
Total Optoelectronic	179	183	186	196	206
Yen/U.S.$ Exchange Rate	110.72	106.07	106.07	106.07	106.07

Source: Dataquest (October 1993)

Table 16
Revenue Growth from All Semiconductors Shipped to Japan for Use in All Applications, 1988-1992 (Yen-Based Percent Change)

	1988	1989	1990	1991	1992
Total Semiconductor (Including Hybrid ICs)	25.6	9.8	-1.6	4.9	-14.9
Hybrid ICs	-3.3	-0.8	-3.7	4.7	-18.9
Total Semiconductor (Excluding Hybrid ICs)	27.4	10.3	-1.6	4.9	-14.8
Total IC	31.9	11.7	-2.2	3.2	-13.9
Bipolar Digital	13.0	-8.2	3.5	-16.7	-25.6
Bipolar Memory	38.4	-41.7	6.0	-19.7	-22.2
Bipolar Logic	8.5	-0.7	3.2	-16.3	-26.0
MOS Digital	47.6	17.6	-4.4	5.3	-12.8
MOS Memory	76.1	35.1	-22.2	-4.8	-11.2
MOS Microcomponent	22.1	9.8	16.6	13.7	-15.1
MOS Logic	40.3	1.3	8.9	10.2	-12.5
Monolithic Analog	2.8	3.0	3.9	7.3	-12.8
Total Discrete	10.0	-0.4	0.6	9.2	-16.6
Total Optoelectronic	26.7	20.8	0.5	13.0	-19.0
U.S.$ Appreciation versus Yen (%)	-9.7	6.2	4.3	-5.6	-7.0

Source: Dataquest (October 1993)

Table 17
Revenue Growth from All Semiconductors Shipped to Japan for Use in All Applications, 1993-1997 (Yen-Based Percent Change)

	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
Total Semiconductor (Including Hybrid ICs)	-1.5	4.8	5.5	11.0	9.8	5.8
Hybrid ICs	-3.5	0.7	5.9	16.9	4.4	4.6
Total Semiconductor (Excluding Hybrid ICs)	-1.4	4.9	5.5	10.8	10.0	5.9
Total IC	0.6	6.0	6.0	12.4	11.2	7.2
Bipolar Digital	-16.2	-15.4	-11.3	-11.9	-13.5	-13.7
Bipolar Memory	-12.6	-34.0	-13.7	-11.0	-17.8	-18.3
Bipolar Logic	-16.7	-12.7	-11.0	-12.0	-13.0	-13.1
MOS Digital	4.4	8.5	7.2	15.0	13.6	9.7
MOS Memory	6.4	9.7	2.7	15.4	5.0	7.7
MOS Microcomponent	1.3	10.2	12.1	19.0	25.0	13.2
MOS Logic	5.0	5.9	8.0	11.0	12.0	8.3
Monolithic Analog	-7.2	2.6	5.9	6.5	4.6	2.3
Total Discrete	-7.3	0.7	4.4	4.4	5.1	1.3
Total Optoelectronic	-9.0	1.9	1.9	5.2	5.1	0.9
U.S. $ Appreciation versus Yen (%)	-12.4	0	0	0	0	-3.5

Source: Dataquest (October 1993)

Table 18
Revenue from All Semiconductors Shipped to Europe for Use in All Applications, 1988-1992 (Millions of U.S. Dollars)

	1988	1989	1990	1991	1992
Total Semiconductor (Including Hybrid ICs)	8,491	9,498	10,415	11,014	12,218
Hybrid ICs	117	136	157	178	151
Total Semiconductor (Excluding Hybrid ICs)	8,374	9,362	10,258	10,836	12,067
Total IC	6,552	7,434	7,958	8,523	9,807
Bipolar Digital	772	627	565	486	426
Bipolar Memory	74	71	55	43	38
Bipolar Logic	698	556	510	443	388
MOS Digital	4,364	5,251	5,224	5,853	7,132
MOS Memory	1,797	2,417	2,050	2,129	2,660
MOS Microcomponent	1,212	1,442	1,802	2,082	2,723
MOS Logic	1,355	1,392	1,372	1,642	1,749
Monolithic Analog	1,416	1,556	2,169	2,184	2,249
Total Discrete	1,516	1,574	1,895	1,828	1,826
Total Optoelectronic	306	354	405	485	434
ECU/U.S.$ Exchange Rate	0.846	0.908	0.788	0.811	0.770

Source: Dataquest (October 1993)

Table 19
Revenue from All Semiconductors Shipped to Europe for Use in All Applications, 1993-1997 (Millions of U.S. Dollars)

	1993	1994	1995	1996	1997
Total Semiconductor (Including Hybrid ICs)	15,089	17,113	18,595	20,354	22,557
Hybrid ICs	165	197	210	218	232
Total Semiconductor (Excluding Hybrid ICs)	14,924	16,916	18,385	20,136	22,325
Total IC	12,691	14,533	15,909	17,563	19,585
Bipolar Digital	389	342	295	255	227
Bipolar Memory	35	29	25	21	17
Bipolar Logic	354	313	270	234	210
MOS Digital	9,492	11,219	12,463	13,870	15,689
MOS Memory	3,614	4,337	4,323	4,600	5,322
MOS Microcomponent	3,930	4,760	5,890	6,820	7,600
MOS Logic	1,948	2,122	2,250	2,450	2,767
Monolithic Analog	2,810	2,972	3,151	3,438	3,669
Total Discrete	1,814	1,940	2,027	2,118	2,275
Total Optoelectronic	419	443	449	455	465
ECU/U.S.$ Exchange Rate	0.860	0.889	0.889	0.889	0.889

Source: Dataquest (October 1993)

Table 20
Revenue Growth from All Semiconductors Shipped to Europe for Use in All Applications, 1988-1992 (U.S.$-Based Percent Change)

	1988	1989	1990	1991	1992
Total Semiconductor (Including Hybrid ICs)	30.7	11.9	9.7	5.8	10.9
Hybrid ICs	18.2	16.2	15.4	13.4	-15.2
Total Semiconductor (Excluding Hybrid ICs)	30.9	11.8	9.6	5.6	11.4
Total IC	38.2	13.5	7.0	7.1	15.1
Bipolar Digital	6.2	-18.8	-9.9	-14.0	-12.3
Bipolar Memory	-15.9	-4.1	-22.5	-21.8	-11.6
Bipolar Logic	9.2	-20.3	-8.3	-13.1	-12.4
MOS Digital	58.1	20.3	-0.5	12.0	21.9
MOS Memory	110.4	34.5	-15.2	3.9	24.9
MOS Microcomponent	50.6	19.0	25.0	15.5	30.8
MOS Logic	23.0	2.7	-1.4	19.7	6.5
Monolithic Analog	13.0	9.9	39.4	0.7	3.0
Total Discrete	10.1	3.8	20.4	-3.5	-0.1
Total Optoelectronic	8.9	15.7	14.4	19.8	-10.5
U.S.$ Appreciation versus ECU (%)	-2.5	7.3	-13.2	2.9	-5.0

Source: Dataquest (October 1993)

Table 21
Revenue Growth from All Semiconductors Shipped to Europe for Use in All Applications, 1993-1997 (U.S.$-Based Percent Change)

	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
Total Semiconductor (Including Hybrid ICs)	23.5	13.4	8.7	9.5	10.8	13.0
Hybrid ICs	9.3	19.4	6.6	3.8	6.4	9.0
Total Semiconductor (Excluding Hybrid ICs)	23.7	13.3	8.7	9.5	10.9	13.1
Total IC	29.4	14.5	9.5	10.4	11.5	14.8
Bipolar Digital	-8.7	-12.1	-13.7	-13.6	-11.0	-11.8
Bipolar Memory	-7.9	-17.1	-13.8	-16.0	-19.0	-14.9
Bipolar Logic	-8.8	-11.6	-13.7	-13.3	-10.3	-11.6
MOS Digital	33.1	18.2	11.1	11.3	13.1	17.1
MOS Memory	35.9	20.0	-0.3	6.4	15.7	14.9
MOS Microcomponent	44.3	21.1	23.7	15.8	11.4	22.8
MOS Logic	11.4	8.9	6.0	8.9	12.9	9.6
Monolithic Analog	24.9	5.8	6.0	9.1	6.7	10.3
Total Discrete	-0.7	6.9	4.5	4.5	7.4	4.5
Total Optoelectronic	-3.5	5.7	1.4	1.3	2.2	1.4
U.S.$ Appreciation versus ECU (%)	11.7	0	0	0	0	2.9

Source: Dataquest (October 1993)

Table 22
Revenue from All Semiconductors Shipped to Europe for Use in All Applications, 1988-1992 (Millions of ECU)

	1988	1989	1990	1991	1992
Total Semiconductor (Including Hybrid ICs)	7,183	8,624	8,207	8,932	9,411
Hybrid ICs	99	123	124	144	116
Total Semiconductor (Excluding Hybrid ICs)	7,084	8,501	8,083	8,788	9,295
Total IC	5,543	6,750	6,271	6,912	7,554
Bipolar Digital	653	569	445	394	328
Bipolar Memory	63	64	43	35	29
Bipolar Logic	591	505	402	359	299
MOS Digital	3,692	4,768	4,117	4,747	5,493
MOS Memory	1,520	2,195	1,615	1,727	2,049
MOS Microcomponent	1,025	1,309	1,420	1,689	2,097
MOS Logic	1,146	1,264	1,081	1,332	1,347
Monolithic Analog	1,198	1,413	1,709	1,771	1,732
Total Discrete	1,283	1,429	1,493	1,483	1,406
Total Optoelectronic	259	321	319	393	334
ECU/U.S.$ Exchange Rate	0.846	0.908	0.788	0.811	0.770

Source: Dataquest (October 1993)

Table 23
Revenue from All Semiconductors Shipped to Europe for Use in All Applications, 1993-1997 (Millions of ECU)

	1993	1994	1995	1996	1997
Total Semiconductor (Including Hybrid ICs)	12,980	15,213	16,531	18,095	20,053
Hybrid ICs	142	175	187	194	206
Total Semiconductor (Excluding Hybrid ICs)	12,838	15,038	16,344	17,901	19,847
Total IC	10,920	12,920	14,143	15,614	17,411
Bipolar Digital	334	304	262	227	202
Bipolar Memory	30	26	22	19	15
Bipolar Logic	304	278	240	208	187
MOS Digital	8,172	9,974	11,080	12,330	13,948
MOS Memory	3,118	3,856	3,843	4,089	4,731
MOS Microcomponent	3,377	4,232	5,236	6,063	6,756
MOS Logic	1,676	1,886	2,000	2,178	2,460
Monolithic Analog	2,414	2,642	2,801	3,056	3,262
Total Discrete	1,558	1,725	1,802	1,883	2,022
Total Optoelectronic	360	394	399	404	413
ECU/U.S.$ Exchange Rate	0.860	0.889	0.889	0.889	0.889

Source: Dataquest (October 1993)

Table 24
Revenue Growth from All Semiconductors Shipped to Europe for Use in All Applications, 1988-1992 (ECU-Based Percent Change)

	1988	1989	1990	1991	1992
Total Semiconductor (Including Hybrid ICs)	27.4	20.1	-4.8	8.8	5.4
Hybrid ICs	15.2	24.8	0.2	16.7	-19.4
Total Semiconductor (Excluding Hybrid ICs)	27.5	20.0	-4.9	8.7	5.8
Total IC	34.7	21.8	-7.1	10.2	9.3
Bipolar Digital	3.5	-12.8	-21.8	-11.5	-16.8
Bipolar Memory	-18.0	3.0	-32.8	-19.5	-16.1
Bipolar Logic	6.5	-14.5	-20.4	-10.6	-16.8
MOS Digital	54.1	29.1	-13.7	15.3	15.7
MOS Memory	105.1	44.4	-26.4	6.9	18.7
MOS Microcomponent	46.7	27.7	8.5	18.9	24.2
MOS Logic	19.8	10.3	-14.5	23.2	1.2
Monolithic Analog	10.1	17.9	21.0	3.6	-2.2
Total Discrete	7.3	11.4	4.5	-0.7	-5.1
Total Optoelectronic	6.1	24.2	-0.7	23.2	-15.0
U.S.$ Appreciation versus ECU (%)	-2.5	7.3	-13.2	2.9	-5.0

Source: Dataquest (October 1993)

Table 25
Revenue Growth from All Semiconductors Shipped to Europe for Use in All Applications, 1993-1997 (ECU-Based Percent Change)

	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
Total Semiconductor (Including Hybrid ICs)	37.9	17.2	8.7	9.5	10.8	16.3
Hybrid ICs	21.9	23.6	6.6	3.8	6.4	12.1
Total Semiconductor (Excluding Hybrid ICs)	38.1	17.1	8.7	9.5	10.9	16.4
Total IC	44.6	18.3	9.5	10.4	11.5	18.2
Bipolar Digital	1.8	-9.0	-13.7	-13.6	-11.0	-9.3
Bipolar Memory	2.6	-14.1	-13.8	-16.0	-19.0	-12.4
Bipolar Logic	1.7	-8.5	-13.7	-13.3	-10.3	-9.0
MOS Digital	48.8	22.0	11.1	11.3	13.1	20.5
MOS Memory	52.2	23.7	-0.3	6.4	15.7	18.2
MOS Microcomponent	61.0	25.3	23.7	15.8	11.4	26.4
MOS Logic	24.4	12.5	6.0	8.9	12.9	12.8
Monolithic Analog	39.3	9.5	6.0	9.1	6.7	13.5
Total Discrete	10.8	10.7	4.5	4.5	7.4	7.5
Total Optoelectronic	7.7	9.4	1.4	1.3	2.2	4.3
U.S.$ Appreciation versus ECU (%)	11.7	0	0	0	0	2.9

Source: Dataquest (October 1993)

Table 26
Revenue from All Semiconductors Shipped to Asia/Pacific-Rest of World for Use in All Applications, 1988-1992 (Millions of U.S. Dollars)

	1988	1989	1990	1991	1992
Total Semiconductor (Including Hybrid ICs)	5,752	6,280	7,333	9,194	12,034
Hybrid ICs	205	137	111	112	125
Total Semiconductor (Excluding Hybrid ICs)	5,547	6,143	7,222	9,082	11,909
Total IC	4,252	4,944	5,823	7,496	9,985
Bipolar Digital	510	404	396	369	381
Bipolar Memory	32	18	22	17	12
Bipolar Logic	478	386	374	352	369
MOS Digital	2,517	3,265	3,878	5,285	7,265
MOS Memory	1,173	1,587	1,557	1,974	2,904
MOS Microcomponent	652	908	1,427	2,197	3,085
MOS Logic	692	770	894	1,114	1,276
Monolithic Analog	1,225	1,275	1,549	1,842	2,339
Total Discrete	1,138	1,027	1,199	1,386	1,649
Total Optoelectronic	157	172	200	200	275

Source: Dataquest (October 1993)

Table 27
Revenue from All Semiconductors Shipped to Asia/Pacific-Rest of World for Use in All Applications, 1993-1997 (Millions of U.S. Dollars)

	1993	1994	1995	1996	1997
Total Semiconductor (Including Hybrid ICs)	15,588	18,709	21,010	23,971	28,918
Hybrid ICs	140	171	194	214	234
Total Semiconductor (Excluding Hybrid ICs)	15,448	18,538	20,816	23,757	28,684
Total IC	13,172	15,914	17,699	20,165	24,553
Bipolar Digital	390	384	363	332	294
Bipolar Memory	12	9	8	7	6
Bipolar Logic	378	375	355	325	288
MOS Digital	9,958	12,221	13,403	15,247	18,901
MOS Memory	4,151	4,986	4,881	5,293	6,663
MOS Microcomponent	4,100	5,125	6,150	7,250	9,050
MOS Logic	1,707	2,110	2,372	2,704	3,188
Monolithic Analog	2,824	3,309	3,933	4,586	5,358
Total Discrete	1,945	2,237	2,664	3,072	3,533
Total Optoelectronic	331	386	453	520	598

Source: Dataquest (October 1993)

Table 28
Revenue Growth from All Semiconductors Shipped to Asia/Pacific-Rest of World for Use in All Applications, 1988-1992 (Percent Change)

	1988	1989	1990	1991	1992
Total Semiconductor (Including Hybrid ICs)	45.0	9.2	16.8	25.4	30.9
Hybrid ICs	43.4	-33.2	-19.0	0.9	11.6
Total Semiconductor (Excluding Hybrid ICs)	45.0	10.7	17.6	25.8	31.1
Total IC	54.4	16.3	17.8	28.7	33.2
Bipolar Digital	24.1	-20.8	-2.0	-6.8	3.3
Bipolar Memory	-8.5	-43.8	22.2	-22.7	-29.4
Bipolar Logic	27.1	-19.2	-3.1	-5.9	4.8
MOS Digital	62.4	29.7	18.8	36.3	37.5
MOS Memory	168.4	35.3	-1.9	26.8	47.1
MOS Microcomponent	67.8	39.3	57.2	54.0	40.4
MOS Logic	-4.4	11.3	16.1	24.6	14.5
Monolithic Analog	54.3	4.1	21.5	18.9	27.0
Total Discrete	20.7	-9.8	16.7	15.6	19.0
Total Optoelectronic	23.6	9.6	16.3	0	37.5

Source: Dataquest (October 1993)

Table 29
Revenue Growth from All Semiconductors Shipped to Asia/Pacific-Rest of World for Use in All Applications, 1993-1997 (Percent Change)

	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
Total Semiconductor (Including Hybrid ICs)	29.5	20.0	12.3	14.1	20.6	19.2
Hybrid ICs	12.0	22.1	13.5	10.3	9.3	13.4
Total Semiconductor (Excluding Hybrid ICs)	29.7	20.0	12.3	14.1	20.7	19.2
Total IC	31.9	20.8	11.2	13.9	21.8	19.7
Bipolar Digital	2.4	-1.6	-5.4	-8.5	-11.4	-5.1
Bipolar Memory	0.0	-25.0	-11.1	-12.5	-14.3	-12.9
Bipolar Logic	2.4	-0.8	-5.3	-8.5	-11.4	-4.8
MOS Digital	37.1	22.7	9.7	13.8	24.0	21.1
MOS Memory	42.9	20.1	-2.1	8.4	25.9	18.1
MOS Microcomponent	32.9	25.0	20.0	17.9	24.8	24.0
MOS Logic	33.8	23.6	12.4	14.0	17.9	20.1
Monolithic Analog	20.7	17.2	18.8	16.6	16.8	18.0
Total Discrete	17.9	15.0	19.1	15.3	15.0	16.5
Total Optoelectronic	20.3	16.8	17.2	14.9	15.0	16.8

Source: Dataquest (October 1993)

For More Information...

Terrance A. Birkholz, Market Research Analyst .... (408) 437-8196
Via fax .... (408) 437-0292

Dataquest®
a company of The Dun & Bradstreet Corporation

Dataquest®

a company of
The Dun & Bradstreet Corporation

Corporate Headquarters
Dataquest Incorporated
1290 Ridder Park Drive
San Jose, California 95131-2398
United States
Phone: 01-408-437-8000
Facsimile: 01-408-437-0292

Dataquest Incorporated
550 Cochituate Road
Framingham, Massachusetts 01701-9324
United States
Phone: 01-508-370-5555
Facsimile: 01-508-370-6262

Invitational Computer Conferences (ICC)
3990 Westerly Place, Suite 100
Newport Beach, California 92660
United States
Phone: (714) 476-9117
Facsimile: (714) 476-9969

Dataquest Japan Limited
Shinkawa Sanko Building
1-3-17, Shinkawa, Chuo-ku
Tokyo 104
Japan
Phone: 81-3-5566-0411
Facsimile: 81-3-5566-0425

Dataquest Korea
Trade Tower, Suite 3806
159 Samsung-dong
Kangnam-gu, Seoul 135-729
Korea
Phone: 011-82-2-551-1331
Facsimile: 011-82-2-551-1330

European Headquarters
Dataquest Europe Limited
Roussel House, Broadwater Park
Denham, Uxbridge
Middlesex UB9 5HP
England
Phone: 44-895-835050
Facsimile: 44-895-835260/1

Dataquest GmbH
Kronstadter Strasse 9
8000 Munich 80
Germany
Phone: 011-49-89-930-9090
Facsimile: 011-49-89-930-3277

Dataquest Europe SA
Tour Gallieni 2
36, Avenue du General de Gaulle
93175 Bagnolet Cedex
France
Phone: 011-33-1-48-97-3100
Facsimile: 011-33-1-48-97-3400

Representative Agencies in
Bangkok, Hong Kong,
Kronberg, North Sydney,
Singapore, Taipei, and Tel Aviv

NU1SEM1WW SCNDWWM59302 BH: 1
Mr. Clark Fuhs
Dataquest Incorporated

****
SJ - INTERNAL DISTRIBUTION
****

Dataquest®

Semiconductors

Worldwide MOS Memory Forecast

Market Statistics

1993 Preliminary

Program: Memories Worldwide
Product Code: MMRY-WW-MS-9301
Publication Date: March 22, 1993

Dataquest®

Semiconductors

Worldwide MOS Memory Forecast

Market Statistics

1993 Preliminary

Program: Memories Worldwide
Product Code: MMRY-WW-MS-9301
Publication Date: March 22, 1993

Table of Contents

List of Tables

Note: All tables show estimated data.

List of Tables (Continued)

Note: All tables show estimated data.

Chapter 1
Worldwide MOS Memory

Introduction

This document contains detailed information on Dataquest's current view of the MOS memory market. Included in this document is:

- 1993-1997 MOS memory forecast

Analyses of the MOS memory market provide insight into high-technology markets and reinforce estimates of consumption, production, and company revenue.

More detailed data on this market may be requested through our client inquiry service. Dataquest's qualitative analysis of these data can be found within the *Dataquest Perspectives* located within the binder of the same name.

Segmentation

This section defines the market segments that are specific to this document. For a complete description of all market segments tracked by Dataquest, please refer to Dataquest's *Semiconductor Market Definitions* guide.

Dataquest defines the MOS memory market as DRAM, SRAM, EPROM, ROM, EEPROM, flash memory, and other MOS memory (OMM). In this volume, Dataquest segments the MOS memory market by product type and density according to the following scheme:

- DRAM (densities from 64K through 256Mb)
- Fast SRAM (densities from 16K through 16Mb), separated into five speed categories
- Slow SRAM (densities from 16K through 16Mb), including conventional and pseudo-SRAM
- EPROM (densities from 16K through 16Mb)
- ROM (densities from 32K through 256Mb)
- EEPROM (densities from 256b through 1Mb)
- Flash memory (densities from 256K through 128Mb)
- Other MOS memory

Definitions

This section lists the definitions that are used by Dataquest to present the data in this document. Complete definitions for all Dataquest terms can be found in Dataquest's *Semiconductor Market Definitions* guide.

Product Definitions

DRAM: Includes Dynamic RAM, Multiport-DRAM (M-DRAM), and Video-DRAM (VRAM). DRAMs have memory cells consisting of a single transistor, and require regular externally cycled memory cell refreshes. This category also includes new architecture DRAMs (NADs) such as Rambus, Cache, Enhanced, and Synchronous DRAMs. These are volatile memories and addressing is multiplexed.

SRAM: Includes Static RAM, Multiport-SRAM (M-SRAM), Battery Backed-Up SRAM (BB-SRAM), and Pseudo-SRAM (PSRAM). SRAMs have memory cells consisting of a minimum of four transistors (PSRAMs have memory cells consisting of a single transistor and are similar to DRAMs). SRAMs do not require externally cycled memory cell refreshes. These are volatile memories and addressing is not multiplexed (except in the case of PSRAM). Note that color palette digital-to-analog converters are included in the mixed-signal data converter category.

EPROM: Erasable Programmable Read-Only Memory. This product classification includes Ultraviolet EPROM (UV EPROM) and One-Time Programmable Read-Only Memory (OTP ROM). EPROMs have memory cells consisting of a single transistor, and do not require any memory cell refreshes. These devices are nonvolatile memories.

Flash Memory: Includes nonvolatile products designed as Flash EPROM/EEPROM that incorporate either 5V or 12V programming supplies and one-transistor (1T) or two-transistor (2T) memory cells with electrical programming and fast bulk/chip erase. Flash memory can only erase data by bulk/chip, not by byte. These devices are nonvolatile memories.

Mask ROM: Mask-Programmable Read-Only Memory. Mask ROM is a form of memory that is programmed by the manufacturer to a user specification using a mask step. Mask ROM is programmed in hardware rather than software. These devices are nonvolatile memories.

EEPROM: Electronically Erasable Programmable Read-Only Memory. Included are Serial EEPROM (S-EEPROM), Parallel EEPROM (P-EEPROM), and Electronically Alterable Read-Only Memory (EAROM). EEPROMs have memory cells consisting of a minimum of two transistors, and do not require memory cell refreshes. This product classification also includes Nonvolatile RAM (NV-RAM), also known as Shadow RAM. These latter semiconductor products are a combination of SRAM and EEPROM technologies in each memory cell. The EEPROM functions as a shadow backup for the SRAM when power is lost. These devices are nonvolatile memories.

Other MOS Memory: Includes all other MOS digital memory not already accounted for in the preceding categories. OMM include MOS digital content-addressable memory (CAM), MOS digital cache-tag RAM, MOS digital first-in/first-out memory (FIFO), MOS digital last-in/first-out memory (LIFO), and ferroelectric memory.

Line Item Definitions

Revenue: Calculated by multiplying a product's overall unit shipment total by the product's ASP.

Unit shipments: All unit shipments, both merchant and captive, for memory suppliers selling to the merchant market; excludes totally captive suppliers, where devices are manufactured solely for the company's own use.

Average selling price (ASP): The average billing price per unit that is paid for a product when it leaves the factory; takes into account discounts given to the distribution channel and multiple-purchase discounts; prices are averaged over all companies, package types, lot sizes, and the entire speed mix, and they represent sales to both military and commercial accounts.

Number of bits: Calculated by multiplying a product's unit shipment total by the number of bits that a single unit of that product contains.

Price per bit (PPB): Calculated by dividing a product's ASP by the number of bits that a single unit of that product contains. This number is reported in microdollars; there are 1 million microdollars per U.S. dollar. For an overall product category (for example, DRAM), this metric is calculated by dividing the category's total revenue by its total number of bits.

Worldwide Economic Growth Outlook

Semiconductor Industry Assumptions

The North American semiconductor market continues to strengthen. Dataquest expects the North American market to grow 20.1 percent in 1993, up from a strong 19.3 percent in 1992. According to the latest WSTS statistics, total semiconductor bookings (three-month moving average) growth for the three months ended in January was 39.3 percent above year-earlier bookings, compared with 40.5 percent in December. Total semiconductor billings growth for the same period was 28.8 percent above year-earlier billings, compared with 31.0 percent in December.

Strength in the North American market can be attributed largely to the continuing strong recovery of the U.S. economy, and especially with respect to investment spending. The Dun & Bradstreet Corporation expects real (that is, inflation adjusted) business fixed investment on equipment to grow 13.1 percent in 1993, compared with 7.3 percent in 1992. In particular, chip demand stems from strong orders of portable PCs, client/server computers, and network hardware.

Dataquest expects the Japanese market to expand at a 6.9 percent dollar-based rate of growth (or 6.0 percent yen-based growth, assuming 0.8 percent depreciation of the U.S.$ against the yen) in 1993, after a 6.4 percent dollar-based (or 13.3 percent yen-based) contraction in 1992. The latest market statistics support this modest outlook. The dollar value of total semiconductor billings for the three months ended in December was 4.8 percent below year-earlier billings and decelerating. The bookings picture is a bit more hopeful: Total semiconductor bookings for the same period were 1.5 percent below year-earlier levels.

Japan's situation is due to more than just weakness in its European export market. Other factors include a heightened level of international competition in chips and systems, rising costs of capital in Japan, and a dearth of new, *high-volume, quick-adoption-rate* consumer electronics systems (for example, VCRs). Dataquest does not expect an improvement in Japan's export market to quickly and painlessly alleviate its structural problems in 1993.

Dataquest forecast the European market to expand at a 13.1 percent dollar-based rate of growth (or 25.8 percent ECU-based growth, assuming 11.2 percent appreciation of the U.S.$ against the ECU) in 1993, up from 12.0 percent dollar-based (or 3.5 percent ECU-based) expansion in 1992. Total semiconductor billings for the three months ended in January were 19.2 percent above year-earlier billings. Total semiconductor bookings for the same period were 36.1 percent above year-earlier levels. The second half of 1992 was characterized by a steep acceleration in billings and bookings growth, with actual growth significantly overshooting trend or equilibrium growth. Further, bookings and billings growth peaked at 48.5 percent and 25.5 percent, respectively, in the fourth quarter. Therefore, Dataquest expects the first half of 1993 to be characterized by robust but decelerating growth converging toward stability in the second half.

Recovery of the U.K. and French economies will help offset—but not completely—decelerating growth in Germany. PC manufacture in Ireland is strong, and much of the growth in the United Kingdom is related to multinational companies increasing their data processing and consumer equipment production. Investment in telecommunications infrastructure and the introduction of GSM mobile cellular phones also provide growth stimulus.

Dataquest forecasts the Asia/Pacific-ROW market to grow 27.6 percent in 1993, accelerating mildly from 25.8 percent growth in 1992. Again, the latest statistics support this outlook. Total semiconductor bookings growth for the three months ended in December was

46.3 percent above year-earlier bookings, compared with 49.7 percent in November. Similar to Europe, the second half of 1992 was characterized by a steep acceleration in bookings growth, with actual growth significantly overshooting trend or equilibrium growth. Therefore, the first half of 1993 likely will be a period of decelerating (but robust) growth converging toward equilibrium. Total semiconductor billings growth for December was 36.9 percent above year-earlier billings. Billings growth will probably peak in the late first-quarter/early-second-quarter period, and stabilize during the second half of 1993. Expansion continues to be driven by foreign and domestic investment and improvement in Western export market conditions.

Forecast Economic Assumptions

Dun & Bradstreet forecasts a mix of accelerating and decelerating positive growth in 1993 for the Group of Seven (G7) Countries.

The U.S., Canadian, Japanese, and U.K. economies are expected to grow at an accelerating pace in 1993. Though modest in comparison with historical rates of expansion during recovery periods, the benefit is that inflationary pressures likely will be held in check, thus helping sustain the expansion's duration. Growth rate forecasts, which assume constant prices and exchange rates, and local currencies, are as follows:

- U.S. real gross domestic product (GDP) is forecast to grow 2.7 percent in 1993, up from 1.9 percent in 1992; and to grow 2.7 percent in 1994.
- Canadian real GDP is forecast to grow 3.0 percent in 1993, up from 1.1 percent in 1992; and to grow 3.4 percent in 1994.
- Japanese real GDP is forecast to grow 2.3 percent in 1993, up from 1.8 percent in 1992; and to grow 3.4 percent in 1994.
- U.K. real GDP is forecast to grow 1.0 percent in 1993, up from a 0.8 percent contraction in 1992; and to grow 2.0 percent in 1994.

On the other hand, the German, French, and Italian economies are expected to experience decelerating growth in 1993. Chief among the moderating influences on growth prospects is the continuing cost burden of Germany's reunification. Forecasts for the German, French, and Italian economies are as follows:

- German real GDP is forecast to grow 0.5 percent in 1993, down from 0.8 percent in 1992; and to grow 2.5 percent in 1994.
- French real GDP is forecast to grow 1.3 percent in 1993, down from 2.0 percent in 1992; and to grow 2.5 percent in 1994.
- Italian real GDP is forecast to grow 0.9 percent in 1993, down from 1.1 percent in 1992; and to grow 1.6 percent in 1994.

Exchange Rates

Dataquest utilizes an average annual exchange rate in converting revenue to U.S. dollar amounts. Table 1-1 shows these rates for 1990 through 1992.

Table 1-1
Exchange Rates

	1990	1991	1992
Japan (Yen/U.S.$)	144.00	135.00	125.95
France (Franc/U.S.$)	5.4421	5.6377	5.1433
Germany (Deutsche Mark/U.S.$)	1.6150	1.6584	1.5179
United Kingdom (U.S.$/Pound Sterling)	1.7859	1.7674	1.8481

Source: Dataquest (March 1993)

Forecast Methodology

Dataquest publishes five-year unit shipments and factory revenue forecasts for the MOS memory market. In doing so, Dataquest utilizes a variety of forecasting techniques (both qualitative and quantitative) that vary by technology area. An overview of Dataquest forecasting techniques can be found in the *Dataquest Research Methodology* document.

MOS Memory Forecast Methodology

The following is Dataquest's MOS memory forecast methodology:

- Survey the leading memory vendors throughout the year for company expectations, as well as for their views of the markets that they participate in.
- Examine statistics provided by a number of industry organizations (such as WSTS and MITI) for up-to-date monthly trends.
- Perform time-series analysis.
- Research demand-side trends such as system sales, add-in demand, and application requirements.
- Monitor supply-side trends such as bit growth projections, new product developments, and general changes in the industry structure.

Tables 1-2 through 1-6 detail semiconductor memory shipments for 1990 through 1997.

Notes to Forecast Tables

Readers should keep the following notes in mind about the tables in this document:

- In 1991, Dataquest began to subdivide its existing classification of SRAMs. SRAMs now are divided into five speed categories: 0-9ns; 10-19ns; 20-44ns; 45-70ns; and greater than 70ns.
- The overall revenue figures contained in this volume may differ from the *Dataquest Semiconductor Consumption Forecast* soon to be published, which also includes a MOS memory line item. This situation has occurred because the *Worldwide MOS Memory Forecast* document incorporates more recent information and much more detailed data. Although we are aware that these discrepancies may be inconvenient, it is our goal to provide our clients with the most accurate data available at the time of publication.

Table 1-2
Factory Revenue from Shipments of Semiconductor Memory to the World, 1990-1997
(Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
DRAM	6,437	6,849	8,566	12,050	15,476	13,394	14,457	18,143	16.2
SRAM	2,434	2,569	2,815	3,452	4,240	4,437	5,343	6,383	17.8
EPROM	1,446	1,362	1,243	1,224	1,185	1,137	1,044	955	-5.1
Flash	35	120	249	565	1,203	1,894	2,536	2,745	61.6
ROM	1,132	1,198	1,208	1,345	1,416	1,571	1,692	1,839	8.8
EEPROM	292	326	378	468	516	552	566	623	10.5
OMM	174	212	187	228	241	247	258	271	7.7
Total	11,949	12,637	14,647	19,332	24,277	23,233	25,897	30,960	16.1
Percent Change	-20.2	5.8	15.9	32.0	25.6	-4.3	11.5	19.5	

Source: Dataquest (March 1993)

Table 1-3
Shipments of Semiconductor Memory to the World, 1990-1997
(Millions of Units)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
DRAM	1,336	1,286	1,488	1,594	1,432	1,217	1,237	1,291	-2.8
SRAM	620	704	928	732	794	724	786	993	1.4
EPROM	424	476	423	423	417	408	392	362	-3.1
Flash	3	12	27	71	152	241	350	437	74.0
ROM	315	383	366	370	319	277	255	238	-8.2
EEPROM	127	213	300	384	457	548	599	685	17.9
OMM	27	32	33	39	41	43	43	45	6.2
Total	2,852	3,105	3,566	3,613	3,611	3,457	3,662	4,051	2.6
Percent Change	4.7	8.9	14.9	1.3	0	-4.3	5.9	10.6	

Source: Dataquest (March 1993)

Table 1-4
Average Selling Price for Shipments of Semiconductor Memory to the World, 1990-1997 (U.S. Dollars)

	1990	1991	1992	1993	1994	1995	1996	1997
DRAM	4.82	5.33	5.75	7.56	10.81	11.00	11.69	14.05
SRAM	3.92	3.65	3.03	4.72	5.34	6.13	6.80	6.43
EPROM	3.41	2.86	2.94	2.89	2.84	2.79	2.66	2.64
Flash	13.23	10.13	9.10	7.98	7.94	7.87	7.25	6.28
ROM	3.59	3.12	3.30	3.63	4.44	5.68	6.63	7.72
EEPROM	2.30	1.53	1.26	1.22	1.13	1.01	0.95	0.91
OMM	6.55	6.70	5.65	5.85	5.90	5.80	5.95	6.05
Average	4.19	4.07	4.11	5.35	6.72	6.72	7.07	7.64
Percent Change	-23.8	-2.9	0.9	30.3	25.6	0	5.2	8.1

Source: Dataquest (March 1993)

Table 1-5
Bits from Shipments of Semiconductor Memory to the World, 1990-1997 (Trillions of Bits)*

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
DRAM	964	1,535	2,838	4,398	6,897	9,015	13,168	18,605	45.7
SRAM	91	127	233	409	635	910	1,503	2,475	60.4
EPROM	182	221	262	301	360	414	437	471	12.5
Flash	2	10	29	82	322	768	1,679	2,534	144.6
ROM	682	955	1,153	1,760	2,354	3,661	5,330	7,543	45.6
EEPROM	1	2	3	4	5	6	7	9	26.7
OMM	0	0	0	0	0	0	0	0	NM
Total	1,922	2,850	4,518	6,954	10,573	14,775	22,124	31,638	47.6
Percent Change	50.9	48.3	58.5	53.9	52.0	39.7	49.7	43.0	

NM = Not meaningful
*Trillion = 1.0×10^{12}
Source: Dataquest (March 1993)

Table 1-6
Price per Bit for Shipments of Semiconductor Memory to the World, 1990-1997 (Microdollars)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
DRAM	6.7	4.5	3.0	2.7	2.2	1.5	1.1	1.0	-20.2
SRAM	26.9	20.2	12.1	8.4	6.7	4.9	3.6	2.6	-26.6
EPROM	7.9	6.2	4.7	4.1	3.3	2.8	2.4	2.0	-15.7
Flash	21.0	11.5	8.6	6.9	3.7	2.5	1.5	1.1	-33.9
ROM	1.7	1.3	1.0	0.8	0.6	0.4	0.3	0.2	-25.3
EEPROM	224.0	153.8	134.2	117.4	101.3	90.1	78.5	67.5	-12.8
OMM	1,169.6	1,155.2	911.3	914.1	842.9	773.3	743.8	711.8	-4.8
Average	6.2	4.4	3.2	2.8	2.3	1.6	1.2	1.0	-21.3
Percent Change	-47.1	-28.7	-26.9	-14.2	-17.4	-31.5	-25.6	-16.4	

Source: Dataquest (March 1993)

Chapter 2
DRAM Forecast Assumptions

Review of 1992

The DRAM market never really slowed down as the year wore on. With strong demand continuing as excess capacity shrank, plus the October Surprise of the high preliminary antidumping margins, an element of cautionary uncertainty was introduced in a market that had been steadily approaching supply-demand balance for several months. Price declines stopped, unit volumes raced past the marker in the road, and the DRAM market for 1992 exceeded all expectations. Everything was in place but the profits, which were noticeably absent for virtually every DRAM supplier.

Vendors were unable (because of weak profitability) and reluctant (because of weak or uncertain profit prospects) to add anything but a minimal amount of DRAM capacity as the year wore on. Only in the fourth quarter were production rates increased. Most DRAM suppliers' capacity programs at the beginning of 1993 were directed only at finishing what had been begun in 1990-1992.

Outlook for 1993-1994

The following sections describe several important factors emerging for 1993.

Antidumping Settlement

The U.S. Department of Commerce ruling in the antidumping charges—with final dumping margins—was expected March 15 and will be followed by damages claims being investigated by the International Trade Commission (ITC). The ITC ruling is scheduled to be announced April 18. Until then, Korean DRAM makers must continue to post a bond to bring DRAMs into the United States. Many expect a suspension agreement to be agreed to before the final rulings are due. On February 9, the European Community settled with Korean vendors over a similar dumping suit, and agreed to a price monitoring system similar to the U.S.-Japanese Semiconductor Trade Agreement, but differing from the existing Japanese-European Reference Price System.

Demand Shows No Signs of Abating

Strong personal computer-led growth continued into the first months of 1993. Both Intel and Advanced Micro Devices (AMD) expect record sales in 1993 of 486- and 386-type MPUs. Intel's fourth quarter results were outstanding. Discussion following the results—bolstered by comments made in Intel's first quarter meeting for security analysts—put forecasts for the Intel 486 are 25 million to 29 million units shipped in 1993. AMD, picking up the lagging edge with its 386 business, will be a 486 player later in the second half. Texas Instruments (TI) and Cyrix are shipping 486-like products.

Average memory configurations for 486 machines are running from 4MB to 6MB per unit, up strongly from 1992, to serve the Windows environment. First in 1988-1989, and increasingly in the present PC boom, software is the DRAM market driver and Microsoft's Bill Gates is the hero of the day for DRAM makers.

Though economically still weak, Japan has a PC market showing signs of domestically repeating the same vicious price cutting the rest of the world has endured for the past 18 months. Dell, Compaq Computer Corporation, Apple, Digital Equipment Corporation, and IBM all have introduced low-price models into the Japanese market, and NEC has countered with price reductions and new DOS-compatible products.

On the supply front, weak capital spending by the Japanese in 1990-1992 has limited their ability to address better-than-expected DRAM demand. The prospects for other significant DRAM makers are mixed: TI has capacity at Acer (Taiwan), in Italy (Avezzano), and new facilities in Japan (KTI). IBM appears to be headed for some difficulty supplying its own needs with the strong PC growth and its desire to service some of the merchant DRAM market as well. Micron Technology has had capacity limited for some time. The Koreans are hamstrung (for the time being) by the Micron antidumping suit, whose settlement (probably in the second quarter) will clear the air and could allow DRAM makers to go full speed for production. However, all are moving forward with substantial capacity expansions, mainly 200mm lines that surely will make DRAMs.

The posture of the new U.S. administration toward trade certainly will get a good test when the Micron DRAM dumping case ultimately is settled. It may be interested in establishing its hard-line philosophy right from the start, and not want to be viewed as caving in to the Koreans. If it does not balance the interests of users and suppliers, this ruling could have far-reaching consequences in the DRAM marketplace.

This uncertainty aside, in all likelihood the DRAM shipment numbers forecast for 1993 will be governed by the ability to supply such a volume (that is, limited supply). As ever, DRAM makers will have to allocate either for 16Mb or for 4Mb DRAM. For others, there also will be allocation issues to be decided among other profitable products (such as TI or IBM making 486s).

Long-Term Outlook

Although bit growth rates have not been changed much since the last Dataquest forecast (August 1992), the true impact of software is proving to be difficult to estimate. The 80 percent growth in DRAM bits shipped from 1991 to 1992 was a surprise to almost everyone, and a level not seen since 1988. Clearly, though, the PC nominally is the DRAM market driver and the hardware is merely the means to implement the power of the software, which runs with a mind of its own, seemingly without limits or consideration for the amount of memory required. The belief that the year-to-year DRAM bit growth would decline from its recent annual average of about 60 percent to 30 or 40 percent annual growth by the year 2000 may be in need of a serious review as the role of software is better understood.

In this forecast revision, as well, forward pricing was brought closer into line with the historic experience curve of the past 12 to 15 years. We have raised some of the forecast average selling prices for 16Mb and 64Mb DRAMs for the later years.

Tables 2-1 through 2-5 detail DRAM shipments for 1990 through 1997.

Table 2-1
Factory Revenue from Shipments of DRAMs to the World, 1990-1997
(Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
64K	38	20	20	6	0	0	0	0	NM
256K	1,208	527	182	116	88	56	24	16	-38.5
256K VRAM	116	94	175	97	64	34	20	16	-38.1
1Mb	4,098	3,564	2,447	1,881	650	264	170	121	-45.2
1Mb VRAM	134	212	431	394	244	174	112	80	-28.6
2Mb VRAM	0	0	24	99	171	150	142	91	30.7
4Mb	844	2,400	5,069	8,058	7,515	4,225	2,420	1,553	-21.1
4Mb VRAM	0	0	1	34	144	156	232	252	228.4
16Mb	0	33	216	1,365	6,600	8,280	10,888	12,615	125.6
64Mb	0	0	0	0	0	55	450	3,400	NM
Total	6,437	6,849	8,566	12,050	15,476	13,394	14,457	18,143	16.2
Percent Change	-22.7	6.4	25.1	40.7	28.4	-13.4	7.9	25.5	

NM = Not meaningful
Source: Dataquest (March 1993)

Table 2-2
Shipments of DRAMs to the World, 1990-1997
(Millions of Units)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
64K	26	14	15	5	0	0	0	0	NM
256K	565	254	130	80	55	35	15	10	-40.1
256K VRAM	55	45	66	43	32	17	10	8	-34.5
1Mb	644	788	760	570	200	80	50	35	-46.0
1Mb VRAM	21	47	64	75	56	42	28	20	-20.7
2Mb VRAM	0	0	1	9	18	21	21	14	58.5
4Mb	24	138	450	790	900	650	440	270	-9.7
4Mb VRAM	0	0	0	1	6	12	20	24	365.3
16Mb	0	0	2	21	165	360	650	870	241.3
64Mb	0	0	0	0	0	0	3	40	NM
Total	1,336	1,286	1,488	1,594	1,432	1,217	1,237	1,291	-2.8
Percent Change	6.5	-3.7	15.7	7.1	-10.1	-15.0	1.6	4.4	

NM = Not meaningful
Source: Dataquest (March 1993)

Table 2-3
Average Selling Price for Shipments of DRAMs to the World, 1990-1997
(U.S. Dollars)

	1990	1991	1992	1993	1994	1995	1996	1997
64K	1.48	1.48	1.34	1.28	-	-	-	-
256K	2.14	2.07	1.40	1.45	1.60	1.60	1.60	1.60
256K VRAM	2.10	2.08	2.65	2.25	2.00	2.00	2.00	2.00
1Mb	6.36	4.52	3.22	3.30	3.25	3.30	3.40	3.45
1Mb VRAM	6.29	4.49	6.75	5.25	4.35	4.15	4.00	4.00
2Mb VRAM	-	-	17.00	11.65	9.50	7.15	6.75	6.50
4Mb	34.59	17.43	11.27	10.20	8.35	6.50	5.50	5.75
4Mb VRAM	-	-	60.00	28.00	24.00	13.00	11.60	10.50
16Mb	-	246.60	114.99	65.00	40.00	23.00	16.75	14.50
64Mb	-	-	-	-	-	275.00	150.00	85.00
Average	4.82	5.33	5.75	7.56	10.81	11.00	11.69	14.05
Percent Change	-27.4	10.5	8.0	31.4	42.9	1.8	6.2	20.2

Source: Dataquest (March 1993)

Table 2-4
Bits from Shipments of DRAMs to the World, 1990-1997
(Trillions of Bits)*

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
64K	2	1	1	0	0	0	0	0	NM
256K	148	67	34	21	14	9	4	3	-40.1
256K VRAM	14	12	17	11	8	4	3	2	-34.5
1Mb	675	826	797	598	210	84	52	37	-46.0
1Mb VRAM	22	50	67	79	59	44	29	21	-20.7
2Mb VRAM	0	0	3	18	38	44	44	29	58.5
4Mb	102	577	1,887	3,314	3,775	2,726	1,845	1,132	-9.7
4Mb VRAM	0	0	0	5	25	50	84	101	365.3
16Mb	0	2	32	352	2,768	6,040	10,905	14,596	241.3
64Mb	0	0	0	0	0	13	201	2,684	NM
Total	964	1,535	2,838	4,398	6,897	9,015	13,168	18,605	45.7
Percent Change	50.2	59.2	84.9	54.9	56.8	30.7	46.1	41.3	

NM = Not meaningful
*Trillion = 1.0×10^{12}
Source: Dataquest (March 1993)

Table 2-5
Price per Bit for Shipments of DRAMs to the World, 1990-1997
(Microdollars)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
64K	22.6	22.5	20.4	19.5	-	-	-	-	NM
256K	8.1	7.9	5.3	5.5	6.1	6.1	6.1	6.1	2.7
256K VRAM	8.0	7.9	10.1	8.6	7.6	7.6	7.6	7.6	-5.4
1Mb	6.1	4.3	3.1	3.1	3.1	3.1	3.2	3.3	1.4
1Mb VRAM	6.0	4.3	6.4	5.0	4.1	4.0	3.8	3.8	-9.9
2Mb VRAM	-	-	8.1	5.6	4.5	3.4	3.2	3.1	-17.5
4Mb	8.2	4.2	2.7	2.4	2.0	1.5	1.3	1.4	-12.6
4Mb VRAM	-	-	14.3	6.7	5.7	3.1	2.8	2.5	-29.4
16Mb	-	14.7	6.9	3.9	2.4	1.4	1.0	0.9	-33.9
64Mb	-	-	-	-	-	4.1	2.2	1.3	NM
Average	6.7	4.5	3.0	2.7	2.2	1.5	1.1	1.0	-20.2
Percent Change	-48.5	-33.2	-32.4	-9.2	-18.1	-33.8	-26.1	-11.2	

NM = Not meaningful

Source: Dataquest (March 1993)

Chapter 3
SRAM Forecast Assumptions

Assumptions behind the 1993 preliminary SRAM forecast are as follows:

- We are due for a correction in 1993. The extended life of the 64K device will correct itself and fall into line with historical end-of-life trends. Designs that use high volumes of 64K will convert in 1993 to the 256K density. This is shown in the forecast as an increase in revenue simultaneous with a decrease in unit shipments.
- Three different markets exist: slow, which begins at the present time at about 45ns; fast, which is anything that is not slow or pseudo-SRAM; and pseudo.
- Pseudo-SRAMs are not forecast to be made obsolete by self-refreshed bytewide DRAMs, although this is likely to happen at a time that cannot be determined. These devices are equivalent except for their pin rotation. Limited acceptance is expected for pseudo-SRAMs for the long term.
- Cache memories built from discrete SRAMs will continue to find a home in most computer systems, despite competition from processors with built-in cache, DRAMs with built-in cache, chip sets and other cache controllers with built-in cache, and exotic, high-speed DRAM interface mechanisms. The reasons for this stem from basic computer architecture, through the price-per-bit of integrated versus discrete SRAM, to simple market differentiation through cache as an option. Cache applications in PCs will be the most important driver of fast SRAM growth.
- Slow SRAMs will move along the same path as has been followed since their inception: to serve as inexpensive storage in an enormous variety of applications, with the lower densities being absorbed into application-specific controllers, ASICs, and microcontrollers. For the purposes of the forecast, "slow" SRAMs comprise both the old "slow" category of devices slower than 70ns, and the 45-70ns category.
- Markets for slow SRAMs comprise consumer goods (video games, camcorders), office equipment (fax machines, autodialers), telecommunications (pagers, central office switches), instrumentation (bar code readers, heart rate monitors), computing equipment (hard disk drives, modems) and wide variety of other applications. Because all of these markets are expected to pick up on a worldwide basis in 1993, the outlook for slow SRAMs also is bright.
- Overall bit growth will loosely parallel that of DRAMs, as has happened in the past decade.

Tables 3-1 through 3-5 detail SRAM shipments for 1990 through 1997.

Table 3-1
Factory Revenue from Shipments of SRAMs to the World, 1990-1997
(Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
16K 10-19ns	0	5	5	1	1	0	0	0	-46.5
16K 20-44ns	0	33	29	9	5	4	2	1	-47.6
16K 45-70ns	0	13	7	4	3	2	2	1	-35.5
16K <70ns	77	0	0	0	0	0	0	0	NM
16K >70ns	117	63	70	13	7	3	3	2	-52.2
64K 0-9ns	0	0	3	30	26	9	3	2	-8.3
64K 10-19ns	0	42	32	20	16	9	5	4	-34.7
64K 20-44ns	0	235	124	79	54	28	16	12	-37.3
64K 45-70ns	0	63	57	30	22	12	7	5	-37.5
64K <70ns	380	0	0	0	0	0	0	0	NM
64K >70ns	368	317	384	82	44	15	8	5	-58.0
64K >70ns PSRAM	3	6	6	3	1	0	0	0	NM
128K >70ns	0	0	4	0	0	0	0	0	NM
256K 0-9ns	0	0	1	131	174	114	80	62	112.9
256K 10-19ns	0	46	34	93	166	94	84	65	13.6
256K 20-44ns	0	273	246	292	424	280	205	238	-0.7
256K 45-70ns	0	58	68	104	152	104	83	87	5.1
256K <70ns	341	0	0	0	0	0	0	0	NM
256K >70ns	703	718	694	327	239	99	68	0	NM
256K >70ns PSRAM	97	162	108	139	103	60	20	36	-19.6
512K 20-44ns	0	0	2	0	0	0	0	0	NM
1Mb 0-9ns	0	0	12	30	18	72	87	139	63.4
1Mb 10-19ns	0	110	51	88	149	303	347	380	49.5
1Mb 20-44ns	0	45	156	285	339	865	766	751	37.0
1Mb 45-70ns	0	59	157	161	188	364	260	309	14.5
1Mb <70ns	69	0	0	0	0	0	0	0	NM
1Mb >70ns	191	244	459	991	899	309	277	175	-17.5
1Mb >70ns PSRAM	87	61	46	72	80	84	74	45	-0.5

(Continued)

Table 3-1 (Continued)
Factory Revenue from Shipments of SRAMs to the World, 1990-1997
(Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
4Mb 0-9ns	0	0	0	0	0	50	78	122	NM
4Mb 10-19ns	0	0	0	25	74	245	327	528	NM
4Mb 20-44ns	0	0	0	29	69	227	222	357	NM
4Mb 45-70ns	0	0	0	244	202	434	297	479	NM
4Mb >70ns	0	0	20	97	629	471	270	326	74.8
4Mb >70ns PSRAM	0	14	40	76	144	136	141	158	31.8
16Mb 0-9ns	0	0	0	0	0	0	0	120	NM
16Mb 10-19ns	0	0	0	0	0	0	760	705	NM
16Mb 20-44ns	0	0	0	0	0	0	405	356	NM
16Mb 45-70ns	0	0	0	0	0	0	340	428	NM
16Mb >70ns	0	0	0	0	0	0	35	336	NM
16Mb >70ns PSRAM	0	0	0	0	13	43	71	150	NM
Total	2,434	2,569	2,815	3,452	4,240	4,437	5,343	6,383	17.8
Percent Change	-26.9	5.6	9.6	22.6	22.8	4.6	20.4	19.5	

NM = Not meaningful
Source: Dataquest (March 1993)

Table 3-2
Shipments of SRAMs to the World, 1990-1997
(Millions of Units)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
16K 10-19ns	0	2	2	0	0	0	0	0	-42.0
16K 20-44ns	0	14	13	4	3	3	2	1	-41.1
16K 45-70ns	0	10	6	3	2	2	1	1	-36.7
16K <70ns	32	0	0	0	0	0	0	0	NM
16K >70ns	91	90	88	13	7	2	1	1	-61.9
64K 0-9ns	0	0	0	2	3	2	1	1	31.7
64K 10-19ns	0	10	11	7	6	4	2	2	-30.6
64K 20-44ns	0	65	75	40	30	15	9	7	-38.7
64K 45-70ns	0	30	31	18	13	7	4	3	-37.4
64K <70ns	69	0	0	0	0	0	0	0	NM
64K >70ns	200	186	220	63	28	9	5	3	-58.2
64K >70ns PSRAM	2	4	4	2	1	0	0	0	NM
128K >70ns	0	0	2	0	0	0	0	0	NM
256K 0-9ns	0	0	0	3	12	11	13	10	223.0
256K 10-19ns	0	2	4	12	26	23	24	19	36.3
256K 20-44ns	0	28	62	96	141	93	68	53	-3.0
256K 45-70ns	0	11	21	35	53	36	28	22	1.1
256K <70ns	21	0	0	0	0	0	0	0	NM
256K >70ns	168	180	248	119	89	36	23	0	NM
256K >70ns PSRAM	23	41	54	69	59	35	11	18	-19.6
512K 20-44ns	0	0	0	0	0	0	0	0	NM
1Mb 0-9ns	0	0	0	0	0	4	9	14	171.1
1Mb 10-19ns	0	1	1	4	10	36	58	93	152.4
1Mb 20-44ns	0	1	9	25	40	132	156	250	96.1
1Mb 45-70ns	0	2	14	21	30	67	67	107	49.5
1Mb <70ns	1	0	0	0	0	0	0	0	NM
1Mb >70ns	6	18	50	152	152	69	75	63	4.6
1Mb >70ns PSRAM	7	9	12	26	30	30	28	23	12.8

(Continued)

Table 3-2 (Continued)
Shipments of SRAMs to the World, 1990-1997
(Millions of Units)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
4Mb 0-9ns	0	0	0	0	0	1	2	3	NM
4Mb 10-19ns	0	0	0	0	1	7	22	35	NM
4Mb 20-44ns	0	0	0	0	2	13	31	50	NM
4Mb 45-70ns	0	0	0	4	7	28	45	72	NM
4Mb >70ns	0	0	0	2	24	35	49	60	210.2
4Mb >70ns PSRAM	0	1	4	11	24	24	35	40	59.8
16Mb 0-9ns	0	0	0	0	0	0	0	0	NM
16Mb 10-19ns	0	0	0	0	0	0	2	5	NM
16Mb 20-44ns	0	0	0	0	0	0	3	7	NM
16Mb 45-70ns	0	0	0	0	0	0	4	10	NM
16Mb >70ns	0	0	0	0	0	0	1	8	NM
16Mb >70ns PSRAM	0	0	0	0	1	3	7	17	NM
Total	620	704	928	732	794	724	786	993	1.4
Percent Change	-1.6	13.4	31.9	-21.2	8.5	-8.8	8.5	26.4	

NM = Not meaningful
Source: Dataquest (March 1993)

Table 3-3
Average Selling Price for Shipments of SRAMs to the World, 1990-1997
(U.S. Dollars)

	1990	1991	1992	1993	1994	1995	1996	1997
16K 10-19ns	-	3.30	3.00	2.50	2.25	2.10	2.00	2.00
16K 20-44ns	-	2.40	2.25	2.00	1.60	1.40	1.25	1.25
16K 45-70ns	-	1.25	1.25	1.25	1.25	1.25	1.25	1.38
16K <70ns	2.44	-	-	-	-	-	-	-
16K >70ns	1.28	0.70	0.80	1.00	1.00	1.50	2.50	2.50
64K 0-9ns	-	-	17.12	15.00	10.00	4.75	2.80	2.80
64K 10-19ns	-	4.18	3.04	2.75	2.50	2.50	2.25	2.25
64K 20-44ns	-	3.63	1.66	2.00	1.80	1.90	1.85	1.85
64K 45-70ns	-	2.11	1.82	1.65	1.70	1.80	1.80	1.80
64K <70ns	5.49	-	-	-	-	-	-	-
64K >70ns	1.84	1.70	1.75	1.30	1.60	1.70	1.80	1.80
64K >70ns PSRAM	1.88	1.72	1.45	1.30	1.20	1.30	-	-
128K >70ns	-	-	2.80	-	-	-	-	-
256K 0-9ns	-	-	48.26	45.00	15.00	10.00	6.00	6.00
256K 10-19ns	-	24.31	8.73	8.00	6.50	4.10	3.50	3.50
256K 20-44ns	-	9.71	4.01	3.05	3.00	3.00	3.00	4.50
256K 45-70ns	-	5.33	3.30	3.00	2.85	2.90	2.95	4.00
256K <70ns	15.94	-	-	-	-	-	-	-
256K >70ns	4.18	4.00	2.80	2.75	2.70	2.80	-	-
256K >70ns PSRAM	4.19	4.00	2.00	2.00	1.75	1.70	1.80	2.00
512K 20-44ns	-	-	18.05	-	-	-	-	-
1Mb 0-9ns	-	-	125.79	150.00	45.00	20.00	10.00	10.00
1Mb 10-19ns	-	200.00	56.28	22.00	14.35	8.50	6.00	4.10
1Mb 20-44ns	-	46.94	18.05	11.50	8.55	6.55	4.90	3.00
1Mb 45-70ns	-	25.47	11.00	7.75	6.35	5.45	3.90	2.90
1Mb <70ns	68.78	-	-	-	-	-	-	-
1Mb >70ns	30.76	13.39	9.20	6.50	5.90	4.50	3.70	2.80
1Mb >70ns PSRAM	12.29	6.50	3.75	2.75	2.70	2.80	2.60	2.00
4Mb 0-9ns	-	-	-	-	-	100.00	39.00	38.00
4Mb 10-19ns	-	-	-	125.00	67.00	34.00	15.00	15.00
4Mb 20-44ns	-	-	-	72.00	30.00	18.00	7.20	7.20
4Mb 45-70ns	-	-	-	66.00	28.00	15.50	6.65	6.65
4Mb >70ns	-	-	95.00	42.00	26.00	13.50	5.50	5.40
4Mb >70ns PSRAM	-	13.54	10.50	7.00	6.00	5.60	4.05	4.00

(Continued)

Table 3-3 (Continued)
Average Selling Price for Shipments of SRAMs to the World, 1990-1997
(U.S. Dollars)

	1990	1991	1992	1993	1994	1995	1996	1997
16Mb 0-9ns	-	-	-	-	-	-	-	300.00
16Mb 10-19ns	-	-	-	-	-	-	400.00	150.00
16Mb 20-44ns	-	-	-	-	-	-	150.00	54.00
16Mb 45-70ns	-	-	-	-	-	-	85.00	45.00
16Mb >70ns	-	-	-	-	-	-	50.00	40.00
16Mb >70ns PSRAM	-	-	-	-	26.10	17.15	10.00	9.00
Average	3.92	3.65	3.03	4.72	5.34	6.13	6.80	6.43
Percent Change	-25.7	-6.9	-16.9	55.5	13.2	14.8	10.9	-5.5

Source: Dataquest (March 1993)

Table 3-4
Bits from Shipments of SRAMs to the World, 1990-1997
(Trillions of Bits)*

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
16K 10-19ns	0	0	0	0	0	0	0	0	NM
16K 20-44ns	0	0	0	0	0	0	0	0	NM
16K 45-70ns	0	0	0	0	0	0	0	0	NM
16K <70ns	1	0	0	0	0	0	0	0	NM
16K >70ns	1	1	1	0	0	0	0	0	-61.9
64K 0-9ns	0	0	0	0	0	0	0	0	NM
64K 10-19ns	0	1	1	0	0	0	0	0	-30.6
64K 20-44ns	0	4	5	3	2	1	1	0	-38.7
64K 45-70ns	0	2	2	1	1	0	0	0	-37.4
64K <70ns	5	0	0	0	0	0	0	0	NM
64K >70ns	13	12	14	4	2	1	0	0	-58.2
64K >70ns PSRAM	0	0	0	0	0	0	0	0	NM
128K >70ns	0	0	0	0	0	0	0	0	NM
256K 0-9ns	0	0	0	1	3	3	4	3	223.0
256K 10-19ns	0	1	1	3	7	6	6	5	36.3
256K 20-44ns	0	7	16	25	37	24	18	14	-3.0
256K 45-70ns	0	3	5	9	14	9	7	6	1.1
256K <70ns	6	0	0	0	0	0	0	0	NM
256K >70ns	44	47	65	31	23	9	6	0	NM
256K >70ns PSRAM	6	11	14	18	15	9	3	5	-19.6
512K 20-44ns	0	0	0	0	0	0	0	0	NM
1Mb 0-9ns	0	0	0	0	0	4	9	15	171.1
1Mb 10-19ns	0	1	1	4	11	37	61	97	152.4
1Mb 20-44ns	0	1	9	26	42	139	164	262	96.1
1Mb 45-70ns	0	2	15	22	31	70	70	112	49.5
1Mb <70ns	1	0	0	0	0	0	0	0	NM
1Mb >70ns	7	19	52	160	160	72	79	66	4.6
1Mb >70ns PSRAM	7	10	13	27	31	32	30	24	12.8

(Continued)

Table 3-4 (Continued)
Bits from Shipments of SRAMs to the World, 1990-1997
(Trillions of Bits)*

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
4Mb 0-9ns	0	0	0	0	0	2	8	13	NM
4Mb 10-19ns	0	0	0	1	5	30	91	148	NM
4Mb 20-44ns	0	0	0	2	10	53	129	208	NM
4Mb 45-70ns	0	0	0	16	30	117	187	302	NM
4Mb >70ns	0	0	1	10	102	146	206	253	210.2
4Mb >70ns PSRAM	0	4	16	45	101	102	146	166	59.8
16Mb 0-9ns	0	0	0	0	0	0	3	7	NM
16Mb 10-19ns	0	0	0	0	0	0	32	79	NM
16Mb 20-44ns	0	0	0	0	0	0	45	111	NM
16Mb 45-70ns	0	0	0	0	0	0	67	159	NM
16Mb >70ns	0	0	0	0	0	0	12	141	NM
16Mb >70ns PSRAM	0	0	0	0	8	42	119	280	NM
Total	91	127	233	409	635	910	1,503	2,475	60.4
Percent Change	24.9	40.3	83.5	75.3	55.3	43.4	65.2	64.6	

NM = Not meaningful
*Trillion = 1.0×10^{12}
Source: Dataquest (March 1993)

Table 3-5
Price per Bit for Shipments of SRAMs to the World, 1990-1997
(Microdollars)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
16K 10-19ns	-	201.4	183.1	152.6	137.3	128.2	122.1	122.1	-7.8
16K 20-44ns	-	146.5	137.3	122.1	97.7	85.4	76.3	76.3	-11.1
16K 45-70ns	-	76.3	76.3	76.3	76.3	76.3	76.3	83.9	1.9
16K <70ns	148.9	-	-	-	-	-	-	-	NM
16K >70ns	78.4	42.7	48.8	61.0	61.0	91.6	152.6	152.6	25.6
64K 0-9ns	-	-	261.2	228.9	152.6	72.5	42.7	42.7	-30.4
64K 10-19ns	-	63.7	46.4	42.0	38.1	38.1	34.3	34.3	-5.8
64K 20-44ns	-	55.3	25.4	30.5	27.5	29.0	28.2	28.2	2.2
64K 45-70ns	-	32.3	27.7	25.2	25.9	27.5	27.5	27.5	0.2
64K <70ns	83.8	-	-	-	-	-	-	-	NM
64K >70ns	28.1	26.0	26.7	19.8	24.4	25.9	27.5	27.5	0.6
64K >70ns PSRAM	28.6	26.2	22.1	19.8	18.3	19.8	-	-	NM
128K >70ns	-	-	21.4	-	-	-	-	-	NM
256K 0-9ns	-	-	184.1	171.7	57.2	38.1	22.9	22.9	-34.1
256K 10-19ns	-	92.7	33.3	30.5	24.8	15.6	13.4	13.4	-16.7
256K 20-44ns	-	37.1	15.3	11.6	11.4	11.4	11.4	17.2	2.4
256K 45-70ns	-	20.3	12.6	11.4	10.9	11.1	11.3	15.3	3.9
256K <70ns	60.8	-	-	-	-	-	-	-	NM
256K >70ns	15.9	15.3	10.7	10.5	10.3	10.7	11.3	-	NM
256K >70ns PSRAM	16.0	15.3	7.6	7.6	6.7	6.5	6.9	7.6	0
512K 20-44ns	-	-	34.4	-	-	-	-	-	NM
1Mb 0-9ns	-	-	120.0	143.1	42.9	19.1	9.5	9.5	-39.7
1Mb 10-19ns	-	190.7	53.7	21.0	13.7	8.1	5.7	3.9	-40.8
1Mb 20-44ns	-	44.8	17.2	11.0	8.2	6.2	4.7	2.9	-30.2
1Mb 45-70ns	-	24.3	10.5	7.4	6.1	5.2	3.7	2.8	-23.4
1Mb <70ns	65.6	-	-	-	-	-	-	-	NM
1Mb >70ns	29.3	12.8	8.8	6.2	5.6	4.3	3.5	2.7	-21.2
1Mb >70ns PSRAM	11.7	6.2	3.6	2.6	2.6	2.7	2.5	1.9	-11.8

(Continued)

Table 3-5 (Continued)
Price per Bit for Shipments of SRAMs to the World, 1990-1997
(Microdollars)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
4Mb 0-9ns	-	-	-	-	-	23.8	9.3	9.1	NM
4Mb 10-19ns	-	-	-	29.8	16.0	8.1	3.6	3.6	NM
4Mb 20-44ns	-	-	-	17.2	7.2	4.3	1.7	1.7	NM
4Mb 45-70ns	-	-	-	15.7	6.7	3.7	1.6	1.6	NM
4Mb >70ns	-	-	22.6	10.0	6.2	3.2	1.3	1.3	-43.6
4Mb >70ns PSRAM	-	3.2	2.5	1.7	1.4	1.3	1.0	1.0	-17.6
16Mb 0-9ns	-	-	-	-	-	-	-	17.9	NM
16Mb 10-19ns	-	-	-	-	-	-	23.8	8.9	NM
16Mb 20-44ns	-	-	-	-	-	-	8.9	3.2	NM
16Mb 45-70ns	-	-	-	-	-	-	5.1	2.7	NM
16Mb >70ns	-	-	-	-	-	-	3.0	2.4	NM
16Mb >70ns PSRAM	-	-	-	-	1.6	1.0	0.6	0.5	NM
Average	26.9	20.2	12.1	8.4	6.7	4.9	3.6	2.6	-26.6
Percent Change	-41.5	-24.7	-40.3	-30.1	-20.9	-27.0	-27.1	-27.4	

NM = Not meaningful
Source: Dataquest (March 1993)

Chapter 4
Nonvolatile Memory Forecast Assumptions

EPROM Forecast Assumptions

Overall EPROM consumption declined in 1992 in line with our expectations. Production levels declined as Intel pulled back from that market in favor of flash memory. AMD, despite earlier indications, found itself in a constrained supply position as it allocated more capacity to flash memory. The result was firmer prices for most products. The future is still clouded regarding high-density EPROM development and production. SGS-Thomson introduced an 8Mb device, but demand for high-density EPROMs does not exist. This should not be confused with high-density flash, because the applications are different. Demand for program/code space—the primary use of EPROMs—is not growing beyond the current generation of 1Mb to 4Mb EPROMs. If and when such demand materializes, we believe that flash will be the solution.

Tables 4-1 through 4-5 detail EPROM shipments for 1990 through 1997.

Flash Memory Forecast Assumptions

Intel, the largest player in this market, suffered a major setback when production plans for its 8Mb and 2Mb products fell far short of projections. The primary reason was that Intel's foundry, NMB Semiconductor, was unable to bring up the process/products as expected. The effect was havoc in the marketplace. Customers that had already designed the 8Mb flash into new systems found themselves with no real alternative. AMD was the major beneficiary of this production snafu. A window of opportunity also appeared for other players to enter the flash memory market. Furthermore, new partnerships flourished as companies re-evaluated flash's potential and their options.

Tables 4-6 through 4-10 detail flash memory shipments for 1990 through 1997.

ROM Memory Forecast Assumptions

The following assumptions apply to ROM:

- ROM applications will be driven by a continually decreasing price per bit. High-density ROMs will not be justified by the size required by the code contained in an application. The size of ROMs is growing faster than the size of the programs contained within them. Current coded renditions of graphics will yield to larger and larger compressed, then digitized, versions of the same graphics as the cost of doing so becomes manageable to the firmware vendor. Likewise, compressed sound will yield to less compressed versions that offer higher fidelity at the cost of higher bit consumption.
- Consumer applications will continue to use the lion's share of ROMs. This market is driven by the cost-sensitivity of such applications, and

is made feasible by the high volumes consumed in this market, where nonrecurring setup charges can be defrayed over a large number of units. Programmable and reprogrammable technologies will continue to be chosen wherever unit costs are of less importance than initial costs (barriers to entry) and flexibility.

- Low-density ROMs will continue to be absorbed into microcontrollers or ASICs as reduced line geometries make this a viable alternative, from a cost standpoint. This trend is the mechanism that causes the less dense devices to become obsolete.
- Price per bit will open new opportunities. Manufacturing efficiencies will determine each contributor's well being in the ROM market.
- Half densities (128K, 512K, 2Mb, 8Mb, and 32Mb, among others) will gain in market share over their current minority position.
- Applications for ROMs will continue to be far-flung.
- The economy will impact the bit growth rate of ROMs more strongly than it will their ASPs.
- The ROM market is not seriously threatened by other nonvolatile technologies such as flash memory because ROMs will continue to offer a lower cost per bit than any other semiconductor memory technology. Other nonvolatile technologies will coexist with ROM and may even create new opportunities for ROM applications.

Tables 4-11 through 4-15 detail ROM shipments for 1990 through 1997.

EEPROM Memory Forecast Assumptions

Serial EEPROMs proved that they are here to stay, and grew quickly. This segment is not threatened by flash memory. Serial EEPROMs are used in consumer and telecommunications applications extensively. Their low price and small package makes them attractive for holding small amounts of data where nonvolatility is a requirement. The 64K segment also grew substantially with increasing demand from telecommunications applications. As we have indicated, the long-term future of high-density EEPROMs is bleak. Barring any new technological miracles, the high-density EEPROM segment should disappear.

Tables 4-16 through 4-20 detail EEPROM shipments for 1990 through 1997.

Table 4-1
Factory Revenue from Shipments of EPROMs to the World, 1990-1997
(Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
16K	13	12	12	10	8	7	5	3	-25.8
32K	18	25	23	17	14	11	8	5	-25.7
64K	88	100	69	60	50	44	38	28	-16.6
128K	103	75	41	40	32	28	26	22	-11.8
256K	361	450	314	297	247	184	140	132	-15.9
512K	279	205	236	188	154	125	110	75	-20.4
1Mb	480	299	241	283	264	309	313	260	1.5
2Mb	70	100	131	158	204	199	146	129	-0.4
4Mb	35	97	176	162	160	163	170	191	1.7
8Mb	0	0	0	9	48	54	63	69	NM
16Mb	0	0	0	0	4	15	25	41	NM
Total	1,446	1,362	1,243	1,224	1,185	1,137	1,044	955	-5.1
Percent Change	-20.1	-5.8	-8.8	-1.5	-3.2	-4.0	-8.2	-8.5	

NM = Not meaningful
Source: Dataquest (March 1993)

Table 4-2
Shipments of EPROMs to the World, 1990-1997
(Millions of Units)

	1990	1991	1992	1993	1994	1995	1996	1997	1992-1997 CAGR (%)
16K	6	5	6	5	4	4	3	2	-23.1
32K	8	11	10	8	7	5	4	3	-23.9
64K	39	57	41	37	32	29	25	18	-15.1
128K	46	42	27	25	20	18	15	13	-14.4
256K	158	205	149	145	130	105	93	88	-10.0
512K	98	72	89	75	69	60	55	43	-13.5
1Mb	64	66	69	82	91	112	125	118	11.4
2Mb	5	12	19	31	45	51	40	39	14.9
4Mb	1	6	14	15	18	22	27	32	18.5
8Mb	0	0	0	0	2	3	4	6	NM
16Mb	0	0	0	0	0	1	1	2	NM
Total	424	476	423	423	417	408	392	362	-3.1
Percent Change	5.5	12.3	-11.1	0.1	-1.4	-2.2	-4.0	-7.6	

NM = Not meaningful
Source: Dataquest (March 1993)

Table 4-3
Average Selling Price for Shipments of EPROMs to the World, 1990-1997
(U.S. Dollars)

	1990	1991	1992	1993	1994	1995	1996	1997
16K	2.15	2.24	2.20	2.15	2.10	2.00	1.90	1.85
32K	2.24	2.33	2.30	2.25	2.20	2.15	2.10	2.05
64K	2.25	1.74	1.70	1.60	1.55	1.50	1.50	1.55
128K	2.27	1.79	1.50	1.60	1.60	1.60	1.75	1.75
256K	2.29	2.20	2.11	2.05	1.90	1.75	1.50	1.50
512K	2.84	2.85	2.66	2.50	2.25	2.10	2.00	1.75
1Mb	7.52	4.51	3.50	3.45	2.90	2.75	2.50	2.20
2Mb	15.25	8.37	6.75	5.10	4.50	3.90	3.65	3.30
4Mb	35.16	15.99	12.99	10.60	8.90	7.43	6.30	6.05
8Mb	-	-	-	31.00	23.00	18.00	15.10	12.50
16Mb	-	-	-	-	38.00	29.00	25.00	18.00
Average	3.41	2.86	2.94	2.89	2.84	2.79	2.66	2.64
Percent Change	-24.2	-16.1	2.7	-1.6	-1.8	-1.9	-4.4	-1.0

Source: Dataquest (March 1993)

Table 4-4
Bits from Shipments of EPROMs to the World, 1990-1997
(Trillions of Bits)*

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
16K	0	0	0	0	0	0	0	0	NM
32K	0	0	0	0	0	0	0	0	NM
64K	3	4	3	2	2	2	2	1	-15.1
128K	6	5	4	3	3	2	2	2	-14.4
256K	41	54	39	38	34	28	24	23	-10.0
512K	52	38	46	39	36	31	29	23	-13.5
1Mb	67	70	72	86	95	118	131	124	11.4
2Mb	10	25	41	65	95	107	84	82	14.9
4Mb	4	25	57	64	75	92	113	132	18.5
8Mb	0	0	0	3	18	25	35	46	NM
16Mb	0	0	0	0	2	8	17	39	NM
Total	182	221	262	301	360	414	437	471	12.5
Percent Change	37.5	21.2	18.5	15.0	19.6	14.8	5.7	7.8	

NM = Not meaningful
*Trillion = 1.0×10^{12}
Source: Dataquest (March 1993)

Table 4-5
Price per Bit for Shipments of EPROMs to the World, 1990-1997
(Microdollars)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
16K	131.0	136.4	134.3	131.2	128.2	122.1	116.0	112.9	-3.4
32K	68.5	71.2	70.2	68.7	67.1	65.6	64.1	62.6	-2.3
64K	34.4	26.6	25.9	24.4	23.7	22.9	22.9	23.7	-1.8
128K	17.3	13.7	11.4	12.2	12.2	12.2	13.4	13.4	3.1
256K	8.7	8.4	8.0	7.8	7.2	6.7	5.7	5.7	-6.6
512K	5.4	5.4	5.1	4.8	4.3	4.0	3.8	3.3	-8.1
1Mb	7.2	4.3	3.3	3.3	2.8	2.6	2.4	2.1	-8.9
2Mb	7.3	4.0	3.2	2.4	2.1	1.9	1.7	1.6	-13.3
4Mb	8.4	3.8	3.1	2.5	2.1	1.8	1.5	1.4	-14.2
8Mb	-	-	-	3.7	2.7	2.1	1.8	1.5	NM
16Mb	-	-	-	-	2.3	1.7	1.5	1.1	NM
Average	7.9	6.2	4.7	4.1	3.3	2.8	2.4	2.0	-15.7
Percent Change	-41.9	-22.2	-23.0	-14.3	-19.1	-16.4	-13.2	-15.1	

NM = Not meaningful
Source: Dataquest (March 1993)

Table 4-6
Factory Revenue from Shipments of Flash Memory to the World, 1990-1997
(Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
256K	10	17	24	68	90	74	49	40	11.0
512K	2	18	25	74	104	108	80	63	20.7
1Mb	22	51	122	203	223	293	322	369	24.7
2Mb	1	34	68	111	176	288	335	371	40.5
4Mb	0	0	4	58	231	254	394	409	148.8
8Mb	0	0	6	36	221	444	670	746	159.0
16Mb	0	0	0	17	159	421	630	491	NM
32Mb	0	0	0	0	0	0	4	58	NM
64Mb	0	0	0	0	0	13	53	190	NM
128Mb	0	0	0	0	0	0	0	9	NM
Total	35	120	249	565	1,203	1,894	2,536	2,745	61.6
Percent Change	218.4	238.9	108.4	126.5	113.0	57.4	33.9	8.3	

NM = Not meaningful
Source: Dataquest (March 1993)

Table 4-7
Shipments of Flash Memory to the World, 1990-1997
(Millions of Units)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
256K	1	3	5	17	26	24	18	16	28.7
512K	0	2	4	15	26	30	25	23	44.4
1Mb	1	5	15	28	50	77	92	110	48.4
2Mb	0	2	4	8	23	45	62	75	83.8
4Mb	0	0	0	2	15	25	54	66	238.7
8Mb	0	0	0	1	9	25	62	95	243.0
16Mb	0	0	0	0	4	15	36	45	NM
32Mb	0	0	0	0	0	0	0	2	NM
64Mb	0	0	0	0	0	0	1	5	NM
128Mb	0	0	0	0	0	0	0	0	NM
Total	3	12	27	71	152	241	350	437	74.0
Percent Change	314.3	342.4	132.2	158.4	114.1	58.8	45.3	25.0	

NM = Not meaningful
Source: Dataquest (March 1993)

Table 4-8
Average Selling Price for Shipments of Flash Memory to the World, 1990-1997 (U.S. Dollars)

	1990	1991	1992	1993	1994	1995	1996	1997
256K	7.58	5.62	5.25	4.10	3.50	3.10	2.80	2.50
512K	13.10	7.59	6.75	4.90	4.00	3.60	3.20	2.75
1Mb	19.54	10.49	8.00	7.25	4.50	3.80	3.50	3.35
2Mb	31.63	21.50	19.00	14.75	7.80	6.40	5.40	4.95
4Mb	-	-	29.00	25.00	15.40	10.15	7.30	6.20
8Mb	-	-	32.00	30.00	24.50	17.75	10.80	7.85
16Mb	-	-	-	55.00	41.75	29.00	17.50	10.90
32Mb	-	-	-	-	-	-	36.00	29.00
64Mb	-	-	-	-	-	65.00	44.00	38.00
128Mb	-	-	-	-	-	-	-	90.00
Average	13.23	10.13	9.10	7.98	7.94	7.87	7.25	6.28
Percent Change	-23.1	-23.4	-10.2	-12.3	-.5	-.9	-7.9	-13.4

Source: Dataquest (March 1993)

Table 4-9
Bits from Shipments of Flash Memory to the World, 1990-1997
(Trillions of Bits)*

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
256K	0	1	1	4	7	6	5	4	28.7
512K	0	1	2	8	14	16	13	12	44.4
1Mb	1	5	16	29	52	81	96	115	48.4
2Mb	0	3	7	16	47	94	130	157	83.8
4Mb	0	0	1	10	63	105	226	277	238.7
8Mb	0	0	2	10	75	210	520	797	243.0
16Mb	0	0	0	5	64	243	604	755	NM
32Mb	0	0	0	0	0	0	3	67	NM
64Mb	0	0	0	0	0	13	81	336	NM
128Mb	0	0	0	0	0	0	0	13	NM
Total	2	10	29	82	322	768	1,679	2,534	144.6
Percent Change	505.0	519.5	177.6	183.5	292.4	138.8	118.5	50.9	

NM = Not meaningful
*Trillion = 1.0×10^{12}
Source: Dataquest (March 1993)

Table 4-10
Price per Bit for Shipments of Flash Memory to the World, 1990-1997 (Microdollars)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
256K	28.9	21.5	20.0	15.6	13.4	11.8	10.7	9.5	-13.8
512K	25.0	14.5	12.9	9.3	7.6	6.9	6.1	5.2	-16.4
1Mb	18.6	10.0	7.6	6.9	4.3	3.6	3.3	3.2	-16.0
2Mb	15.1	10.3	9.1	7.0	3.7	3.1	2.6	2.4	-23.6
4Mb	-	-	6.9	6.0	3.7	2.4	1.7	1.5	-26.5
8Mb	-	-	3.8	3.6	2.9	2.1	1.3	0.9	-24.5
16Mb	-	-	-	3.3	2.5	1.7	1.0	0.6	NM
32Mb	-	-	-	-	-	-	1.1	0.9	NM
64Mb	-	-	-	-	-	1.0	0.7	0.6	NM
128Mb	-	-	-	-	-	-	-	0.7	NM
Average	21.0	11.5	8.6	6.9	3.7	2.5	1.5	1.1	-33.9
Percent Change	-47.4	-45.3	-24.9	-20.1	-45.7	-34.1	-38.7	-28.3	

NM = Not meaningful
Source: Dataquest (March 1993)

Table 4-11
Factory Revenue from Shipments of ROMs to the World, 1990-1997
(Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
32K	1	1	0	0	0	0	0	0	NM
64K	12	9	5	2	0	0	0	0	NM
128K	8	13	4	2	1	0	0	0	NM
256K	53	67	33	23	12	2	0	0	NM
512K	63	53	39	21	7	2	0	0	NM
1Mb	285	334	278	191	133	53	27	12	-46.9
2Mb	200	179	135	116	86	64	37	18	-33.1
4Mb	386	306	338	294	195	125	71	41	-34.5
8Mb	92	214	281	370	361	385	313	176	-9.0
16Mb	31	21	96	151	239	258	319	305	26.0
32Mb	0	0	0	161	245	367	383	468	NM
64Mb	0	0	0	14	131	234	431	568	NM
128Mb	0	0	0	0	7	82	104	184	NM
256Mb	0	0	0	0	0	0	8	69	NM
Total	1,132	1,198	1,208	1,345	1,416	1,571	1,692	1,839	8.8
Percent Change	5.8	5.8	0.8	11.4	5.3	11.0	7.7	8.7	

NM = Not meaningful
Source: Dataquest (March 1993)

Table 4-12
Shipments of ROMs to the World, 1990-1997
(Millions of Units)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
32K	0	0	0	0	0	0	0	0	NM
64K	7	5	3	1	0	0	0	0	NM
128K	5	9	3	2	1	0	0	0	NM
256K	32	38	22	17	9	2	0	0	NM
512K	27	27	20	11	4	1	0	0	NM
1Mb	104	131	123	91	66	28	15	7	-43.7
2Mb	53	58	49	47	38	29	17	9	-28.8
4Mb	74	77	92	107	78	52	31	19	-27.0
8Mb	12	37	47	72	76	86	72	45	-0.9
16Mb	2	3	7	15	29	38	49	50	46.4
32Mb	0	0	0	7	13	27	38	55	NM
64Mb	0	0	0	0	5	12	29	44	NM
128Mb	0	0	0	0	0	2	4	8	NM
256Mb	0	0	0	0	0	0	0	1	NM
Total	315	383	366	370	319	277	255	238	-8.2
Percent Change	5.4	21.5	-4.4	1.0	-13.9	-13.2	-7.7	-6.7	

NM = Not meaningful

Source: Dataquest (March 1993)

Table 4-13
Average Selling Price for Shipments of ROMs to the World, 1990-1997
(U.S. Dollars)

	1990	1991	1992	1993	1994	1995	1996	1997
32K	1.60	2.29	-	-	-	-	-	-
64K	1.60	1.65	1.55	1.55	-	-	-	-
128K	1.65	1.51	1.45	1.20	1.12	-	-	-
256K	1.68	1.77	1.50	1.35	1.30	1.25	1.20	-
512K	2.35	1.99	1.95	1.90	1.85	1.80	1.75	-
1Mb	2.75	2.55	2.25	2.10	2.00	1.90	1.80	1.68
2Mb	3.80	3.10	2.75	2.50	2.25	2.20	2.10	2.00
4Mb	5.20	4.00	3.69	2.75	2.50	2.40	2.30	2.15
8Mb	7.75	5.84	5.95	5.12	4.75	4.50	4.35	3.90
16Mb	19.00	8.32	12.90	10.24	8.25	6.75	6.50	6.10
32Mb	-	-	-	23.00	19.00	13.50	10.00	8.50
64Mb	-	-	-	45.00	29.00	19.00	15.00	12.90
128Mb	-	-	-	-	65.00	43.00	29.00	23.00
256Mb	-	-	-	-	-	-	75.00	53.00
Average	3.59	3.12	3.30	3.63	4.44	5.68	6.63	7.72
Percent Change	0.5	-12.9	5.5	10.3	22.2	27.8	16.7	16.5

Source: Dataquest (March 1993)

Table 4-14
Bits from Shipments of ROMs to the World, 1990-1997 (Trillions of Bits)*

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
32K	0	0	0	0	0	0	0	0	NM
64K	0	0	0	0	0	0	0	0	NM
128K	1	1	0	0	0	0	0	0	NM
256K	8	10	6	5	2	0	0	0	NM
512K	14	14	10	6	2	1	0	0	NM
1Mb	109	137	129	95	70	29	16	7	-43.7
2Mb	110	121	103	98	80	61	36	19	-28.8
4Mb	311	321	384	449	327	218	130	80	-27.0
8Mb	100	307	395	606	638	718	604	377	-0.9
16Mb	28	42	125	247	487	641	822	839	46.4
32Mb	0	0	0	235	433	913	1,285	1,845	NM
64Mb	0	0	0	20	302	825	1,926	2,953	NM
128Mb	0	0	0	0	13	255	483	1,074	NM
256Mb	0	0	0	0	0	0	27	349	NM
Total	682	955	1,153	1,760	2,354	3,661	5,330	7,543	45.6
Percent Change	60.2	40.1	20.8	52.7	33.7	55.5	45.6	41.5	

NM = Not meaningful
*Trillion = 1.0×10^{12}
Source: Dataquest (March 1993)

Table 4-15
Price per Bit for Shipments of ROMs to the World, 1990-1997
(Microdollars)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
32K	48.8	70.0	-	-	-	-	-	-	NM
64K	24.4	25.2	23.7	23.7	-	-	-	-	NM
128K	12.6	11.5	11.1	9.2	8.5	-	-	-	NM
256K	6.4	6.8	5.7	5.1	5.0	4.8	4.6	-	NM
512K	4.5	3.8	3.7	3.6	3.5	3.4	3.3	-	NM
1Mb	2.6	2.4	2.1	2.0	1.9	1.8	1.7	1.6	-5.7
2Mb	1.8	1.5	1.3	1.2	1.1	1.0	1.0	1.0	-6.1
4Mb	1.2	1.0	0.9	0.7	0.6	0.6	0.5	0.5	-10.3
8Mb	0.9	0.7	0.7	0.6	0.6	0.5	0.5	0.5	-8.1
16Mb	1.1	0.5	0.8	0.6	0.5	0.4	0.4	0.4	-13.9
32Mb	-	-	-	0.7	0.6	0.4	0.3	0.3	NM
64Mb	-	-	-	0.7	0.4	0.3	0.2	0.2	NM
128Mb	-	-	-	-	0.5	0.3	0.2	0.2	NM
256Mb	-	-	-	-	-	-	0.3	0.2	NM
Average	1.7	1.3	1.0	0.8	0.6	0.4	0.3	0.2	-25.3
Percent Change	-33.9	-24.5	-16.5	-27.1	-21.3	-28.6	-26.0	-23.2	

NM = Not meaningful
Source: Dataquest (March 1993)

Table 4-16
Factory Revenue from Shipments of EEPROMs to the World, 1990-1997
(Millions of U.S. Dollars)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
256b	17	18	26	33	35	34	27	23	-2.3
512b	0	6	7	8	8	9	10	11	7.5
1K	49	62	70	75	70	61	49	40	-10.7
2K	38	52	50	52	51	56	59	60	3.9
4K	54	28	41	57	68	77	80	94	17.9
8K	0	0	4	7	9	12	10	12	24.5
16K	27	32	33	38	48	65	78	89	21.9
64K	59	74	84	92	98	99	119	138	10.4
256K	45	48	55	57	60	36	23	19	-18.7
512K	0	1	1	0	0	0	0	0	NM
1Mb	3	5	8	49	68	104	114	138	77.8
Total	292	326	378	468	516	552	566	623	10.5
Percent Change	-8.6	11.7	16.0	23.8	10.2	6.9	2.7	9.9	

Source: Dataquest (March 1993)

Table 4-17
Shipments of EEPROMs to the World, 1990-1997
(Millions of Units)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
256b	23	25	40	55	63	75	69	66	10.5
512b	0	7	10	12	14	17	19	23	18.0
1K	49	100	144	167	180	179	168	160	2.2
2K	17	39	47	65	79	112	130	155	26.7
4K	20	13	21	38	59	85	106	138	45.6
8K	0	0	2	4	5	8	10	12	48.0
16K	7	11	15	19	26	37	52	71	37.2
64K	10	15	18	21	25	30	41	55	25.5
256K	1	2	4	4	5	4	3	3	-7.2
512K	0	0	0	0	0	0	0	0	NM
1Mb	0	0	0	1	1	2	2	3	91.1
Total	127	213	300	384	457	548	599	685	17.9
Percent Change	7.4	67.5	40.9	28.1	18.8	19.9	9.4	14.3	

NM = Not meaningful
Source: Dataquest (March 1993)

Table 4-18
Average Selling Price for Shipments of EEPROMs to the World, 1990-1997
(U.S. Dollars)

	1990	1991	1992	1993	1994	1995	1996	1997
256b	0.75	0.72	0.65	0.60	0.56	0.45	0.39	0.35
512b	-	0.82	0.75	0.70	0.60	0.55	0.50	0.47
1K	1.00	0.62	0.49	0.45	0.39	0.34	0.29	0.25
2K	2.20	1.33	1.05	0.80	0.65	0.50	0.45	0.39
4K	2.75	2.11	1.95	1.50	1.15	0.90	0.75	0.68
8K	-	2.51	2.25	2.00	1.75	1.50	1.00	0.95
16K	3.73	2.82	2.25	2.05	1.89	1.75	1.50	1.25
64K	5.75	5.01	4.75	4.50	3.90	3.30	2.90	2.50
256K	38.19	19.46	15.00	13.50	11.80	9.25	8.50	7.75
512K	-	44.88	39.02	-	-	-	-	-
1Mb	100.00	92.56	79.00	70.00	68.00	65.00	60.00	55.00
Average	2.30	1.53	1.26	1.22	1.13	1.01	0.95	0.91
Percent Change	-14.9	-33.4	-17.7	-3.4	-7.3	-10.9	-6.1	-3.8

Source: Dataquest (March 1993)

Table 4-19
Bits from Shipments of EEPROMs to the World, 1990-1997
(Trillions of Bits)*

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
256b	0	0	0	0	0	0	0	0	NM
512b	0	0	0	0	0	0	0	0	NM
1K	0	0	0	0	0	0	0	0	NM
2K	0	0	0	0	0	0	0	0	NM
4K	0	0	0	0	0	0	0	1	45.6
8K	0	0	0	0	0	0	0	0	NM
16K	0	0	0	0	0	1	1	1	37.2
64K	1	1	1	1	2	2	3	4	25.5
256K	0	1	1	1	1	1	1	1	-7.2
512K	0	0	0	0	0	0	0	0	NM
1Mb	0	0	0	1	1	2	2	3	91.1
Total	1	2	3	4	5	6	7	9	26.7
Percent Change	27.2	62.6	33.0	41.5	27.7	20.2	17.8	27.8	

NM = Not meaningful
*Trillion = 1.0×10^{12}
Source: Dataquest (March 1993)

Table 4-20
Price per Bit for Shipments of EEPROMs to the World, 1990-1997
(Microdollars)

	1990	1991	1992	1993	1994	1995	1996	1997	CAGR (%) 1992-1997
256b	2,929.7	2,796.3	2,539.1	2,343.8	2,187.5	1,757.8	1,523.4	1,367.2	-11.6
512b	-	1,598.3	1,464.8	1,367.2	1,171.9	1,074.2	976.6	918.0	-8.9
1K	976.6	605.5	478.5	439.5	380.9	332.0	283.2	244.1	-12.6
2K	1,074.2	650.6	512.7	390.6	317.4	244.1	219.7	190.4	-18.0
4K	671.4	514.8	476.1	366.2	280.8	219.7	183.1	166.0	-19.0
8K	-	306.4	274.7	244.1	213.6	183.1	122.1	116.0	-15.8
16K	227.7	172.0	137.5	125.1	115.4	106.8	91.6	76.3	-11.1
64K	87.8	76.5	72.5	68.7	59.5	50.4	44.3	38.1	-12.1
256K	145.7	74.2	57.2	51.5	45.0	35.3	32.4	29.6	-12.4
512K	-	85.6	74.4	-	-	-	-	-	NM
1Mb	95.4	88.3	75.3	66.8	64.8	62.0	57.2	52.5	-7.0
Average	224.0	153.8	134.2	117.4	101.3	90.1	78.5	67.5	-12.8
Percent Change	-28.1	-31.3	-12.7	-12.5	-13.7	-11.1	-12.9	-14.0	

Source: Dataquest (March 1993)

For More Information...

Lane Mason, Director/Principal Analyst .... (408) 437-8120

Via fax .... (408) 437-0292

Dataquest®

a company of
The Dun & Bradstreet Corporation

Corporate Headquarters
Dataquest Incorporated
1290 Ridder Park Drive
San Jose, California 95131-2398
United States
Phone: 01-408-437-8000
Facsimile: 01-408-437-0292

Dataquest Incorporated
550 Cochituate Road
Framingham, Massachusetts 01701-9324
United States
Phone: 01-508-370-5555
Facsimile: 01-508-370-6262

Invitational Computer Conferences (ICC)
3990 Westerly Place, Suite 100
Newport Beach, California 92660
United States
Phone: (714) 476-9117
Facsimile: (714) 476-9969

Dataquest Japan Limited
Shinkawa Sanko Building
1-3-17, Shinkawa, Chuo-ku
Tokyo 104
Japan
Phone: 81-3-5566-0411
Facsimile: 81-3-5566-0425

Dataquest Korea
Dacheung Building, Room 1105
648-23 Yorksam-dong
Kangnam-gu, Seoul 135-080
Korea
Phone: 011-82-2-556-4166
Facsimile: 011-82-2-552-2661

European Headquarters
Dataquest Europe Limited
Roussel House, Broadwater Park
Denham, Uxbridge
Middlesex UB9 5HP
England
Phone: 44-895-835050
Facsimile: 44-895-835260/1

Dataquest GmbH
Kronstadter Strasse 9
8000 Munich 80
Germany
Phone: 011-49-89-930-9090
Facsimile: 011-49-89-930-3277

Dataquest Europe SA
Tour Gallieni 2
36, Avenue du General de Gaulle
93175 Bagnolet Cedex
France
Phone: 011-33-1-48-97-3100
Facsimile: 011-33-1-48-97-3400

Representative Agencies in
Bangkok, Hong Kong,
Kronberg, North Sydney,
Singapore, Taipei, and Tel Aviv

0014566

Dataquest®

Dataquest®

Semiconductors

Semiconductor Market Definitions

Dataquest Guide

1993

Program: Semiconductors
Product Code: SCND-WW-GU-9301
Publication Date: October 11, 1993

Dataquest®

Semiconductors

Semiconductor Market Definitions

Dataquest Guide

1993

Program: Semiconductors
Product Code: SCND-WW-GU-9301
Publication Date: October 11, 1993

Table of Contents

List of Figures

List of Tables

Chapter 1
Market Share Survey Overview

Each year, Dataquest surveys semiconductor vendors to estimate their annual sales. The survey covers 148 semiconductor vendors worldwide (this varies according to mergers, acquisitions, liquidations, start-ups, and so on) by 61 individual semiconductor product categories (excluding subtotals), 6 application segments, and 5 world regions (Europe is split into further subregions). This exercise helps Dataquest maintain its dynamic database of semiconductor supply by company, and semiconductor shipments by world region and product. The information gained is supplemented by, and cross-checked with, Dataquest's various other information sources.

The semiconductor market share survey takes place in the fourth quarter of each year. Our preliminary estimates are completed by the end of the calendar year under review, and the results are summarized in several Dataquest reports. Preliminary vendor rankings also are featured in a Dataquest press release. Final estimates are published in the first quarter of the following year.

The categories for which semiconductor revenue is reported are defined comprehensively for the purpose of clarity and guidance to survey participants. These definitions may occasionally be revised, altered, or expanded to reflect changes in the industry. To support these definitions, Dataquest will issue an annual survey guide to all participants in its semiconductor market share survey program. This document comprises the 1993 survey guide.

Chapter 2

Semiconductor Companies Surveyed Worldwide for 1993

In 1993, Dataquest surveyed semiconductor companies throughout the world.

North American Companies Surveyed

The following North American companies were surveyed:

- ACC Microelectronics
- Actel
- Acumos
- Advanced Micro Devices
- Allegro MicroSystems
- Altera
- Analog Devices
- Appian Technology
- Applied Micro Circuits
- AT&T
- Atmel
- Brooktree
- Burr-Brown
- California Micro Devices
- Catalyst
- Cherry Semiconductor
- Chips & Technologies
- Cirrus Logic
- Comlinear
- Cypress Semiconductor
- Cyrix
- Dallas Semiconductor
- DSP Group
- Elantec
- Electronic Designs
- ETEQ Microsystems
- Exar

- General Instrument
- Gennum
- Gould AMI
- Harris
- Hewlett-Packard
- Honeywell
- Hughes
- IMI
- Integrated Device Technology
- Integrated Information Technology
- Intel
- International Business Machines
- International Microelectronic Products
- International Rectifier
- ITT
- Kulite
- Lattice
- Linear Technology
- Logic Devices
- LSI Logic
- Maxim
- Micrel
- Micro Linear
- Micro Power Systems
- Microchip Technology
- Micron Technology
- Microsemi
- Mitel
- Motorola
- National Semiconductor
- NCR
- Novasensor
- Oak Technology
- Optek

- OPTi
- Performance Semiconductor
- Powerex
- Quality Semiconductor
- Quality Technologies
- Raytheon
- Rockwell
- SEEQ Technology
- Semtech
- Sierra Semiconductor
- Silicon General
- Silicon Systems
- Siliconix
- Sipex
- Solitron
- Standard Microsystems
- Supertex
- Symphony Laboratories
- Teccor Electronics
- Tektronix
- Teledyne
- Texas Instruments
- Trident Microsystems
- TRW
- Tseng Labs
- Unitrode
- Universal
- VLSI Technology
- VTC
- WaferScale Integration
- Weitek
- Western Digital
- Xicor
- Xilinx
- Zilog

Japanese Companies Surveyed

The following Japanese companies were surveyed:

- Fuji Electric
- Fujitsu
- Hitachi
- Matsushita Electronics
- Mitsubishi Electric
- NEC
- New Japan Radio
- Nippon Steel Semiconductor
- Oki Electric Industry
- Ricoh
- Rohm
- Sanken Electric
- Sanyo Electric
- Seiko Epson
- Sharp
- Shindengen Electric Manufacturing
- Sony
- Toko
- Toshiba
- Yamaha

European Companies Surveyed

The following European companies were surveyed:

- ABB-Hafo
- ABB-Ixys
- Austria Mikro Systeme
- Ericsson
- EM Microelectronic
- Eupec
- European Silicon Structures
- Fagor
- GEC Plessey Semiconductors

- Micronas
- Mietec
- Philips Semiconductors
- Semikron
- SGS-Thomson
- Siemens
- Tag
- TEMIC
- TCS (Thomson Composants Spatiaux)
- Westcode Semiconductors
- Zetex

Asia/Pacific Companies Surveyed

The following Asia/Pacific companies were surveyed:

- Daewoo
- Dongsung Semiconductor
- Goldstar
- Hualon Microelectronics
- Hyundai
- Korean Electronics
- Macronix
- MOSel/Vitelic
- Samsung
- Silicon Integrated Systems
- United Microelectronics
- Winbond Electronics

Summary

The following summarizes the semiconductor companies surveyed in 1993:

- 96 North American companies
- 20 Japanese companies
- 20 European companies
- 12 Asia/Pacific companies
- 148 Worldwide companies

Chapter 3
General Sales Definitions

Sales to Customer

All sales are reported according to customer location, that is, the shipping destination. The five regions that Dataquest recognizes are North America, Japan, Europe, Asia/Pacific, and Rest of World (ROW).

Finished Semiconductor Products

Defined as assembled and tested semiconductor products. *Only count sales of finished semiconductor products to distributors and equipment manufacturers.* Do not include sales of finished semiconductors to other semiconductor vendors for value-added resale. Resale revenue will be estimated separately for these companies. Also, only count sales made by an overseas subsidiary to a distributor or equipment manufacturer as opposed to counting sales from headquarters to an overseas subsidiary.

Unfinished Semiconductor Products

Defined as wafer and die foundry products. *Only count sales of unfinished semiconductor products to distributors and equipment manufacturers.* Do not include sales of unfinished semiconductors to other semiconductor vendors for resale. Resale revenue will be estimated separately for these companies. Also, only count sales made by an overseas subsidiary to a distributor or equipment manufacturer as opposed to counting sales from headquarters to an overseas subsidiary.

Internal Semiconductor Sales

Defined as revenue from finished or unfinished semiconductor products from *intracompany* (internal) transfers to divisions of your company and/or subsidiaries of your parent company that manufacture end equipment. Internal semiconductor sales are classified as *in-house semiconductor sales*, or *captive semiconductor sales*, depending on whether your company sells semiconductors on the merchant market.

In-House Semiconductor Sales

Defined as internal semiconductor sales *if your company also sells semiconductors on the merchant market.* **Include all in-house semiconductor sales at market prices.** Market price is defined as the price at which the same product is sold to equipment manufacturers.

Captive Semiconductor Sales

Defined as internal semiconductor sales *if your company does not sell semiconductors on the merchant market.* **Do not include captive semiconductor sales.**

Hybrid Products

Defined as products that comprise a number of active semiconductor die and/or passive components in a single package. *Only count sales of hybrid products that conform with the definitions for "finished semiconductor products" or "unfinished semiconductor products."*

Multichip Modules (MCM) and Board-Level Products

Defined as products that comprise a number of active semiconductor and/or passive components mounted on a silicon printed substrate, polyimide multilayer printed substrate, or a printed circuit board (PCB). Only count sales of MCM products and board-level products that conform with the definitions for "finished semiconductor products" or "unfinished semiconductor products." *Only include the market price of the active semiconductors in the module or board-level product.*

System-Level Products

Defined as products that comprise a number of module and/or board-level products amounting to a single system or subsystem. Examples include development systems, hardware platforms, and box-level products. *Do not include any sales from such system-level products.*

Nonrecurring Engineering (NRE) Charges

Defined as NRE charges made to customers as the result of costs incurred during the design or customizing of a semiconductor device for that customer. Only count NRE charges when they occur in the following product areas:

- Design charges for ASICs including gate arrays, cell-based ICs, and full-custom ICs
- Mask charges that result from the customizing of a programmable array logic (PAL), when the customer's fuse pattern is masked into it to produce a hard-wired array logic (HAL)
- Mask charges that result from the customizing of ROMs
- Mask charges that result from the storage of the customer's program in a microcontroller

Only count revenue from NRE charges on active semiconductor products that conform with the definitions for "finished semiconductor products" or "unfinished semiconductor products." Include these NRE charges as part of the revenue received from associated semiconductor product. Do not include revenue from NRE charges incurred during research, feasibility studies, or facility rental to third parties.

Electronic Design Automation (EDA) Software

EDA software is used to automate the design of semiconductors. Dataquest includes revenue from ASIC semiconductor vendors that also sell their own EDA software. *Include any revenue derived from EDA software in the appropriate ASIC product category.* The applicable categories are PLD, gate array, and cell-based IC.

IPR Income

Defined as intellectual property rights, income from royalties, licensing agreements, technology transfers, and dispute settlements. *Do not include any such IPR income.*

Chapter 4
Exchange Rate Definitions

When converting a company's local currency sales into U.S. dollars, or vice versa, it is important to use the preliminary 1993 exchange rates provided in Table 4-1. This will prevent inconsistencies in the conversion of offshore sales between each company. The *preliminary* 1993 exchange rate estimate uses actual exchange rates through September 1993 and assumes that the September rate applies throughout the months of October through December. The annual rate is estimated as the arithmetic mean of the 12 monthly rates. Table 4-1 outlines these rates. Exchange rates for historical years are available on request.

At the beginning of 1994, the *actual* 1993 annual exchange rate will be calculated as the simple arithmetic mean of the 12 1993 *actual* monthly rates. Then, the regional *dollar-based* revenue estimates will be revised given the actual *local-currency* revenue estimates and the *actual* 1993 annual exchange rate.

Table 4-1
Average 1992 and 1993 Exchange Rates per U.S. Dollar

Country	1992 Rate	1993 Estimate	U.S.$ Expected Appreciation (Percent)
Austria (Schilling)	10.95	11.55	5.6
Belgium (Franc)	32.02	34.47	7.6
China (Renminbi)	5.5082	5.7441	4.3
Denmark (Krone)	6.0153	6.4794	7.7
ECU	0.770	0.853	10.7
Finland (Markka)	4.4507	5.7423	29.0
France (Franc)	5.2712	5.6409	7.0
Germany (Mark)	1.5554	1.6427	5.6
Great Britain (Pound)	0.5686	0.6651	17.0
Greece (Drachma)	181.74	227.19	19.7
Hong Kong (Dollar)	7.7401	7.7386	0
India (Rupee)	27.9666	30.9939	10.8
Ireland (Punt)	0.5860	0.6816	16.3
Italy (Lira)	1,227.75	1,557.94	26.9
Japan (Yen)	126.45	110.46	-12.6
Malaysia (Ringgit)	2.5459	2.5723	1.0
Netherlands (Guilder)	1.7512	1.8444	5.3
Norway (Krone)	6.1824	7.0534	14.1
Portugal (Escudo)	134.34	159.72	18.9
Singapore (Dollar)	1.6285	1.6157	-0.8
South Korea (Won)	782.63	799.45	2.1

(Continued)

Table 4-1 (Continued)
Average 1992 and 1993 Exchange Rates per U.S. Dollar

Country	1992 Rate	1993 Estimate	U.S.$ Expected Appreciation (Percent)
Spain (Peseta)	101.90	126.55	24.2
Sweden (Kroner)	5.8105	7.7833	34.0
Switzerland (Franc)	1.3976	1.4694	5.1
Taiwan (Dollar)	24.93	26.21	5.1
Thailand (Baht)	25.42	25.27	-0.6

Source: Dataquest (October 1993)

Chapter 5
Semiconductor Product Category Hierarchy

The semiconductor product category hierarchy in Table 5-1 begins with total semiconductor, and indents each subcategory in the left-hand column according to its position in the hierarchy. At each level in the hierarchy, all subcategories that contribute to this level are shown as a subcategory summation in the right-hand column. Any level in the hierarchy that does not depend on any subcategories is marked as a "Data Point."

Table 5-1
Semiconductor Product Category Hierarchy

Total Semiconductor (Including Hybrids):	Total Semiconductor (Excluding Hybrids) + Hybrid Integrated Circuit
Hybrid Integrated Circuits:	Data Point
Total Semiconductor (Excluding Hybrids):	Total Integrated Circuit (Excluding Hybrids) + Total Discrete + Total Optical Semiconductor
Total Integrated Circuit (Excluding Hybrids):	Digital Monolithic Bipolar IC + Digital Monolithic MOS IC + Analog IC
Bipolar Digital IC:	Bipolar Digital Memory IC + Bipolar Digital Logic IC
Bipolar Digital Memory IC:	Data Point
Bipolar Digital Logic IC:	Bipolar Digital Logic Application-Specific IC + Bipolar Digital Standard Logic IC + Other Bipolar Digital Logic IC
Bipolar Digital Logic ASIC:	Bipolar Digital Gate Array + Bipolar Digital Programmable Logic Device + Bipolar Digital Cell-Based IC/Custom IC
Bipolar Digital GA:	Data Point
Bipolar Digital PLD:	Data Point
Bipolar Digital CBIC/Custom:	Data Point
Bipolar Digital Standard Logic IC:	Data Point
Other Bipolar Digital Logic IC:	Data Point
MOS Digital IC:	MOS Memory IC + MOS Microcomponent IC + MOS Logic IC
MOS Digital Memory IC:	DRAM + SRAM + EPROM + EEPROM + Flash Memory + Mask ROM + Other MOS Digital Memory IC
DRAM:	Data Point
SRAM:	Data Point
EPROM:	Data Point
EEPROM:	Data Point
Flash Memory:	Data Point
Mask ROM:	Data Point
Other MOS Memory IC:	Data Point
MOS Digital Microcomponent IC:	MOS Digital Microprocessor + MOS Digital Microcontroller + MOS Digital Microperipheral + Programmable Digital Signal Processor

(Continued)

Table 5-1 (Continued)
Semiconductor Product Category Hierarchy

MOS Digital MPU:	8- and 16-bit CISC MPU + 32-bit and greater CISC MPU + 32-bit and greater RISC MPU
8- and 16-bit CISC MPU:	Data Point
32-bit and greater CISC MPU:	Data Point
32-bit and greater RISC MPU:	Data Point
MOS Digital MCU:	4-bit MCU + 8-bit MCU + 16-bit MCU
4-bit MCU:	Data Point
8-bit MCU:	Data Point
16-bit MCU:	Data Point
MOS Digital MPR:	System Core Logic Chipsets + Graphics and Imaging Controllers + Communications Controllers + Mass Storage Controllers + Audio/Other Controllers
System Core Logic Chipsets:	Data Point
Graphics and Imaging Controllers:	Data Point
Communications Controllers:	Data Point
Mass Storage Controllers:	Data Point
Audio/Other Controllers:	Data Point
Programmable DSP:	Data Point
MOS Digital Logic IC:	MOS Digital Logic Application-Specific IC + MOS Digital Standard Logic IC + Other MOS Digital Logic IC
MOS Digital Logic ASIC:	CMOS Digital Gate Array + BiCMOS Digital Gate Array + MOS Digital Programmable Logic Device + MOS Digital Cell-Based IC + MOS Digital Full-Custom IC
CMOS Digital GA:	Data Point
BiCMOS Digital GA:	Data Point
MOS Digital PLD:	Data Point
MOS Digital CBIC:	Data Point
MOS Digital FCIC:	Data Point
MOS Digital Standard Logic IC:	Data Point
Other MOS Digital Logic IC:	Data Point
Analog IC:	Amplifier/Comparator IC + Voltage Regulator/Reference IC + Data Convertor/Switch/Multiplexer IC + Interface IC + Telecom IC + Disk Drive IC + Other Special Function IC + Linear Array/ASIC + Mixed-Signal ASIC + Total Special Consumer IC + Special Automotive IC + Smart Power IC
Amplifier/Comparator IC:	Data Point
Voltage Regulator/Reference IC:	Data Point
Data Converter/Switch/Multiplexer IC:	Data Point
Interface IC:	Data Point
Telecom IC:	Data Point
Disk Drive IC:	Data Point

(Continued)

Table 5-1 (Continued)
Semiconductor Product Category Hierarchy

Other Special Function IC:	Data Point
Linear Array/ASIC:	Data Point
Mixed-Signal ASIC:	Data Point
Total Special Consumer IC:	Video Special Consumer IC + Audio Special Consumer IC + Other Special Consumer IC
Video Special Consumer IC	Data Point
Audio Special Consumer IC	Data Point
Other Special Consumer IC	Data Point
Special Automotive IC:	Data Point
Smart Power IC	Data Point
Total Discrete:	Transistor + Diode + Thyristor + Other Discrete
Transistor:	Small-Signal Transistor + Power Transistor
Small-Signal Transistor:	Data Point
Power Transistor:	Bipolar Power Transistor + MOS Power Transistor + Power Insulated Gate Bipolar Transistor (IGBT)
Bipolar Power Transistor:	Data Point
MOS Power Transistor:	Data Point
Power IGBT:	Data Point
Diode:	Small-Signal/Reference Diode + Power Diode/Rectifier
Small-Signal/Reference Diode:	Data Point
Power Diode/Rectifier:	Data Point
Thyristor:	Data Point
Other Discrete:	Data Point
Total Optical Semiconductor:	LED Lamp/Display + Optocoupler + CCD + Laser Diode + Photosensor + Other Optical Semiconductor
LED Lamp/Display:	Data Point
Optocoupler:	Data Point
CCD:	Data Point
Laser Diode:	Data Point
Photosensor:	Data Point
Other Optical Semiconductor:	Data Point

Source: Dataquest (October 1993)

Chapter 6
Semiconductor Product Category Definitions

The semiconductor product category definitions in Table 6-1 begin with total semiconductor, and continue through each subcategory in the same order as shown in the preceding semiconductor product category hierarchy. At each level in the hierarchy, all subcategories that contribute to this level are shown as a subcategory summation in the right-hand column. Comprehensive definitions are given at every level.

Table 6-1
Semiconductor Product Category Definitions

Total Semiconductor (Including Hybrids):	(Total Semiconductor (Excluding Hybrids) + Hybrid Integrated Circuit)
	Defined as an active semiconductor product that contains semiconducting material (such as silicon, germanium, or gallium arsenide, but excluding ceramics) and reacts dynamically to an input signal, either by modifying its shape or adding energy to it. This definition excludes standalone passive components, such as capacitors, resistors, inductors, oscillators, crystals, transformers, and relays.
Hybrid Integrated Circuit:	Defined as a semiconductor product consisting of more than one die contained in a single package. A hybrid IC may perform 100 percent linear, 100 percent digital, or mixed-signal (both linear and digital) functions. Includes hybrid implementation of all monolithic IC functions described in the following categories. Includes all hybrid ICs manufactured using bipolar, MOS, or BiCMOS technologies.
Total Semiconductor (Excluding Hybrids):	(Total Integrated Circuit + Total Discrete + Total Optical Semiconductor)
	Defined as an active semiconductor product that contains semiconducting material (such as silicon, germanium, or gallium arsenide, but excluding ceramics) and reacts dynamically to an input signal, either by modifying its shape or adding energy to it. Includes monolithic IC only. This definition excludes standalone passive components, such as capacitors, resistors, inductors, oscillators, crystals, transformers, and relays.
Total Integrated Circuit:	(Digital Monolithic Bipolar IC + Digital Monolithic MOS IC + Analog IC)
	An IC is defined as a large number of passive and/or active discrete semiconductor circuits integrated into a single package. A monolithic IC is one in which discrete circuits are integrated onto a single die.
Digital Bipolar IC:	(Bipolar Digital Memory IC + Bipolar Digital Logic IC)
	A bipolar digital IC is defined as a monolithic semiconductor product in which 100 percent of the die area performs digital functions, and concurrently, 100 percent of the die area is manufactured using bipolar semiconductor technology. A digital function is one in which data-carrying signals vary in discrete values.

(Continued)

Table 6-1 (Continued)
Semiconductor Product Category Definitions

Bipolar Digital Memory IC:	Defined as a bipolar digital semiconductor product in which binary data is stored and electronically retrieved. Includes ECL random-access memory (RAM), read-only memory (ROM), programmable ROM (PROM), last-in/first-out (LIFO) memory, and first-in/first-out (FIFO) memory. Not included are products made with mixed bipolar CMOS (that is, BiCMOS) with TTL or ECL outputs, which are classified as MOS.
Bipolar Digital Logic IC:	(Bipolar Digital Logic Application-Specific IC + Bipolar Digital Standard Logic IC + Other Bipolar Digital Logic IC)
	Defined as a bipolar digital semiconductor product in which more than 50 percent of the die area performs logic functions.
Bipolar Digital Logic ASIC:	(Bipolar Digital Gate Array + Bipolar Digital Programmable Logic Device + Bipolar Digital Cell-Based IC/ Bipolar Digital Full-Custom IC)
	Defined as a single-user bipolar digital logic IC that is manufactured using vendor-supplied tools and/or libraries. Do not include bipolar digital ASICs incorporating microprocessor cells or microcontroller cells, as these should be reported in the other bipolar digital logic IC category.
Bipolar Digital GA:	Bipolar Digital Gate Array is defined as an ASIC device that is customized by the vendor to end-user specification using layers of interconnect. Included in this category are generic or base wafers with embedded functions, such as SRAM and EEPROM.
Bipolar Digital PLD:	Bipolar Digital Programmable Logic Device is defined as an ASIC device that is customized by the end user after assembly. Included in this category are bipolar field-programmable logic (bipolar FPL), bipolar field-programmable gate array (bipolar FPGA), bipolar programmable array logic (bipolar PAL), bipolar programmable logic array (bipolar PLA), bipolar electrically programmable logic devices (bipolar EPLDs), and bipolar complex PLDs.
Bipolar Digital CBIC/Custom IC:	Bipolar Digital Cell-Based IC is defined as an ASIC device that is produced from a library of standard circuits/cells to a single-user specification. This process involves automatic routing and placement of cells. Included in this definition is bipolar standard cell IC. Excluded from this definition are cell-based ICs with processor cores. These should be reported under Other Bipolar Digital Logic IC.
	Bipolar Digital Custom IC is defined as an ASIC device that is produced for a single user using a full set of masks. This manufacturing process involves manual routing and placement of cells.
Bipolar Digital Standard Logic IC:	Defined as commodity bipolar family logic with fewer than 150 gates. Sometimes referred to as glue logic. Examples include TTL, ECL, and the following other family logic: TTL-compatible SSI, MSI, LSI; standard, AS, FAST, LS, ALS lines; and ECL-compatible SSI, MSI, LSI. Also included are RTL and DTL.

(Continued)

Table 6-1 (Continued)
Semiconductor Product Category Definitions

Other Bipolar Digital Logic IC:	Defined as all other bipolar digital logic ICs not accounted for in the preceding categories. Includes bipolar commodity family logic with 150 or more gates, bipolar digital general-purpose logic not belonging to any families, and bipolar digital microcomponent ICs.
MOS Digital IC:	(MOS Digital Memory IC + MOS Digital Microcomponent IC + MOS Digital Logic IC) A MOS digital IC is defined as a monolithic semiconductor product in which 100 percent of the die area performs digital functions, and concurrently, any portion of the die area that is manufactured using metal-oxide semiconductor (MOS) technology. A digital function is one in which data-carrying signals vary in discrete values. Includes mixed technology manufacturing, such as BiMOS and BiCMOS, where there is some MOS technology employed.
MOS Digital Memory IC:	(DRAM + SRAM + EPROM + EEPROM + Flash Memory + Mask ROM + Other MOS Digital Memory IC) Defined as a MOS digital IC in which binary data is stored and electronically retrieved.
DRAM:	Defined as a Dynamic RAM, Multiport-DRAM (M-DRAM), and Video-DRAM (V-DRAM). DRAMs have memory cells consisting of a single transistor, and require regular externally cycled memory cell refreshes. These are volatile memories and addressing is multiplexed.
SRAM:	Defined as a Static RAM, Multiport-SRAM (M-SRAM), Battery Backed-Up SRAM (BB-SRAM), and Pseudo SRAM (PSRAM). SRAMs have memory cells consisting of a minimum of four transistors, except PSRAM, which has a memory cell consisting of a single transistor and is similar to a DRAM. SRAMs do not require externally cycled memory cell refreshes. These are volatile memories and addressing is not multiplexed (except in the case of PSRAM). Note that color palette DACs are included in the Data Converter/Switch/Multiplexer IC category of analog ICs.
EPROM:	Defined as Erasable Programmable Read-Only Memory. This product classification includes Ultraviolet EPROM (UV EPROM) and One-Time Programmable Read-Only Memory (OTP ROM). EPROMs have memory cells consisting of a single transistor, and do not require any memory cell refreshes. These devices are considered nonvolatile memories.
EEPROM:	Defined as Electrically Erasable Programmable Read-Only Memory. Includes Serial EEPROM (S-EEPROM), Parallel EEPROM (P-EEPROM), and Electrically Alterable Read-Only Memory (EAROM). EEPROMs have memory cells consisting of a minimum of two transistors, and do not require memory cell refreshes. Also includes Nonvolatile RAM (NV-RAM), also known as Shadow RAM. These semiconductor products are a combination of SRAM and EEPROM technologies in each memory cell. The EEPROM functions as a shadow backup for the SRAM when power is lost. These devices are considered nonvolatile memories.

(Continued)

Table 6-1 (Continued)
Semiconductor Product Category Definitions

Flash Memory:	Defined as nonvolatile products designed as Flash EPROM/EEPROM that incorporate either 5V or 12V programming supplies and one-transistor (1T) or two-transistor (2T) memory cells with electrical programming and fast bulk/block erase. Flash memory can only erase data by bulk/block, not by byte.
Mask ROM:	Defined as Mask-Programmable Read-Only Memory. Mask ROM is a form of memory that is programmed by the manufacturer to a user specification using a mask step. Mask ROM is programmed in hardware rather than software. These devices are considered nonvolatile memories.
Other MOS Digital Memory IC:	Defined as all other MOS digital memory not already accounted for in the preceding categories. Includes MOS digital content addressable memory (CAM), MOS digital cache-tag RAM, MOS digital first-in/first-out memory (FIFO), MOS digital last-in/first-out (LIFO) memory, and ferroelectric memory.
MOS Digital Microcomponent IC:	(MOS Digital Microprocessor + MOS Digital Microcontroller + MOS Digital Microperipheral + Programmable Digital Signal Processor) Defined as a MOS digital IC that contains a data processing unit or serves as an interface to such a unit.
MOS Digital MPU:	(8- and 16-bit CISC MPU + 32-bit and greater CISC MPU + 32-bit and greater RISC MPU) MOS Digital Microprocessor is defined as a semiconductor product serving as the central processing unit (CPU) of a system. Consists of an instruction decoder, arithmetic logic unit (ALU), registers, and additional logic. An MPU performs general-purpose computing functions by executing external instructions and manipulating data held in external memory. Includes MOS digital MPUs incorporating or originating from an ASIC design. Wordwidths for microprocessors are defined by the maximum number of data bits used by the integer unit inside the chip. Wordwidths are either 8-, 16-, 32-, or 64-bit. Various microprocessors may have an I/O bus with a different width than the integer unit. Do not use this I/O bus as the determining factor for wordwidth. A CISC MPU is defined as a microprocessor that is based upon an instruction set that uses complex instructions. A RISC MPU is based upon a reduced or simplified instruction set.
8- and 16-bit CISC MPU:	Examples of 8-bit CISC MPUs are the 6800, 6502, Z80, and 8080. Examples of 16-bit CISC MPUs are the 80286 and Z8000.
32-bit and greater CISC MPU:	Examples of 32-bit CISC MPUs are the 68000, 80386, 80486, and Pentium.
32-bit and greater RISC MPU:	Examples of 32-bit RISC MPUs are Alpha, MIPS, PA-RISC, PowerPC, and SPARC.

(Continued)

Table 6-1 (Continued)
Semiconductor Product Category Definitions

MOS Digital MCU:	MOS Digital Microcontroller is defined as a semiconductor product serving as a dedicated or embedded controller in a system. Consists of an integral MPU, nonvolatile memory for use as Program Store, and volatile memory for temporary storage of code or data. MCUs typically contain microperipherals and, as a result, an MCU can perform basic computing functions without support from microperipheral (MPR) products. Includes MOS digital MCUs incorporating or originating from an ASIC design. Wordwidths for microcontrollers are defined by the maximum number of data bits used by the integer unit inside the chip. Wordwidths are either 4-, 8-, or 16-bit; 32-bit MCUs should be reported in the 16-bit category.
4-bit MCU:	Examples of 4-bit MCUs are the uPD75X, HMCS-400, LC65, and similar families.
8-bit MCU:	Examples of 8-bit MCUs include the 68HC05/6805, 68HC11, 8051, Z8uPD78xx, and PIC families.
16-bit MCU:	Examples of 16-bit MCUs include the 80196/8096, uPD78K, M377XX, and 68HC16.
MOS Digital MPR:	(System Core Logic Chipsets + Graphics and Imaging Controllers + Communications Controllers + Mass Storage Controllers + Audio/Other Controllers) MOS Digital Microperipheral is defined as a semiconductor product serving as a logical support function to an MPU in a system. An MPR provides enhancement of system performance and/or interface with external systems. Includes MOS digital MPRs comprising more than one device, such as PC chip sets. Examples of a MOS digital MPR include: memory and bus controllers (for example, PC logic chip sets, DRAM controllers, memory management units (MMU), and DMA controllers; peripheral interface controllers (for example, graphics controllers, LAN controllers, UARTs, keyboard controllers, and mass storage controllers); and coprocessors (for example, math coprocessors—or FPUs—and other coprocessors).
System Core Logic Chipsets:	Defined as a device dedicated to a particular microprocessor interface that performs some of the basic interface functions such as memory management DRAM control, cache control, bus interface controllers, DMA controllers, and interrupt controllers.
Graphics and Imaging Controllers:	Defined as a device that typically interfaces to some form of system bus to interpret, control, and display the visual output of systems (computer-generated graphics, live video, and other images), including PC graphics chips, image processors, and video codecs.
Communications Controllers:	Defined as a device that controls, formats, and performs handshaking for the transmission and reception of information between systems or intelligent devices, which includes network controllers, integrated fax/modem chips, serial UARTs, and other communications interfaces.

(Continued)

Table 6-1 (Continued)
Semiconductor Product Category Definitions

Mass Storage Controllers:	Defined as a device used to control data storage into and retrieval from all forms of mass storage media (magnetic, optical, and other), which includes controllers used within host computers (host-side) and within mass storage drives (device-side).
Audio/Other Microperipherals:	Defined as a device used to input or output information through other forms including audio input/output controllers, keyboard controllers, pen-input controllers, parallel port controllers, and various miscellaneous devices.
pDSP:	Defined as a high-speed programmable general-purpose arithmetic unit used for performing complex mathematical operations such as Fourier transforms. DSPs embedded into an MPU or MCU are classified as either an MPU or MCU, respectively.
MOS Digital Logic IC:	(MOS Digital Logic Application-Specific IC + MOS Digital Standard Logic IC + Other MOS Digital Logic IC)
	Defined as an MOS digital IC in which more than 50 percent of the die area performs logic functions. Excludes MOS digital microcomponent ICs.
MOS Digital Logic ASIC:	(CMOS Digital Gate Array + BiCMOS Digital Gate Array + MOS Digital Programmable Logic Device + MOS Digital Cell-Based IC + MOS Digital Full-Custom IC)
	Defined as a single-user logic IC that is manufactured using vendor-supplied tools and/or libraries. Do not include ASICs incorporating microprocessor or microcontroller cells, which should be included in microprocessor or microcontroller revenue.
CMOS Digital GA:	CMOS Digital Gate Array is defined as a MOS GA manufactured entirely in complementary metal-oxide semiconductor (CMOS) technology. This ASIC is customized by the vendor to end-user specification using layers of interconnect. Included in this category are generic or base wafers with embedded functions, such as SRAM and EEPROM.
BiCMOS Digital GA:	BiCMOS Digital Gate Array is defined as a MOS GA manufactured using bipolar and complementary metal-oxide semiconductor (CMOS) technologies. The ASIC is customized by the vendor to end-user specification using layers of interconnect. Included in this category are generic or base wafers with embedded functions, such as SRAM and EEPROM.
MOS Digital PLD:	MOS Digital Programmable Logic Device is defined as an ASIC device that is customized by the end user after assembly. Included in this category are MOS field-programmable logic (MOS FPL), MOS field-programmable gate array (MOS FPGA), MOS programmable array logic (MOS PAL), MOS programmable logic array (MOS PLA), MOS electrically programmable logic device (MOS EPLD), and MOS complex PLDs.

(Continued)

Table 6-1 (Continued)
Semiconductor Product Category Definitions

MOS Digital CBIC:	MOS Digital Cell-Based IC is defined as an ASIC device that is produced from a library of standard circuits/cells to a single-user specification. This process involves automatic routing and placement of cells. Included in this definition is MOS standard cell IC. Excluded from this definition are cell-based ICs with processor cores. These should be reported under MOS digital microcomponent IC.
MOS Digital FCIC:	MOS Digital Full-Custom IC is defined as an ASIC device that is produced for a single user using a full set of masks. This process involves manual routing and placement of cells.
MOS Digital Standard Logic IC:	Defined as commodity MOS family logic with fewer than 150 gates. Sometimes referred to as glue logic. Examples include: HC, HCT, AC, ACT, FACT, and 74BC BiCMOS family logic.
Other MOS Digital Logic IC:	Defined as all other MOS digital logic ICs not accounted for in the preceding categories. Includes MOS commodity family logic with 150 or more gates, and MOS digital general-purpose logic not belonging to any families.
Total Analog IC:	(Amplifier/Comparator IC + Voltage Regulator/Reference IC + Data Converter/Switch/Multiplexer IC + Interface IC + Telecom IC + Disk Drive IC + Other Special function IC + Linear Array/ASIC + Mixed-Signal ASIC + Total Special Consumer IC + Special Automotive IC + Smart Power IC)
	An analog IC is a semiconductor product that deals in the realm of electrical signal processing, power control, or electrical drive capability. It is one in which some of the inputs or outputs can be defined in terms of continuously or linearly variable voltages, currents, or frequencies. Includes only monolithic analog ICs manufactured using bipolar, MOS, or BiCMOS technologies. A monolithic IC is a single die contained in a single package.
Amplifier/Comparator IC:	An Amplifier IC is defined as a general-purpose linear IC that provides a voltage or current gain to an input signal. Includes operational amplifiers (mono, dual, and quad, among others), instrumentation amplifiers, buffer amplifiers, and power amplifiers. Consumer-dedicated amplifier ICs are counted in special consumer IC. Amplifier ICs designed specifically for one customer using vendor-supplied tools and/or libraries are counted in linear array ASIC.
	A Comparator IC is defined as a general-purpose linear IC that compares two analog signal inputs and provides a single logic bit output. Although the output could be considered digital, these products are classed as linear ICs because they are specialty high-gain amplifiers, used in an open-loop mode, and for which the output is constrained to only two states. By using a comparator, an unknown voltage can be compared with a known reference voltage. Comparator ICs designed specifically for one customer using vendor-supplied tools and/or libraries are counted in linear array ASIC.

(Continued)

Table 6-1 (Continued)
Semiconductor Product Category Definitions

Voltage Regulator/Reference IC:	A Voltage Regulator IC is defined as a general-purpose linear IC that outputs a variable current at a regulated DC voltage to other circuits from a variable current and voltage input. Regulator ICs are either linear regulators in which the device provides an input-to-output voltage drop, or switching regulators, in which the device provides switched quantities of power to a smoothing circuit to gain higher efficiency and reduce power dissipation. Voltage regulator ICs designed specifically for one customer using vendor-supplied tools and/or libraries are counted in linear array ASIC. A Voltage Reference IC is defined as a general-purpose linear IC that outputs a precise reference voltage to other circuits from a variable voltage input. A reference IC differs from a regulator IC in that it is not expected to power other circuits. In fact, voltage regulator ICs incorporate a voltage reference circuit. Voltage reference ICs designed specifically for one customer using vendor-supplied tools and/or libraries are counted in linear array ASIC.
Data Converter/Switch/Multiplexer IC:	A Data Converter IC is defined as a general-purpose mixed-signal IC that converts an analog signal into a digital signal, or vice versa. Includes analog-to-digital converters (ADCs), digital-to-analog converters (DACs), comparators, sample-and-hold circuits (SHCs), voltage-to-frequency circuits (VFCs), frequency-to-voltage circuits (FVCs), synchro-to-digital circuits (SDCs), and digital-to-synchro circuits (DSCs). All these are general-purpose data converter ICs. Also included in this category are color-palette DACs. Consumer-dedicated data converter ICs are counted in special consumer IC, under monolithic linear ICs. Data converter ICs designed specifically for one customer using vendor-supplied tools and/or libraries are counted in mixed-signal ASIC. A Switch/Multiplexer IC is defined as a mixed-signal IC that digitally controls analog transmission gates. These products connect or disconnect the analog signal path in analog circuits. Analog switches operate in a mode where each switch is operated independently by a single logic bit. Multiplexers are multiple analog switches that are connected in a dependent manner, where only one signal path is connected through to the output depending on the state of a digital address word (greater than one bit). Thus, analog multiplexers are really addressable signal selector switches that select one-out-of-many signals for further analog processing. Because these addressable analog switches were the key element in time-division multiplexing, the term "multiplexer" has remained. They are an important part of the data conversion product family in that they are used to provide time-division multiplexing of signal inputs to a fast analog-to-digital converter. Switch/multiplexer ICs designed specifically for one customer using vendor-supplied tools and/or libraries are counted in mixed-signal ASIC.

(Continued)

Table 6-1 (Continued)
Semiconductor Product Category Definitions

Interface IC:	Defined as a general-purpose mixed-signal IC that serves as an interface between a digital system and other external nonsemiconductor systems. Includes line drivers, peripherals drivers, display drivers, keyboard encoders, receivers, transmitters, and transceivers. Interface ICs designed specifically for one customer using vendor-supplied tools and/or libraries are counted in mixed-signal ASIC.
Telecom IC:	Defined as a general-purpose mixed-signal IC used for voice band communication or data communication over voice band media. This category includes codecs, combos and SLACs, SLICs, modem and fax/modem ICs, dialer and ringer ICs, repeaters, cellular communications ICs, ISDN ICs, telecom filter ICs, and other telecom-specific circuits. Telecom ICs designed specifically for one customer using vendor-supplied tools and/or libraries are counted in mixed-signal ASIC.
Disk Drive IC:	Defined as a mixed-signal IC that is designed specifically for the rotating mass storage market. Applications include the read/write path from preamp up to the ENDEC, head positioning controller, and spindle motor control. Disk drive ICs designed specifically for one customer using vendor-supplied tools and/or libraries are counted in mixed-signal ASIC.
Other Special Function IC:	Defined as either general-purpose linear ICs that do not fit into the other categories, or market/application-specific linear ICs for which a category does not yet exist. The main products that fall into this category include timers, phase-locked loops (PLLs), voltage-controlled oscillators (VCOs), signal/function generator ICs, and analog multipliers. Other special function ICs designed specifically for one customer using vendor-supplied tools and/or libraries are counted in Linear Array/ASIC IC category.
Linear Array/ASIC:	Defined as a single-user linear IC that is manufactured using vendor-supplied tools and/or libraries. Linear arrays fall into one of three types, as follows: 1. Arrays of discrete-level cells such as transistors and diodes 2. Arrays of discrete device combinations referred to as tiles 3. Arrays of higher level functional macro cells such as operational amplifiers, comparators, VCOs, references, and other analog functions. These arrays are interconnected with a metal mask or by means of some user-programmable interconnect scheme. Unlike cell-based designs, they do not have a unique set of masks for all layers.
Mixed-Signal ASIC:	Defined as a mixed-signal analog IC that is manufactured for a single user, using vendor-supplied tools and/or libraries.

(Continued)

Table 6-1 (Continued)
Semiconductor Product Category Definitions

Total Special Consumer IC:	(Video Special Consumer IC + Audio Special Consumer IC + Other Special Consumer IC)
	Defined as a general-purpose linear IC that is dedicated to general consumer applications but is not application-specific. Consumer ICs designed specifically for one customer using vendor-supplied tools and/or libraries are counted in linear array ASIC.
Video Special Consumer IC:	Defined as a linear IC implemented in video applications.
Audio Special Consumer IC:	Defined as a linear IC implemented in audio applications, including radio, and speech synthesis and recognition.
Other Special Consumer IC:	Defined as a linear IC implemented in other consumer applications such as electronic games, personal and home appliances, and electronic cameras.
Special Automotive IC:	Defined as a linear IC that is used in the following automotive applications: entertainment, engine control, safety, traction, and in-car electrical and suspension systems. Special automotive ICs designed specifically for one customer using vendor-supplied tools and/or libraries are counted in linear array ASIC.
Smart Power IC:	Defined as mixed-signal ICs that can control large currents of voltages at the output. These devices combine digital logic inputs with control logic and power outputs. To be considered a power device, the outputs must be capable of switching either one amp of current, at any voltage, or 100V (or more) at any current.
Total Discrete:	(Transistor + Diode + Thyristor + Other Discrete)
	A discrete semiconductor is defined as a unit building block performing a fundamental semiconductor function.
Transistor:	(Small-Signal Transistor + Power Transistor)
Small-Signal Transistor:	Defined as signal transistors, RF microwave transistors, dual transistors, MOS field-effect transistors (MOS-FETs), conductivity modulated field-effect transistors (COMFETs), insulated gate bipolar transistors (IGBTs), and MOS-bipolar transistors (MBTs). All rated below 1W power dissipation.
Power Transistor:	(Bipolar Power Transistor + MOS Power Transistor + Power IGBT) All rated 1W power dissipation and above.
Bipolar Power Transistor:	Defined as bipolar Darlington transistor, bipolar microwave transistor, and bipolar radio frequency (RF) transistor.
MOS Power Transistor:	Defined as MOS field-effect transistor (MOS-FET), MOS Darlington transistor, MOS microwave transistor, and MOS radio frequency (RF) transistor.
IGBT Power Transistor:	Defined as insulated gate bipolar transistor (IGBT). Also includes conductivity modulated field-effect transistor (COMFET), MOS-bipolar transistor (MBT), and GEMFET.
Diode:	(Small-Signal/Reference Diode + Power Diode/Rectifier)

(Continued)

Table 6-1 (Continued)
Semiconductor Product Category Definitions

Small-Signal/Reference Diode:	Defined as signal diodes, Schottky diodes, zener diodes, switching diodes, voltage reference diodes, voltage regulator diodes, and rectifier diodes. All are rated below 0.1A.
Power Diode/Rectifier:	Defined as zener diodes and rectifier diodes. All are rated 0.1A and above.
Thyristor:	Defined as thyristors, silicon-controlled rectifiers (SCRs), diacs, and triacs. Also includes solid-state relays (SSRs) incorporating triacs, thyristors, resistors, and capacitors.
Other Discrete:	Defined as all other discrete semiconductor products not accounted for in the preceding categories. Includes microwave diodes, varactors, tuning diodes, tunnel effect diodes, and selenium rectifiers. Does not include thermistors and varistors.
Total Optical Semiconductor:	(LED Lamp/Display + Optocoupler + CCD + Laser Diode + Photosensor + Other Optical Semiconductor)
	Defined as a semiconductor product in which photons induce the flow of electrons, or vice versa. Other functions may also be integrated onto the product. This category does not include LCD, incandescent displays, fluorescent displays, cathode ray tubes (CRTs), or plasma displays.
LED Lamp/Display:	(LED Lamp + LED Display)
	An LED lamp is defined as a light-emitting diode: a semiconductor product consisting of a single die in which photons are emitted at frequencies dependent upon the semiconductor material employed. An LED display is defined as an array of LEDs: a semiconductor product consisting of more than one die in which photons are emitted at frequencies dependent upon the semiconductor material employed.
Optocoupler:	Defined as an optocoupler or opto isolator. A semiconductor product consisting of an LED separated from a photosensor by a transparent, insulating, dielectric layer. These are mounted inside an opaque package. Includes optointerrupters, in which the separation between LED and photosensor is large enough to allow external physical systems to influence the device.
CCD:	Defined as a charge-coupled device. A semiconductor product consisting of an array of photodiodes, an analog CCD shift register, and an output circuit. Includes linear array CCDs with serial shift registers and area array CCDs with parallel shift registers. Includes charge injection device (CID), charge-coupled photodiode (CCP), charge-priming device (CPD), and self-scanning photodiode (SSP).
Laser Diode:	Defined as a diode that produces coherent light. A semiconductor product in which the heterojunction structure stimulates light amplification by stimulated emission of radiation (laser), resulting in coherent light. Includes Fabrey-Perot laser diodes, pulsed laser diodes, and phase-shifted laser diodes.

(Continued)

Table 6-1 (Continued)
Semiconductor Product Category Definitions

Photosensor:	(Photodiode + Phototransistor)
	Defined as a diode or transistor in which photons are used to affect current flow or electric potential.
Other Optical Semiconductor:	Defined as all other optical semiconductor devices not accounted for in the preceding categories. Includes solar cells and optical thermal piles.

Source: Dataquest (October 1993)

Chapter 7
Worldwide Geographic Region Definitions

North America

Includes Canada, Mexico, and the United States (50 states).

Japan

Japan is the only single-country region.

Europe

Western Europe

Includes Austria, Belgium, Denmark, Eire (Ireland), Finland, France, Germany (including former East Germany), Greece, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and Rest of Western Europe (Andorra, Cyprus, Gibraltar, Liechtenstein, Monaco, San Marino, Vatican City, Iceland, Malta, and Turkey).

Eastern Europe

Includes Albania, Bulgaria, the Czech Republic and Slovakia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, the republics of the former Yugoslavia, and the republics of the former USSR (Belorussia, Russian Federation, Ukraine, Georgia, Moldavia, Armenia, Azerbaijan, Kazakhstan, Uzbekistan, Tadjikistan, Kirghizia, and Turkenistan).

Asia/Pacific

Includes Asia/Pacific's newly industrialized economies (NIEs) and the Rest of Asia/Pacific regions. NIEs include Hong Kong, Singapore, South Korea, and Taiwan. The Rest of Asia/Pacific region includes Australia, Cambodia, China, India, Indonesia, Laos, Malaysia, Maldives, Myanmar, Nepal, New Zealand, Pakistan, the Philippines, Sri Lanka, Thailand, and Vietnam.

Rest of World

Includes Africa, the Caribbean, Central America, the Middle East, Oceania, and South America.

Chapter 8
Semiconductor Application Segment Definitions

Data Processing

Defined as computer systems, data storage devices, terminals, input/output devices, dedicated systems, and other data processing equipment:

- Computer systems include supercomputers, mainframe computers, midrange computers (also known as superminicomputers and minicomputers) workstations, and personal computers (including portable computers).
- Data storage devices include flexible/removable disk drives, fixed/rigid disk drives, optical disk drives, and tape drives (streamers).
- Terminals include alphanumeric terminals, graphics terminals, and funds transfer terminals.
- Input/output devices include printers, media-to-media data conversion, magnetic ink character recognition, monitors, optical scanning equipment, plotters, voice recognition/synthesizer equipment, mice, keyboards, and digitizers.
- Dedicated systems include electronic copiers, electronic calculators, smart cards, dictating/transcribing equipment, electronic typewriters and dedicated word processors, banking systems and funds transfer systems and terminals, point-of-sale terminals and electronic cash registers, and mailing/letter-handling/addressing equipment.
- Other data processing equipment include IC cards, memory cards, and game software

Communications

Defined as premise telecom equipment, public telecom equipment, mobile/radio communications equipment, broadcast and studio equipment, and other telecom equipment:

- Premise telecom equipment includes image and text communication such as facsimile and video teleconferencing; data communications equipment such as modems, statistical multiplexers, T1 multiplexers, front-end processors, DSU/CSU, protocol converters, local area networks (LANs), internetworking, network management and packet data switching/wide area networks (WANs); premise switching equipment, such as PBX telephone equipment, and key telephone systems; call processing equipment, such as voice messaging systems, interactive voice response systems, call accounting and automatic call distributors (ACDs); and desktop terminal equipment such as telephone sets/pay telephones and teleprinters.

- Public telecom equipment includes transmission equipment, such as multiplexers, carrier systems, microwave radio, laser and infrared transmission equipment, and satellite communications equipment; and central office switching equipment.
- Mobile/radio communications equipment includes mobile radio systems such as cellular telephones, mobile radios and mobile radio base station equipment; portable radio receivers and transmitters; radio checkout equipment; and other RF communications equipment.
- Broadcast and studio equipment includes audio equipment, video equipment, transmitters and RF power amplifiers, studio transmitter links, cable TV equipment, closed circuit TV equipment, and other equipment such as studio and theater equipment.
- Other telecom equipment includes intercom equipment and electrical amplifiers, and communications equipment not elsewhere classified.

Industrial

Defined as security/energy management systems, manufacturing systems and instruments, medical equipment, and other industrial equipment:

- Security/energy management systems include alarm systems, such as intrusion detection and fire detection systems, and energy management systems.
- Manufacturing systems and instruments include semiconductor production equipment, controllers and actuators, sensor systems, management systems, and robotics; and semiconductor-dedicated automatic test equipment (ATE), all other ATE, oscilloscopes and waveform analyzers, nuclear instruments, and other test and measurement equipment.
- Medical equipment includes X-ray equipment, ultrasonic and scanning equipment, blood and body fluid analyzers, patient monitoring equipment, and other diagnostic and therapeutic equipment.
- Other industrial equipment includes vending machines, power supplies, traffic control equipment, and industrial equipment not elsewhere classified.

Consumer

Defined as audio equipment, video equipment, personal electronics, appliances, and other consumer equipment:

- Audio equipment includes compact disc players, radios, stereo components, musical instruments, tape recorders, and other audio equipment such as tuners and headphone stereos.
- Video equipment includes videocassette recorders (VCRs), video cameras and camcorders, videodisk players, and color, monochrome, and LCD televisions.

- Personal electronics include electronic games and toys, cameras, watches, and clocks.
- Appliances include air conditioners, microwave ovens, washers and dryers, refrigerators, dishwashers, and ranges and ovens.
- Other consumer equipment includes automatic garage door openers and consumer equipment not classified elsewhere.

Military and Civil Aerospace

Defined as military electronic equipment and civil aerospace.

- Military electronic equipment includes military electronics, such as radar and sonar, missiles and weapons, space-related electronics, communications and navigation equipment, electronic warfare, aircraft systems, military computer systems, military simulation systems, and military electronics not classified elsewhere.
- Civil aerospace includes civilian aerospace electronics, such as radar, space-related electronics, communications and navigation equipment, flight systems, and simulation systems.

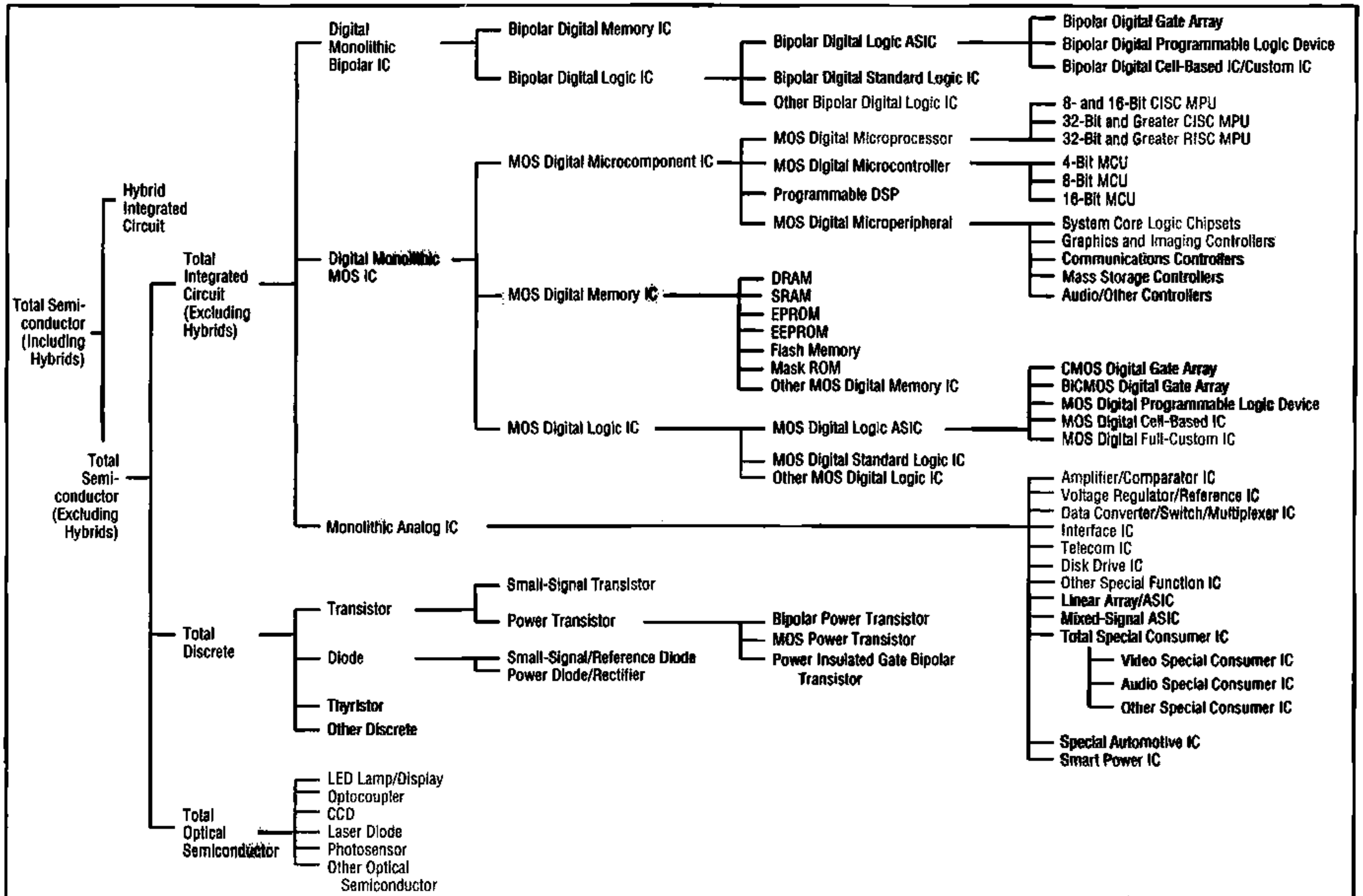
Transportation

Defined as in-car entertainment systems, body control electronics, driver information systems, power train systems, and safety and convenience systems:

- In-car entertainment systems include AM/FM radio, cassette, compact disc player, radio cassette combination systems, two-way radio communications systems, and CB radio.
- Body control electronics include vehicle controls such as four-wheel steering control and 2WD/4WD control; multiplex systems such as driver's door, auto-climate control, door locks, windshield wipers, heated rear windows, memory seats, remote security systems, steering wheel, suspension control and traction control; lighting controls including automatic headlight systems, timers, reminders, and sequential signal controls; and other body control electronics including aerodynamic aid control and power roof/window controls.
- Driver information systems include electronic dashboard/instrument clusters, analog or digital clusters, electronic analog/digital clocks and compasses, electronic thermometers, head-up displays, navigation and location systems, and signal and warning lights.
- Power train systems include engine management systems, power train sensors, ignition control, fuel injection systems, fuel flow, engine temperature, air temperature, coolant level, and wheel speed sensors.
- Safety and convenience systems include air conditioners, air purifier systems, air bag control systems, antilock braking systems, active suspension, collision avoidance systems, collision warning systems, and cruise control.

Appendix A
Semiconductor Product Hierarchy

Figure A-1
Semiconductor Product Hierarchy



Source: Dataquest (October 1993)

G9004594

For More Information...

Terrance A. Birkholz, Market Research Analyst ....(408) 437-8196
Via fax ....(408) 437-0292

Dataquest®
a company of The Dun & Bradstreet Corporation

Dataquest®

a company of
The Dun & Bradstreet Corporation

Corporate Headquarters
Dataquest Incorporated
1290 Ridder Park Drive
San Jose, California 95131-2398
United States
Phone: 01-408-437-8000
Facsimile: 01-408-437-0292

Dataquest Incorporated
550 Cochituate Road
Framingham, Massachusetts 01701-9324
United States
Phone: 01-508-370-5555
Facsimile: 01-508-370-6262

Invitational Computer Conferences (ICC)
3990 Westerly Place, Suite 100
Newport Beach, California 92660
United States
Phone: (714) 476-9117
Facsimile: (714) 476-9969

Dataquest Japan Limited
Shinkawa Sanko Building
1-3-17, Shinkawa, Chuo-ku
Tokyo 104
Japan
Phone: 81-3-5566-0411
Facsimile: 81-3-5566-0425

Dataquest Korea
Trade Tower, Suite 3806
159 Samsung-dong
Kangnam-gu, Seoul 135-729
Korea
Phone: 011-82-2-551-1331
Facsimile: 011-82-2-551-1330

European Headquarters
Dataquest Europe Limited
Roussel House, Broadwater Park
Denham, Uxbridge
Middlesex UB9 5HP
England
Phone: 44-895-835050
Facsimile: 44-895-835260/1

Dataquest GmbH
Kronstadter Strasse 9
8000 Munich 80
Germany
Phone: 011-49-89-930-9090
Facsimile: 011-49-89-930-3277

Dataquest Europe SA
Tour Gallieni 2
36, Avenue du General de Gaulle
93175 Bagnolet Cedex
France
Phone: 011-33-1-48-97-3100
Facsimile: 011-33-1-48-97-3400

Representative Agencies in
Bangkok, Hong Kong,
Kronberg, North Sydney,
Singapore, Taipei, and Tel Aviv

0015292

NO1SEM1WW SCNDWWG09301 BH: 1
Mr. Clark Fuhs
Dataquest Incorporated
1-1100
****
SJ - INTERNAL DISTRIBUTION
****

Dataquest Research Methodology

Dataquest®

RSOP-COR-GU-9201
August 31, 1992

Dataquest Research Methodology

Dataquest®

RSOP-COR-GU-9201
August 31, 1992

Published by Dataquest Incorporated

The content of this report represents our interpretation and analysis of information generally available to the public or released by knowledgeable individuals in the subject industry, but is not guaranteed as to accuracy or completeness. It does not contain material provided to us in confidence by our clients.

Table of Contents

List of Tables

List of Figures

Chapter 1
Introduction

Fundamental to the way Dataquest conducts its research is the underlying philosophy that the best research and analysis uses appropriate methodology. Such methodology includes a balance between primary and secondary data collection; between supply-side, vendor-based analysis and demand-side, consumer-preference analysis; between focused, industry-specific research and coordinated, "big picture" analysis; and between the informed, insightful perspectives of experienced industry professionals and the rigorous, disciplined techniques of seasoned market researchers. Ultimately, this leads to a balance between data and analysis—the combination of which provides unique insight and maximum tangible value to our clients.

The purpose of the *Dataquest Research Methodology Guide* is to provide a clear and concise overview of Dataquest's research methodologies. This guide discusses research methodology as it pertains to vendor-based research, user-based research, and market forecasting.

Each methodology is discussed separately for explanatory clarity. In no way does this organization imply that one type of research is done in isolation of the other types. For example, vendor-based research, user-based research, and market forecasts all rely on the services provided by both primary and secondary research. Also, results from vendor-based research and user-based research are inputs to market forecasting. Indeed, the free flow of information among the different research specialties creates synergy that is key to Dataquest's research methodology.

Dataquest is committed to a rigorous research methodology. Dataquest applies accepted market research techniques to the dynamic world of changing technology, fluctuating business conditions, and evolving client needs. The methodologies described in this document serve the multiple needs of our clients in a constantly changing marketplace.

Chapter 2
Research Methods

Dataquest recognizes the importance of a variety of information sources and the impact they have on the value of the services we provide. Dataquest conducts primary market research as well as secondary research to produce timely, detailed, and accurate analyses of high-technology marketplaces. The combination of these two research approaches yields a rich pool of data that can be used to answer specific questions, to produce market statistics, and to analyze and forecast industry trends.

Primary research can be distinguished from secondary research in several important ways, as follows:

- Primary information is first-hand data collected by the researcher. Secondary research is information that already has been published and typically is bought for research purposes.
- Primary research is custom research in areas where data or information does not previously exist. On the other hand, much of the secondary information has been compiled and published for some particular purpose other than market research.
- Availability is another key distinction between primary and secondary research. Primary research is proprietary data and available on a selective basis. Secondary research is public information and generally easy to obtain.

Dataquest views primary and secondary research as complementary components in its data gathering, drawing on each to produce vital information for high-tech markets.

Primary Research

Dataquest relies heavily on primary research as a means to collect original data. Primary research is conducted with end users in business, households, government, and schools; and with product vendors, suppliers, manufacturers, and distributors. Primary information is collected by Dataquest's in-house field interviewing groups as well as by industry analysts worldwide.

There are three basic interviewing methods used by Dataquest: telephone interviews, mail interviews, and personal interviews. The choice of which method to use is determined by the objective of the project.

Telephone Interviews

Dataquest uses telephone-based field interviewing for much of its primary research. This method is usually employed when the study design requires a large randomly selected sample from a population, when eligibility is difficult to determine (necessitating many contacts for a completed interview), when the interview is relatively short, or when face-to-face contact is impossible or unnecessary. In some cases, questionnaires are faxed to the respondent prior to the telephone interview.

Telephone interviewing is conducted regularly by Dataquest's in-house field interviewing groups in San Jose and Paris. The charter of Dataquest's field interviewing groups is to collect and ensure quality data in a timely and cost-effective manner. These objectives are possible because of the following competitive advantages unique to Dataquest's interviewing group:

- Dataquest uses interviewers who specialize by industry, ensuring consistent, high-quality information
- Dataquest has complete access to information-gathering resources
- Dataquest experiences increased productivity because of industry contacts and knowledge of technologies

Dataquest's San Jose facility conducts interviews in North America, South America, Japan, and Asia/Pacific. Interviewing in Japan is also conducted from Dataquest's Tokyo office. Dataquest's Primary Research Centre, located in Paris, conducts interviews in 12 languages throughout the European region.

Central location interviewing has many advantages. It allows for central monitoring to ensure that correct interviewing procedures are being followed. Furthermore, if a respondent requests clarification on the meaning or intent of a question, it can be handled on the spot.

Dataquest's field interviewers participate in a briefing on each project prior to implementation. Interviewers are trained specifically in handling open-ended questions and questions that ask for "other" responses.

Mail Questionnaires

Dataquest uses mail questionnaires infrequently for the following three reasons:

- Low response rate—Mail surveys have a lower response rate than do personal or telephone interviews. The danger with low response rates is that those who return the questionnaires may be "different" or not representative of the universe of respondents, thereby introducing bias.

- Accuracy—There is no interviewer in mail surveys who can explain the purpose of the project, clarify the questions, or resolve any problems. Respondent confusion about the questions can adversely affect survey accuracy.
- Time—It takes several weeks to conduct a mail survey, and most clients cannot wait that long.

Mail surveys cannot be used for an unstructured study in which the interviewer formulates the questions as the interview progresses. Personal and telephone interviews are more flexible in that they can be terminated or altered at any point, whereas mail surveys are inflexible.

Paper and pencil questionnaires are used in some specialized situations such as trade conferences and other group meetings.

Personal Interviews

Personal interviews are less structured and more intensive than phone interviews. There is a longer and more flexible relationship with the respondent resulting in data that has more depth and richness.

There are two basic types of personal interviews: nonstructured and semistructured. Nonstructured and semistructured interviews differ in the amount of guidance given by the interviewer. In the nonstructured interview, the respondent is given considerable freedom to respond within the bounds of topics specified by the interviewer. In semistructured interviews, the interviewer have a specific list of topics to cover with the respondent.

Focus groups are another form of personal interviews. Focus groups consist of 8 to 12 people who gather for two to three hours with a trained group facilitator to discuss a product, service, organization, or other marketing entity. The participants are paid an honorarium for attending. The meeting is held in a focus group room equipped with a two-way mirror for filming and observation. The group facilitator encourages remarks from the participants, while at the same time focusing their discussion. The comments are tape recorded and analyzed.

Secondary Research

Dataquest recognizes the importance of secondary research in all its analytical and intelligence functions. Although secondary information alone does not answer complex market research questions, secondary research has major advantages and roles in the market research process. Dataquest uses secondary information for the following:

- Provide basic working knowledge of industries
- Gather facts about the technology, products, and applications
- Monitor developments

- Explore new territory or emerging technologies
- Gain insight for preliminary analysis
- Signal need for primary research
- Gather information quickly and at a lower cost than primary research.

In conducting secondary research, Dataquest employs a methodology to ensure that appropriate information is obtained to meet the diverse needs of its researchers. With a process-oriented approach, Dataquest is not only able to achieve time and cost efficiencies, but also is able to focus on finding the desired data from the pool of secondary information that currently exists. This process can be summarized as follows:

- Define the topic and data points to be collected
- Select secondary sources to search
- Conduct information search through multiple sources, using electronic databases, CD-ROMs and print resources
- Assemble and review information from all sources
- Present results of the information gathered

Because an impressive amount of secondary information exists concerning high-technology industries and the companies within these markets, Dataquest's researchers routinely use secondary research in the following key areas:

- Market sizing
- Validating estimates
- Cross-checking information, such as market share
- Checking trends that influence markets
- Checking company growth rates
- Verifying shipment totals and pricing information
- Supporting assumptions used in forecasting

Because our researchers and analysts are expected to review all types of information to keep abreast of market trends and industry events, Dataquest understands that access to information is a crucial part of the market research process. Dataquest has invested substantial resources to ensure that current information is available and accessible by all research staff.

The secondary research process is managed by professional librarians who understand how and where to get the secondary information necessary to support the needs of analysts and researchers. Dataquest's librarians are not only expert in searching all types of information sources, but also in selecting and obtaining key resources that researchers need on a frequent basis. The librarians work closely with the research staff to answer the complex questions that arise during the course of our market research.

Each major Dataquest location maintains a library facility that typically offers a comprehensive collection of information sources covering the full range of high-technology companies, markets, and industries tracked by Dataquest. Sources of secondary information typically utilized by Dataquest include the following:

- Articles in the general business and trade press
- Financial information from annual reports and other SEC documents
- Company and product directories
- Company press releases and product literature
- Government reports, statistics and economic data
- Trade association data
- Credit reports

In-house research collections are supplemented by online database services including Dialog, Lexis/Nexis, Dow Jones, Newsnet, Data-Star, and CompuServe. Other specialized databases from such companies as Dun & Bradstreet and Thomson Financial are also available to the research staff.

The benefits of buying secondary information on CD-ROM were recognized a number of years ago, and Dataquest became an early adopter of this information format. Today we have numerous CD-ROMs available for retrieving financial information, trade press articles, product information, and company profiles. Because of the high information content and ease of use of these products, these resources are used heavily by our research staff. In addition, analysts and researchers are able to receive secondary information on their own computer workstations. For instance, Dataquest currently has agreements for real-time information feeds from companies like BusinessWire and PR Newswire that are accessible from the researcher's desktop.

Chapter 3
Vendor-Based Research

Each year, Dataquest tracks the shipments and revenue of thousands of vendors worldwide. This research helps Dataquest maintain a dynamic database of product shipments by company, and product consumption by region of the world.

Dataquest conducts product market share surveys on a quarterly, semiannual, or annual basis. The annual market share actually includes two surveys—a preliminary and a final survey. The preliminary estimates are completed by the end of the calendar year being reported, and the results are summarized in a report which is released early in the new year. Preliminary vendor rankings are featured in a Dataquest press release. Final market share estimates are prepared during the first quarter, and the results are published in a reference report released in the spring.

Dataquest believes that the estimates presented in its market share documents are the most accurate and meaningful statistics available. While Dataquest takes care in gathering, analyzing, and categorizing its data, clients must be aware of the definitions and assumptions that Dataquest uses when they interpret the estimates presented in the market statistics documents. Other companies, government agencies, and trade associations may use slightly different definitions of product categories and regional groupings, thereby reporting different results. These differences should be kept in mind when making comparisons between data provided by Dataquest and those provided by other suppliers.

Dataquest's Methodology

Dataquest's vendor-based research incorporates both market sizing and market share research activities.

Market Size

Market size is defined as the universe of all companies competing in a market. The universe of companies is based on a core list of companies that Dataquest has developed over time. Each year, Dataquest checks the universe to add companies previously not included, and to delete companies no longer competing in the market.

Dataquest uses its proprietary market sizing bibliography as a foundation for market sizing research. The market sizing bibliography describes sources of information that identify companies participating in various markets. These sources include industry associations, business and financial sources, and other secondary sources. Dataquest analysts search these sources to develop a list of companies that is as comprehensive as possible. Special attention is devoted to identifying companies not included in our previous data collection.

Once the universe of companies in an industry is identified, researchers estimate the approximate size of each company. Size is one of the variables used in identifying a company as a leading vendor and as a company that Dataquest will track in greater detail. The largest companies are usually considered to be leading vendors in an industry. In addition to size, identification of a company as a vendor that merits more detailed attention is based on our ongoing relationships with industry contacts and industry events.

Smaller companies in each market are also noted. Shipments and revenue for smaller companies are estimated using the same general procedures applied to larger companies. The data from smaller companies usually are aggregated and reported as "other companies." These estimates are incorporated into overall market size statistics.

Market Share

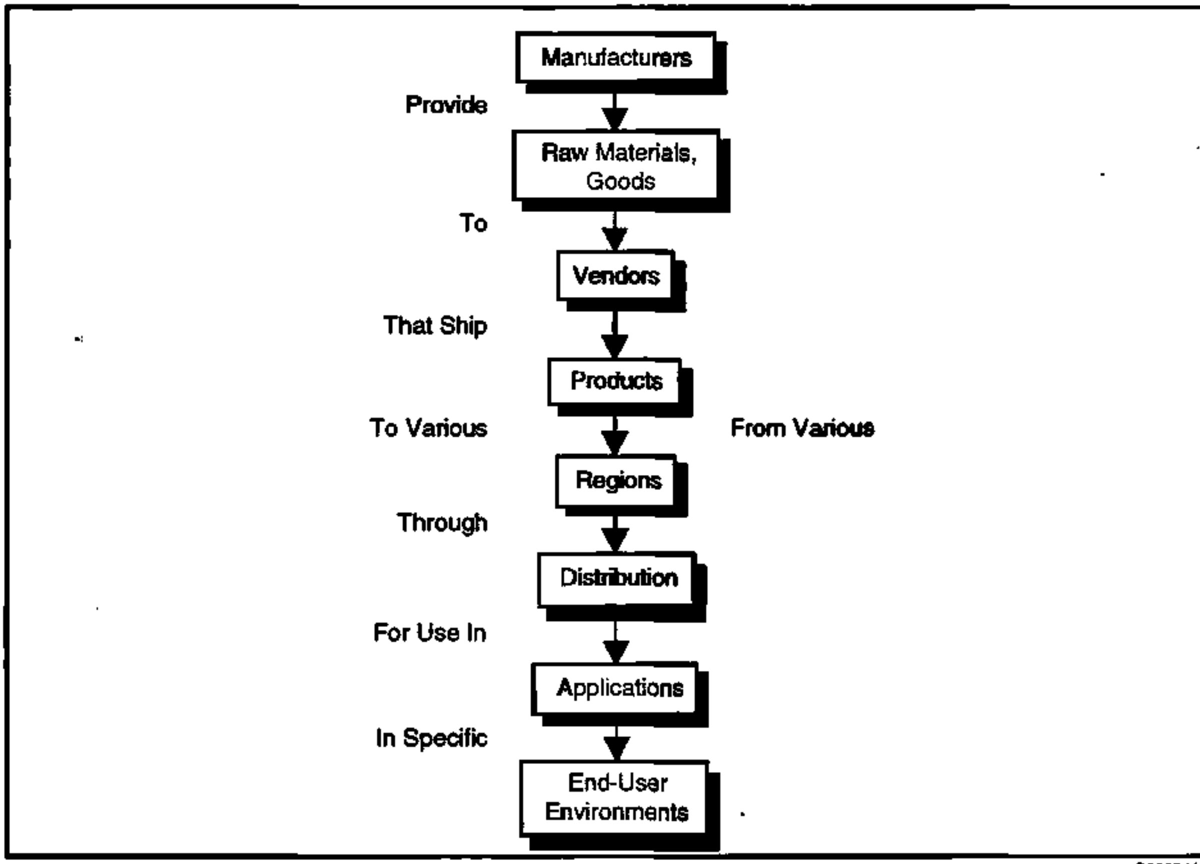
The purpose of market share is to estimate the presence of a leading vendor in a product market. Market presence may be measured in terms of unit shipments or revenue. Market share is critical for companies to assess their absolute and relative position in a market, and thus develop appropriate competitive strategies.

Definitions

The *Dataquest High-Technology Guide* is the corporatewide reference for segmentation and definition of technologies and markets. Definitions explain Dataquest's understanding of technologies. Segmentation refers to the way in which a market is divided into different dimensions including companies, products, regions, distribution, applications, and user environments. These dimensions are illustrated in Figure 3-1. The segments and terms found in the *Dataquest High-Technology Guide* are used consistently throughout Dataquest's products and within all Dataquest's worldwide offices.

Dataquest has defined regions of the world for the purposes of tracking and reporting company production and consumption. Those regions are North America, Europe, Japan, Asia/Pacific, and Rest of World. The country composition of these regions is given in the *Dataquest High-Technology Guide*.

Figure 3-1
Dataquest's Research Dimensions



Source: Dataquest (August 1992) G2000416

Shipment Estimates

Dataquest prepares estimates of shipments for each product and company prior to market share data collection. Shipments are estimated at the most disaggregate level possible (such as by company, by product, or by region). These initial estimates are based on the following:

- Company year-to-date performance
- Validating information, such as press releases, Wall Street news items, industry contacts, and online sources
- Dataquest forecasts of product revenue and shipments, by product and by regional market

Initial estimates represent Dataquest's best estimate of company performance during the previous year. The estimates are treated as confidential.

Data Collection

Data collected in our vendor surveys are used in a bottom-up analysis defining market revenue, market size, and market share. Market share data collection involves virtually all Dataquest researchers and interviewers. Dataquest estimates of product shipments and revenue for the year are provided to each company. The company is asked to respond to Dataquest with revisions or corrections as appropriate.

The accuracy of information provided to Dataquest varies. Some companies are known for always reporting accurate numbers, whereas other companies are less uniform in their reporting practices. With experience, analysts become familiar with the different and varied reporting styles of the companies involved.

Dataquest analysts cross-check all information with the goal of defining the most accurate estimate possible. This effort requires the ability to integrate information from different sources. It relies on the analyst's ability to perceive and process information provided indirectly. The skill and sensitivity of the individual researcher is a critical element.

Collection of top-level aggregate data (worldwide and regional unit shipments and revenue) from a vendor is the responsibility of the Dataquest office located within the same region of the world as the vendor being surveyed. Collection of bottom-up disaggregate data (regional and country shipments of each vendor) is the responsibility of the Dataquest office located within the region of consumption. The rationale for this division of labor is that the Dataquest office located within a particular region is best suited to perform data collection tasks related to manufacturers located within that region. The local Dataquest office is also most able to comment on facets of consumption within that region, regardless of the location of company headquarters.

For example, Dataquest San Jose is responsible for data estimation and collection for North America-based vendors and their worldwide and regional shipments. Similarly, Dataquest Europe estimates and collects data on worldwide and regional shipments for European-based vendors, and Dataquest Japan is responsible for the estimates and collection of worldwide and regional shipments for Japanese vendors. Dataquest Seoul and Dataquest Taiwan estimate and collect the worldwide shipments data for South Korean and Taiwanese vendors, respectively. Vendors located in the Rest-of-World region are, in most cases, the responsibility of Dataquest San Jose. This assignment forces a reconciliation between Dataquest's analysts and Dataquest's offices, resulting in a single worldwide estimate for any given product.

Once the vendor-based data are collected, they are compiled into a single market-specific database. Subsets of the data based upon the region of consumption are then furnished to Dataquest's regional offices. The regional analysts examine their specific regional consumption data (worldwide vendors' shipments into their regions), and compare the estimates to the results of their individual regional data collection efforts.

This methodology harnesses the advantage provided by Dataquest's regional analysts. It enables regional analysts, by strength of their location, to collect data from vendors based within their region. Furthermore, it makes allowances for differences in regional pricing, distribution methods, and application usages, and their effects on the market share estimates. At the same time, it allows the regional analysts to examine the shipment data of worldwide vendors into their region in order to account for differences within their region of the marketplace.

An additional advantage of this approach is the assignment of ultimate responsibility for a particular vendor to a particular analyst. This assignment forces a running dialogue and information exchange among offices.

Quality Control and Validation

All market share data are validated through cross-checks to assure quality. The checks include the following:

- Check aggregate data against at least two other data points
- Check large market share changes
- Check large volume changes
- Check current trends against historical trends
- Check against complementary or substitute products
- Check against installed base
- Check against other Dataquest data
- Check company growth rates against competitors

Dataquest utilizes both primary and secondary sources to produce market statistics data. Primary research is supplemented with secondary research to verify market size, shipment totals, and pricing information. Either primary or secondary information is used to validate estimates. Where data cannot be collected from primary sources, estimates are checked against secondary sources. Revenue reported in one market covered by a vendor are also evaluated against that vendor's revenue in other markets covered by Dataquest to make sure that revenue is not double counted. In addition, Dataquest may check with multiple sources at one company to verify data.

The data collected in our vendor surveys are considered public information. The names of respondents are always kept confidential, and all data are published as Dataquest estimates. All respondents are notified of Dataquest policies when market estimates are initially sent.

Companies in the market share survey review Dataquest's initial estimates and respond with their comments or revisions. If a company chooses not to participate in the data collection effort, Dataquest either uses initial estimates, or adjusts the initial estimates based on responses by other companies.

Documentation

Detailed notes and documentation are maintained on each company surveyed in the market share sample, as well as the supplemental group of companies used to estimate total market size. Documentation includes handwritten notations indicating sources of data and any relevant secondary information.

Quarterly and Semiannual Shipments and Pricing

Dataquest monitors selected companies on a monthly, quarterly, or semiannual basis. Typically, this research and analysis is limited to unit shipments and product pricing of the most important leading companies in a market. Companies selected for this in-depth research have products that meet the following criteria:

- Significantly greater than average growth
- "Bell-weather" indicators of future market activity
- Receive disproportionate market-participant attention.

The purpose of this in-depth monitoring is to assure that Dataquest estimates stay current with important market shifts that occur between market share and data collection cycles. This research serves as valuable input for updating expectations of short-range market activity.

Chapter 4
User-Based Research

User-based research serves as a complement to Dataquest's traditional vendor-based research. By focusing on the consumer, user-based research reflects the demand-side of product markets. Dataquest's user-based research includes studies of market penetration, installed base, technology plans, product configurations, product pricing and positioning, customer satisfaction, and new product testing and concept evaluations.

Project Design

The most important aspect of user-based research is to define the purpose of the research. What is the question that the client wants to answer? If there are multiple questions, what is the main question? Once the project's purpose is identified, a design is prepared to guide research activity. The design covers the entire range of research activity, including definition of research objectives, questionnaire development, sample design, field interviewing, statistical analysis, and the final report. It also includes a timeline and milestones that can be used to assess progress.

Questionnaire Development

Questionnaires are developed in consultation with the project leader or client. Questions are phrased in a form that will facilitate complete and usable responses. Special attention is devoted to minimizing response biases potentially caused by such factors as answer order, question order, generalization, and scaling.

Questionnaires typically contain the following three main sections:

- Introduction and screener page that outlines the purpose of the study and identifies the correct person to participate in the interview
- Specific questions to meet the project's objectives
- Demographic questions that enable the respondents to be grouped together and the data analyzed in subsets

Sample Design

Sample design involves definition of sample parameters, determination of the sample approach, and the most appropriate source for the sample. Sample parameters are determined according to the population of interest in the study. For example, a survey of corporate computer use would likely include parameters such as the number of employees and annual sales. A study measuring users' interest level in video games would include sample parameters such as household composition and annual household income.

Once the sample parameters have been defined, a sampling approach is developed. Dataquest uses two types of sampling approaches: probability sampling and quota sampling.

Probability sampling is used for data that are to be projected to the population at large, such as market penetration data. In this approach, each potential respondent has an equal probability of being selected. A study that requires 200 completed interviews would begin with names of 1,000 potential respondents, if the anticipated response rate is 20 percent.

Quota sampling is an alternative to probability sampling and is used when simplicity and cost-effectiveness are important considerations. In quota sampling, a profile of the population to be studied is developed and quotas are set so that the final sample is forced to fit the main population profile. An example would be a study of U.S. business establishments with results reported by industry. The 1990 U.S. Census data reveal that government institutions represent approximately 3 percent of U.S. business establishments, services represent 31 percent, manufacturing represents 7 percent, and other businesses represent 59 percent. For a study requiring 500 completed interviews, quotas would be set so that 15 respondents would come from government institutions, 155 respondents would come from services, 35 respondents would be from manufacturing businesses, and 295 respondents represent other businesses.

Dataquest uses a variety of sampling sources depending on the nature of the research. Databases from Dun & Bradstreet, including Dun's Marketing Service databases of nine million U.S. businesses, are frequently used. Other sources include UCC1 filings that identify sites with specific computer and telecommunications equipment, and mailing lists from industry trade publications. Dataquest also has proprietary respondent databases that are used for research in specific high-technology markets.

Data Collection

Data collection in end user research relies heavily on primary research. Dataquest's primary research procedures are described in detail in an earlier section of this document.

Dataquest maintains sizable primary research units in San Jose, California and Paris. In addition, staff responsible for primary research data collection are located in London, Tokyo, Seoul, Taiwan, and Framingham, Massachusetts.

Preparation for the primary research includes in-depth briefings with the interviewers to review details of the project, the questionnaire, and procedures for collecting information. At the beginning of the project, preliminary interviews are conducted to validate the effectiveness of the questionnaire. Suggested changes can then be discussed and incorporated into the final questionnaire. The actual interviews are conducted online or with hard copy, depending on the format most appropriate for the objective of the study. Considerable time goes into quality control. The interview process is carefully monitored and responses are reviewed for accuracy and completeness at all stages of a project.

Data Analysis

Dataquest uses a full range of practical capabilities to conduct statistical analysis of user-based data. After data collection is completed, the data are cleaned and prepared for analysis. As a quality control check, frequency and percentage data are calculated for each response to every question.

Specific cuts of data are determined jointly by Dataquest and the client. Initial tables are produced according to predetermined specifications. Once the initial tables are reviewed, the need for further cuts of data often becomes apparent. An iterative process then occurs in which questions are formulated, additional analyses are conducted, and new sets of tables are prepared.

A variety of data analysis techniques are used to answer Dataquest's research questions. Techniques commonly used include validity and reliability testing, correlations, regression analysis, factor analysis, analysis of variances, and significance testing. Dataquest also measures customer satisfaction and importance ratings using a matrix gap analysis technique. The statistical analysis packages used to analyze data at Dataquest include SAS, SPSS, Survey System, and ACA/Ci2.

Chapter 5
Market Forecasting

Dataquest's charter includes the task of forecasting high-technology markets. There are two important benefits of forecasting market activity, as follows:

- Forecasting provides a structured and logically rigorous setting in which to clarify expectations about the future. This structured setting maximizes the likelihood of generating forecasts that are internally consistent.
- Forecasts help reduce business risk by aiding executives in planning strategy and tactics based on likely future events and trends.

There are two basic components to Dataquest's forecasting methodology: theory and facts. Theory and facts are complementary—one cannot be substituted for the other. Theory provides a simplified situation with the same logical structure as more complicated reality, and it uses the former to understand the latter. Facts may appear to be self-evident; however, facts do not "speak for themselves." To use facts effectively, they must be interpreted in terms of an underlying structure, embodied in a theory.

Dataquest forecasts begin with facts about real world events. Most generally, facts regarding the real world include level of economic activity, prices, technology characteristics, user demographics, political environment, and other exogenous or outside influences.

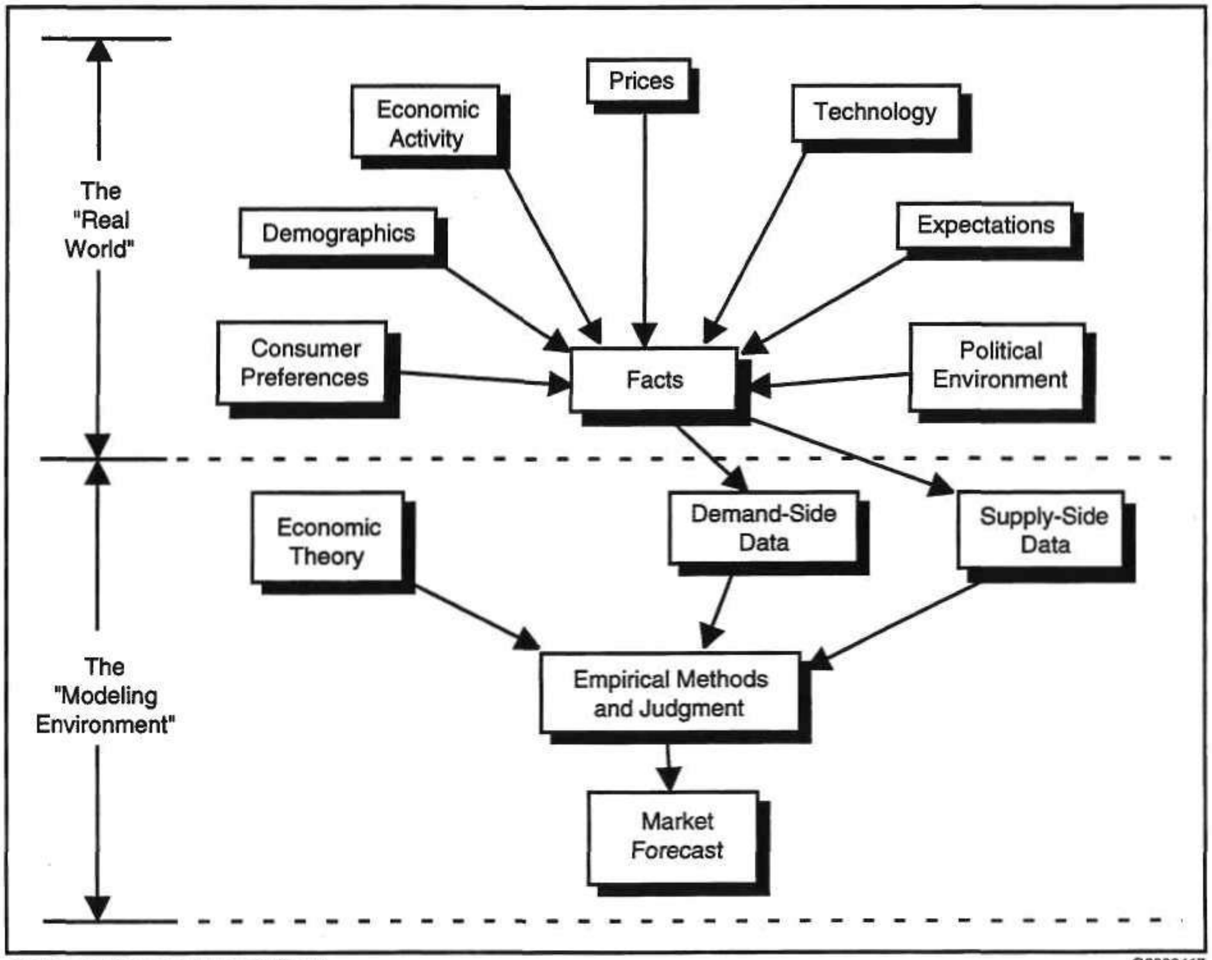
Facts lead to data representing observations. Data are broadly classified as either demand-side or supply-side, depending on the side of the market they influence. Empirical methods combine data with economic theory to yield market analysis and forecasts.

Figure 5-1 outlines the key elements and flow of Dataquest's forecasting methodology.

Theoretical Framework, Variables, and Data

High-technology markets are complex; furthermore, high-technology markets generate an abundance of facts. The volume of high-technology publications and information is evidence of this situation. Therefore, before generating a market forecast, it is necessary to reduce the market's complexity to a manageable level with a simplifying conceptual framework, typically referred to as an analytical model.

Figure 5-1
Dataquest's Forecasting Methodology



Source: Dataquest (August 1992)
G2000417

Dataquest uses standard microeconomic models as the basic theoretical framework for analyzing high-technology markets. These models include the following:

- Models of consumer behavior to analyze the demand-side of a market
- Models of production, the company, and the industry to analyze the supply-side of a market
- Models of market supply and demand

These models are the accepted paradigms for analyzing economic and market phenomena. They have withstood years of rigorous empirical testing and verification.

High-technology markets also yield an abundant flow of facts about real world events. These facts lead to a set of data, representing observations such as unit shipments, revenue, market share, and average selling prices. Dataquest classifies these data according to broad categories called variables that are grouped as demand-side variables or supply-side variables.

Dataquest includes the following demand-side variables in its product forecasts:

- Overall level of economic and business activity, industry conditions, and related industry conditions
- Prices of substitute products
- Prices of complementary products
- Expected future prices of the product being forecast
- Consumer preferences
- Demographics

Dataquest also includes the following supply-side variables in its product forecasts:

- Prices of resources and inputs used in a product's production
- Technological improvements that allow for decreases in the cost of production
- Outside factors that may alter supply or influence a company's production costs, such as trade barriers

Some variables are more easily quantified than others. For example, a country's overall level of economic activity can be measured directly by estimating its Gross Domestic Product (GDP). Product prices and resource prices also are normally directly observable. Other variables are more elusive and intangible. Information on consumer tastes and preferences may have to be sampled. Likewise, expectations of future products and resource prices are not directly observable, but must be inferred. Thus, a variable's consideration does not necessarily imply collection of the corresponding data.

Examples of specific data used in Dataquest forecasts include the following:

- Unit consumption and production
- Consumption and production revenue
- Average selling price (final user price, list price, and manufacturer price)
- Installed base, saturation, and retirements
- Input/output (I/O) ratios and tie ratios
- Market penetration and total available market (TAM)

Supply and demand market models have the added advantage of maximizing the internal consistency of Dataquest's numerous forecasts. By modeling and forecasting the supply-side and the demand-side of a product, Dataquest analysts are able to check for "market clearing." The principle of market clearing states that whatever quantity of a product is supplied to a market must by necessity find a "home" in the market, either with the final or ultimate user or in inventory, and vice versa. In other words, after the fact, supply equals demand. (This does not imply that *planned* supply necessarily equals *planned* demand.) Whatever inconsistencies arise in the modeling and forecasting process must be eliminated or rationalized by changes in inventory levels or prices, or both.

Another check for internal consistency makes use of the high-technology food chain (see Figure 5-2). The high-technology food chain is the simplified conceptual arrangement of the production of high-technology goods according to the order of utilization. In the food chain approach, each product uses the preceding product as an input to production. For example, integrated circuits (ICs) are produced from silicon wafers, workstations are produced from ICs, and so on. By checking product flows through the food chain, Dataquest is able to monitor the consistency of its various forecasts at different stages of the food chain. In addition, modeling the food chain enables Dataquest to forecast possible production bottlenecks and their implications for other product markets.

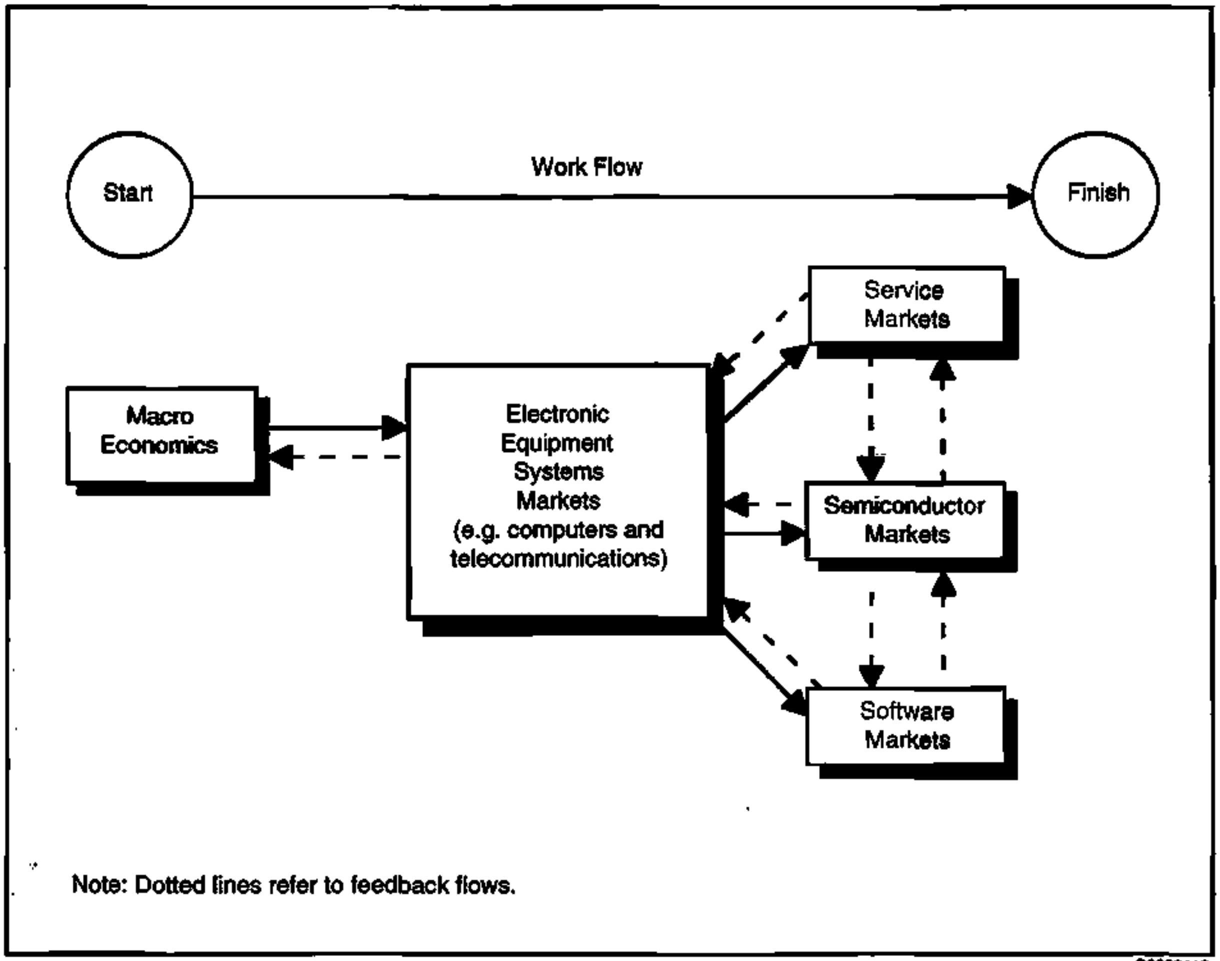
At the beginning of each forecast cycle, Dataquest assesses current and expected future international macroeconomic conditions. Dataquest uses the macroeconomic forecasts and analysis developed by the Economic Analysis Department of The Dun & Bradstreet Corporation.

In the next stage, given the macroeconomic outlook, forecasts of the electronic equipment systems markets are developed. At this stage, effort is concentrated on the systems markets and the important variables that influence these markets. All other things are held constant.

In the final stage, given the macroeconomic outlook and the systems outlook, forecasts of the semiconductor, software, and services markets are developed. Again, all other things are held constant; feedback from the semiconductor, software, and services markets to the systems markets, and the economy in general, are ignored.

The serial flow of effort described above should not be construed to imply that there is not a free forward or backward flow of communications between, for example, workstation analysts and semiconductor analysts; or lateral communications between, for example, mainframe analysts and personal computer analysts, or between semiconductor analysts and software analysts. The purpose of Dataquest's forecasting framework is to mirror real-world conditions, and then to use the approach to logically analyze current business conditions and to generate expectations about the future.

Figure 5-2
The High-Technology Food Chain



Source: Dataquest (August 1992)

G2000418

The factors or variables that are given or "held constant" are referred to as forecast assumptions. Forecast assumptions are the conditions upon which a forecast is based. A typical set of forecast assumptions includes expectations about macroeconomic conditions, currency exchange rates, technology characteristics, productive capacity, end-user market conditions, and political conditions (such as the reunification of Germany, changes in Central and Eastern Europe, and so forth).

While some assumptions may be universally applied to all market forecasts (macroeconomic expectations and currency exchange rates), assumptions about other markets may themselves forecast markets further up the food chain. For example, a semiconductor market forecast will use the most recent PC market forecast as a given assumption.

Long-Run Trends versus Short-Run Fluctuations

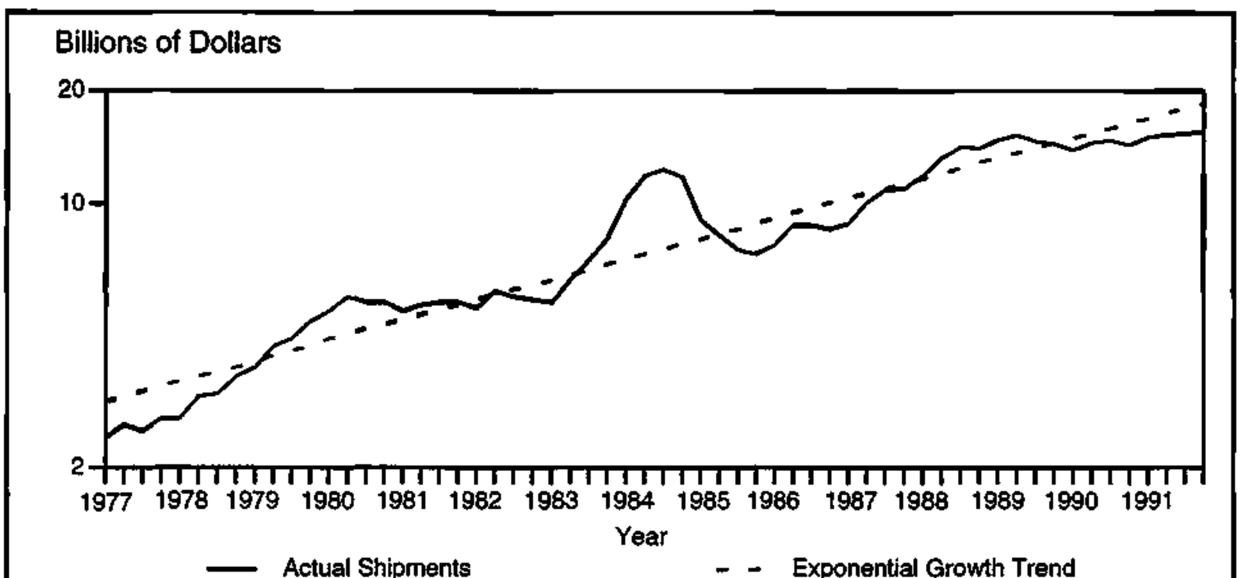
The basic thrust of the Dataquest forecasting models is that high-technology markets show short-term fluctuations around long-term trends.

The long-run equilibrium movements determine the basic trends of the markets as they grow over time. The short-run movements around the long-run equilibrium are referred to as market fluctuations.

Market fluctuations result from unexpected changes in market conditions or from changes in technology. Manufacturers' expectations about future market conditions may differ significantly from actual market conditions. As an example, personal computer manufacturers accumulated huge semiconductor inventories in 1984 and 1985 in anticipation of a boom in PC sales (see Figure 5-3). When actual PC sales fell short of the expected boom, the quantity of chips supplied to the market was greater than the quantity demanded at prevailing prices, and prices fell. Chip producers and consumers revised their plans in light of the new information and market conditions, and the market adjusted accordingly, albeit painfully.

Discontinuous changes in technology may be either anticipated or unanticipated. For example, the emergence of 1Mb DRAM technology (an anticipated technological change) put a discontinuity, or a kink, in what would have been an otherwise relatively smooth revenue growth path of DRAM devices.

Figure 5-3
North America Semiconductor Market



Source: Dataquest (August 1992)

G2000419

Seldom, if ever, does a high-technology market settle down to its long-run equilibrium long enough to grow along its trend growth path. Therefore, what we observe over time is a continuously fluctuating market tracing out its trend or long-run growth envelope. This is demonstrated in Figure 5-3. The solid line represents the actual growth path of North American market semiconductor revenue; the dotted line represents the trend growth path of revenue.

The farther into the future one forecasts, the greater the level of uncertainty about the expected state of a market. We have a clearer idea of events that we expect to disturb the market in the short term—and thus give rise to market fluctuations—than we do in the long term. The significance of the trend value in the final year of the forecast is that it is simply the expected value—or midpoint—of an ever-widening confidence interval or envelope. Of the range of possible future outcomes, it is the most likely or probable outcome.

Although Dataquest is constrained to forecasting under conditions of incomplete information, by no means are we completely unaware of all future events. For example, the analysts that monitor technology markets usually have information regarding manufacturing capacity at some future date. Dataquest includes such information in its forecasts.

In summary, the trend or long-range values of a forecast represent the expected value of a probability distribution of likely future outcomes. In the absence of shocks and other disturbances, high-technology markets tend to converge toward a long-run equilibrium growth path.

Empirical Methods

Microeconomic models provide a general conceptual framework to analyze market behavior. The task of forecasting, however, requires more specific, empirical models. No single empirical model or method is necessarily appropriate for forecasting all the different products and services that Dataquest follows. Furthermore, a strong case can be made for using more than one empirical model to forecast a product as a check of the robustness of a forecast.

All Dataquest empirical models combine prior information with sample data to produce forecast estimates. Prior information includes historical data of an industry, product, or market; knowledge accumulated by Dataquest analysts from industry experience; and the collective body of knowledge resident at Dataquest. Sample data consist of information that Dataquest collects and analyzes describing recent events about an industry, product, or market. Sample data are obtained through primary research, technical discussions with industry and company officials, announcements and articles in the trade press, and judgmental data based on knowledge, experience, and professional intuition.

There are four types of empirical techniques commonly used for forecasting at Dataquest.

Judgmental Methods

Judgmental techniques are useful in situations where past data are scarce, causal relationships have not been identified or quantified, or some other major change has occurred in the forecasting context (such as a war or a trade agreement) that is not accounted for by other techniques. The validity of using these methods by themselves is uncertain, although using them correctly can provide very good forecasts, especially in uncertain environments. The objective of these judgmental methods is to provide logical, unbiased, and systematic quantitative estimates. Examples of judgmental methods include the Jury of Executive Opinion and the Delphi method.

Technological Methods

Technological techniques are particularly appropriate for very new technologies with little or no data, or very long range forecasting. These methods are highly exploratory, and large errors are quite likely. Examples of technological methods include curve fitting, including trend extrapolation, S-shaped curves, and envelope S-curves; and analogous data.

Time Series Models

Time-Series techniques extrapolate past data into the future. The premise is that some underlying pattern exists in the variable being forecast. Examples of time series models include moving averages, exponential smoothing, decomposition models, and Box-Jenkins techniques.

Causal Models

The premise of causal models is that changes in the value of the variable of interest (for example, shipments of Product A) are closely associated with changes in some other variables (for example, the cost of Product B). Consequently, if future values of these other variables (cost of Product B) can be estimated, they can be used to forecast the desired variable (shipments of Product A). Examples of causal models include regression analysis, leading indicator analysis, and input-output models.

Forecast Quality Control

All forecasts must strictly adhere to the following guidelines to ensure internal consistency:

- The same value of a variable must be used throughout Dataquest
- Analysts may vary the relationship between variables, according to their own research findings, but not the values of the variables
- Not all variable relationships hold true for all industries, therefore analysts may specify which sets of data to use
- Data must conform to Dataquest standard segmentation
- Final forecasts must be approved before release

- All preliminary data are clearly stated as such.
- The source of the information and date are always cited

Ultimately, the most important and toughest quality check that Dataquest forecasts must pass before publication is the test of reasonableness. The test of reasonableness is imposed by the team of experienced Dataquest researchers and analysts. Empirical methods are indispensable to economize the task of generating forecast estimates, but they are no substitute for the seasoned intuition of practical experience.

Chapter 6
Summary

When Dataquest clients receive research and analysis with the familiar citation "Source: Dataquest," they receive the end result of a rigorous methodology involving primary and secondary data collection, supply-side and demand-side market analysis, and the cross-industry perspective afforded by Dataquest's uniquely broad and in-depth worldwide coverage of high technology.

Behind the published research is a thorough body of knowledge involving industry professionals and research experts. As a result, Dataquest's clients receive more than simply a single and solitary point of information for planning and decision making. Dataquest provides comprehensive market research to its clients, including the highest-quality vendor-based research, user-based research, and market forecasts.

Appendix A
Currency Conversion

As a worldwide company, Dataquest tracks high-technology markets and companies in five major regions of the world: North America (United States and Canada), Japan, Europe, Asia/Pacific, and Rest of World.

Since most high-technology companies sell their products in more than one country, and since we cannot simply aggregate foreign currencies to estimate worldwide value, we have adopted a common currency, the U.S. dollar, by which we evaluate and compare all markets and all companies. We have chosen the U.S. dollar for the following reasons:

- Since World War II, the U.S. dollar has been the major reserve currency of choice for industrialized nations, although its dominance has diminished in recent years
- Dataquest is a U.S.-headquartered corporation

Although Dataquest tracks data in five regions, we deal with regional currencies and currency conversion issues for three markets—Europe, Japan, and Asia/Pacific. The currencies involved are the Austrian schilling, the Belgian franc, the Chinese renminbi, the Danish krone, the Dutch guilder, the Finnish markka, the French franc, the German mark, the Greek drachma, the Hong Kong dollar, the India rupee, the Irish punt, the Italian lira, the Luxembourg franc, the Malaysia ringgit, the Norwegian krone, the Portuguese escudo, the Singapore dollar, the Spanish peseta, the Swedish krona, the Swiss franc, the Thailand baht, the U.K. pound, the European Currency Unit (ECU), the Japanese yen, and the Korean won. Dataquest deals only in a U.S. dollar base for the North American and Rest of World markets for the following reasons:

- North America: Typically, the Canadian portion of the North American market is quite small (10 percent or less) and the relative values of the U.S. and Canadian dollars do not fluctuate widely.
- Rest of World: This region is made up of hundreds of separate countries, each with its own currency, and accounts for less than 1 percent of most high-technology markets.

Method

Data Collection

Data for Japanese, Asian, and European companies are usually collected in the local currency of the companies being tracked. For example, Dataquest collects Japanese companies' revenue in Japanese yen. If a company wishes to report data in U.S. dollars, we request that it use the most recent year-to-date currency exchange rate supplied by Dataquest.

Average Currency Exchange Rates

Once the data are collected, Dataquest uses the average currency exchange rate for the period of time interest, and converts the foreign currency into U.S. dollars. The average exchange rate for a quarter is calculated by summing the values for the three months of the quarter and dividing the sum by three. Similarly, the average exchange rate for a year is calculated by summing the values for the 12 months of the year and dividing the sum by 12.

The choice of which exchange rate to use is determined by the precise period of time being evaluated. Most of our historical market sizing and market share data are evaluated in calendar-year or calendar-quarter time periods. However, in evaluating the fiscal year or fiscal quarter performance of an individual company, the exchange rate must be calculated for the specific fiscal period under review. For example, NEC Corporation's fiscal year ends March 31. Therefore, when evaluating NEC's financial performance in U.S. dollars, the proper exchange rate would be the average yen per dollar exchange rate for the 12 months beginning April 1 of the previous year and ending March 31 of the current year.

Currency Conversion: Unweighted Exchange Rates

Handling historical data reported in foreign currencies is relatively straightforward when unweighted exchange rates are used. Dataquest maintains a database of average monthly exchange rates for the currencies of major European and Asian countries. These exchange rates are compiled by Dun & Bradstreet.

Conversion of U.S. Dollar to Currency Unit

The formula for converting U.S. dollars to other currencies is as follows:

(U.S. Dollar Value) × (Currency Unit per U.S. Dollar Exchange Rate) = Currency Unit Value

Example:
If U.S.$1 = £0.65, then
$30,000 = £19,500

The formula used is: $30,000 × £0.65 = £19,500.

Conversion of Currency Unit to U.S. Dollar

The formula for converting other currencies to U.S. dollars is as follows:

> (Currency Unit Value) / (Currency Unit per U.S. Dollar Exchange Rate) = U.S. Dollar Value
>
> Example:
> If £0.65 = U.S.$1, then
> £20,000 = $30,769
>
> The formula used is: £20,000 / £0.65 = $30,769.

Exchange rates can be expressed in either of two ways: Currency Unit per U.S. Dollar, or U.S. Dollar per Currency Unit. The two are reciprocals of each other. Traditionally, the former is preferred for ease of use, as shown in the following example:

Currency Unit per U.S. Dollar: One U.S. dollar equals 134.68 Japanese yen.

U.S. Dollar per Currency Unit: One Japanese yen equals .00743026 U.S. dollars.

Currency Conversion: Weighted Exchange Rates

In certain circumstances, it is desirable to weight exchange rates according to the chronological pattern of consumption in a market over a period of time, or according to the relative importance of various regional markets (a "basket of currencies").

Weighting According to a Chronological Pattern of Consumption

Dataquest tracks consumption in certain markets on a calendar-quarter basis. Each quarter the European and Japanese currencies are valued differently against the U.S. dollar. Simply summing the values of the four quarters and dividing by four would yield an arithmetic mean annual exchange rate; however, this exchange rate would not be the true, effective exchange rate for the year for that market. The example outlined in Table A-1 shows why:

Table A-1
Example of an Arithmetic Mean Annual Exchange Rate

	Q1	Q2	Q3	Q4	Year
U.S.$ Size of Market	100	150	200	250	700
Japanese Yen Size of Market	16,270	23,145	26,420	27,625	93,460
Exchange Rate (Yen per U.S.$)	162.7	154.3	132.1	110.5	
Weighted Average Exchange Rate					133.5
Arithmetic Mean					139.9

Source: Dataquest (August 1992)

In the example presented in Table A-1, the arithmetic mean is higher than the weighted average. The weighted average is calculated by the following formula:

93,460/700=133.5

The arithmetic mean is calculated by the following formula:

(162.7+154.3+132.1+110.5)/4 = 139.9

When more than one market is tracked, and when a weighted average exchange rate is used, every market will have a different effective exchange rate because the pattern of consumption over four quarters will not be identical for every market.

Weighting According to a Basket of Currencies

The European Community has a ready-made basket of currencies, known as the European Currency Unit (ECU). The ECU, which was established in March 1979, is a basket of currencies composed of specific amounts of the currencies of the member countries of the EC (excluding Greece prior to September 1984 and including Greece thereafter). Each currency's share in the ECU basket is weighted broadly in line with the respective country's GNP and foreign trade. The ECU is used when forecasting future market trends in Europe.

Normalized Currency Valuation

Although Dataquest rarely uses normalized currency valuation, this is a useful technique for measuring "true" growth for individual companies or groups of companies. It is especially appropriate during times of rapid and dramatic currency exchange rate changes.

Normalization of exchange rates is an attempt to express more accurately how a company's revenue changed in one time period compared with the previous time period.

An example of a situation in which normalized exchange rates are useful occurred in September of 1985. At that time, the Group of Five major economic powers (the United States, United Kingdom, Germany, France, and Japan) met and instituted economic policies that resulted in a rapid devaluation of the dollar against the Japanese yen and other currencies. This devaluation continued throughout 1986. The average yen per dollar exchange rate in 1985 was 238.4. In 1986 it was 168.37, a 29 percent decline in the value of the dollar against the yen (based on how many yen you could buy with one dollar), or a 42 percent rise in the value of the yen against the dollar (because you could now buy 0.0059393 dollars with one yen, compared with only 0.0041945 dollars per yen in 1985).

A normalized view of Japanese company revenue growth in 1986 would remove the currency fluctuations from the non-U.S. dollar revenue the company received. Although the yen-valued revenue of

Table A-2
Japanese Companies' Total Semiconductor Revenue

	1985	1986	Growth Rate (%)	Difference
Using Actual Exchange Rates				
Worldwide ($M)	10,144	14,307	41.0	4,163
In Japan ($M)	7,387	10,691	44.7	3,304
Worldwide (¥M)	2,414.3	2,389.3	-1.0%	
In Japan (¥M)	1,758.1	1,785.4	1.6%	
Exchange Rate (¥/$)	238	167		
Using Constant Exchange Rates				
Worldwide ($M)	10,144	10,039	-1.0	-105
In Japan ($M)	7,387	7,502	1.6	115
Exchange Rate (¥/$)	238	238		

Source: Dataquest (August 1992)

Japanese companies declined in 1986 compared with 1985, Japanese companies experienced a rise in dollar-valued revenue, most of which was due solely to exchange rate fluctuations. The example outlined in Table A-2 illustrates this.

Forecasting

Dataquest does not forecast exchange rates per se; however, we do forecast semiconductor markets in several regions of the world, and we use the U.S. dollar as a common currency for market comparisons. In the forecast period, Dataquest assumes that the most recent actual month's exchange rate will apply throughout all future months of the forecast. For example, the current semiconductor forecast uses actual exchange rates through June 1992, and assumes that the June rate applies throughout all future months. Then the quarterly and annual exchange rates are estimated as described above.

Dataquest®

a company of
The Dun & Bradstreet Corporation

Dataquest Incorporated
1290 Ridder Park Drive
San Jose, California 95131-2398
United States
Phone: 01-408-437-8000
Facsimile: 01-408-437-0292

Dataquest Incorporated
Dataquest/Ledgeway
The Corporate Center
550 Cochituate Road
Framingham, Massachusetts 01701-9324
United States
Phone: 01-508-370-5555
Facsimile: 01-508-370-6262

Dataquest Europe Limited
Roussel House Broadwater Park
Denham, Near Uxbridge
Middlesex UB9 5HP
England
Phone: 44-895-835050
Facsimile: 44-895-835260/1

Dataquest Japan Limited
Shinkawa Sanko Building
1-3-17 Shinkawa Chuo-ku
Tokyo 104
Japan
Phone: 81-3-5566-0411
Facsimile: 81-3-5566-0425

Offices in
Costa Mesa, Munich,
Paris, and Seoul

Representative Agencies in
Bangkok, Hong Kong,
Kronberg, North Sydney,
Singapore, and Taipei

SEMMS-0832320
Mark FitzGerald
Senior Industrial Analyst
320-1264
Internal Distribution