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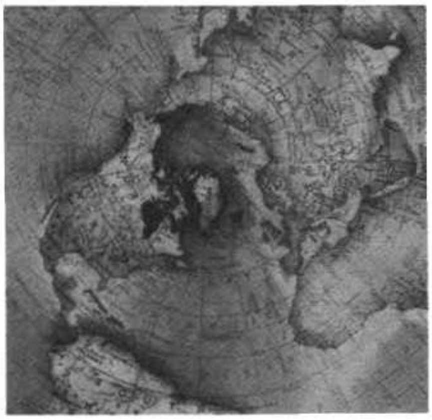

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Third-Party DRAM Module Manufacturer Study

Focus Report

Program: Memories Worldwide
Product Code: DPGR-WW-FR-9702
Publication Date: April 21, 1997
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Third-Party DRAM Module Manufacturer Study

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Chapter 1
Executive Summary

DRAM modules are the predominant means of providing flexible main memory sizes in all types of systems, from personal computers to workstations and printers. Third-party memory module manufacturers have carved out a niche in this market, between the DRAM suppliers and the original equipment manufacturers (OEMs). Third-party memory module manufacturers buy DRAM directly from DRAM manufacturers or on the open market, install them into single in-line memory modules (SIMMs) or dual in-line memory modules (DIMMs), and then sell the memory modules into aftermarket channels or to OEMs.

The last Dataquest Focus Report on the memory module aftermarket was published in December 1993. The aftermarket refers to DRAM modules sold with PCs at the point of purchase or as upgrades for the installed base of computers. The aftermarket is also where third-party manufacturers sell the majority of their DRAM modules. Worldwide third-party DRAM module revenue has grown from $2 billion in 1992 to $6.1 billion in 1996. This represents a 32 percent compound annual growth rate (CAGR).

Third-party DRAM module companies had a relatively successful year in 1996. Revenue from third-party DRAM modules declined 12 percent in 1996. On the surface this looks bad, but when compared with DRAM manufacturers, whose DRAM revenue declined by 40 percent in 1996, the positive aspect of the year becomes apparent.

A Market Expected to Return to Growth

Dataquest believes the third-party DRAM module market will return to growth in 1997. DRAM density transitions, like the recent transition from 4Mb to 16Mb DRAM ICs, creates a need for DRAM module manufacturing flexibility. The acceptance of new and upcoming PC features, such as multimedia extensions (MMX), Accelerated Graphics Port (AGP), Universal Serial Bus (USB), and 3-D graphics, enable the development of new, memory-hungry software. This, coupled with the natural progression toward expanding main memory size and a slowdown in DRAM IC price declines, creates an environment that third-party module manufacturers can leverage. The combined impact of these market conditions is the basis for Dataquest's 1997 forecast of 14 percent growth for DRAM modules manufactured by third-party companies. Looking beyond 1997, Dataquest expects continued revenue growth as this industry moves into the next century.

The Organization of This Report

This report presents an overview of the entire third-party DRAM module industry. The first part reviews this market and includes a ranking of the top third-party companies and their DRAM module revenue. The middle of this report presents the results of Dataquest's survey of third-party manufacturers, forecasts of the third-party DRAM module market, the DRAM IC market, and the PC market, a discussion of major industry issues, and a look at the third-party business model. This report concludes with a discussion of regional issues and a section devoted to vendor profiles and a listing of third-party manufacturers.

Chapter 2
Market Overview

There are two distinct providers of DRAM memory modules, DRAM manufacturers and third-party module manufacturers. This Focus Report reports only on the third-party manufacturers. A later Focus Report will cover the DRAM manufacturer module business. Traditionally, there has been little overlap between the markets served by third-party module manufacturers and DRAM manufacturers. Third-party module manufacturers are typically privately held companies that sell 75 percent of their modules into what is known as the memory module aftermarket. Aftermarket memory modules augment the base memory a computer is shipped with. DRAM manufacturers differ in that they sell their modules almost exclusively to major OEMs. There is little reason to expect either type of manufacturer to attempt to raid the market held by the other. The reasons for this will become evident further on in this report.

Table 2-1 shows Dataquest's ranking of the top third-party DRAM module companies and Dataquest's estimate of their DRAM module revenue and market share.

Table 2-1
Third-Party DRAM Module Company Ranking, 1996

	1995 Revenue ($M)	1996 Revenue ($M)	Growth (%)	Market Share (%)
Kingston	1,100	980	-10.9	16
ACDC	560	480	-14.3	8
Century	440	400	-9.1	7
PNY	451	396	-12.3	6
Wintec	440	395	-10.2	6
Smart	260	382	46.9	6
Melco	184	268	45.2	4
Viking	257	252	-1.9	4
VisionTek	225	224	-0.4	4
Southland	272	218	-20.0	4
Centon	235	215	-8.5	4
Ma Labs	208	182	-12.5	3
GoldenRAM	194	178	-8.2	3
I-O Data	300	177	-41.0	3
Simple	196	148	-24.5	2
TechWorks	145	120	-17.2	2
MGV	203	113	-44.4	2
Unigen	190	80	-57.9	1
Others	1,080	925	-14.4	15
Total	6,941	6,133	-11.6	-

Source: Dataquest (April 1997)

This ranking of third-party companies shows a clear-cut leader in this industry, Kingston Technology, and then a clustering of companies in the $200 million-to-$400 million range. The companies competing in this industry may look similar at first glance, but there are identifiable differences. For example, Kingston's goal is to be the "OEM" of memory. How does Kingston expect to accomplish this? Kingston supports high-end, machine-specific memory modules and avoids generic, commodity modules. American Computer and Digital Components (ACDC), Kingston's closest competitor on a revenue basis, takes a different approach. ACDC supports a full line of DRAM modules, but it concentrates on manufacturing low-priced modules.

Celestica is not included on the list of third-party DRAM module manufacturers. Celestica is an electronic equipment contract manufacturer that manufactures memory modules on the same scale as Kingston. In late 1996, Celestica changed its memory module business strategy to include the sale of Celestica-branded memory modules in the distribution and resale channel. Prior to this change Celestica manufactured only on a captive basis. Many contract manufacturers assemble memory modules for DRAM manufacturers, OEMs, and third-party memory module manufacturers but are not considered third-party module suppliers because they are captive manufacturers. Large electronic equipment contract manufacturers, like Solectron, actually shy away from memory modules, preferring to assemble higher-margin products, such as motherboards. Another difference is that electronic equipment contract manufacturers do not sell the memory modules they assemble under their own brand name. This is where Celestica differs from its contract manufacturing competitors. If Celestica continues to follow a traditional third-party memory module manufacturer approach, it will be included in the next report.

Looking beyond the companies listed, there are on the scale of 100 small third-party companies with revenue ranging from $1 million to nearly $100 million. These companies are either very focused or are hybrid memory module manufacturers and distributors. Because of their small size, these companies face difficulty in procuring steady sources of DRAM. This forces these small companies to procure DRAM ICs and DRAM modules from DRAM brokers and other third-party module manufacturers.

The last section of this report includes third-party DRAM module manufacturer vendor profiles and a listing of additional third-party companies.

Methodology

The bulk of this report is based upon surveys of third-party DRAM module manufacturers taken during January and February 1997 and on conversations with these manufacturers. The data was then compared with other secondary sources, including Dun & Bradstreet reports, conversations with purchasers of modules, other surveys, and conversations with manufacturers of related products.

The module forecasts are based upon the Dataquest Memories Worldwide program's DRAM forecast, Dataquest's computer systems forecasts, Dataquest's *DRAM Supply/Demand Quarterly Statistics* report, and input from the survey respondents and their customers.

Definitions

The following definitions apply in this report:

- Module: Any collection of DRAM chips on a circuit card, where the only function of this card is to increase the main memory size of a system. DRAM modules include cards used solely for main memory but containing circuitry for error correction or to translate bus protocols. Cards can use either connectors or card-edge fingers for insertion into the system. Cards with functions other than memory enhancement, that is, those with a CPU or other important nonmemory function, are not included.
- Third-party DRAM module manufacturer: A company that purchases DRAM directly from DRAM manufacturers or on the open market, installs or contracts out DRAM installation into a module, and then sells the memory modules into aftermarket channels or to OEMs. A third-party module manufacturer does not manufacture DRAM ICs and is not a subsidiary of a DRAM manufacturer. Revenue for modules manufactured by one third-party company but marked with another third-party company's brand counts only for the company whose brand appears on the product. Revenue for modules manufactured by a third-party module company for an OEM will be counted as revenue for the third-party company, regardless of the brand name (the third-party's own brand, a DRAM manufacturer's brand, or an OEM brand name) on the module. Electronic equipment contract manufacturers are not counted as third-party module manufacturers because they are captive manufacturers.

Sales Opportunities

Memory modules are either part of a computer's base memory, which is installed by the PC OEM, or are added later in the aftermarket.

Computer Manufacturers

PCs offer sets of features at various price points. In order to meet these price points, the OEM configures the PC and then ships it with a base level of main memory appropriate to the price point.

The base configuration of main memory today is usually provided as a memory module (except in the case of notebook computers, where base memory is soldered down), because different DRAM IC configurations can be used to manufacture a single density. The use of memory modules for base memory is generally higher during periods of DRAM density transitions, such as the recently completed conversion from 4Mb to 16Mb DRAM ICs. If there is no debate over which density of DRAM offers the lowest cost per bit, some PC manufacturers use soldered-down base memory on the motherboard instead of DRAM modules. Avoiding the use of a SIMM or DIMM for the base memory configuration can save several cents per board in manufacturing costs.

Third-party module manufacturers have traditionally not supplied memory modules to PC OEMs for use as base memory. The third party is growing its OEM channel business, but by manufacturing DRAM modules for the OEM's memory upgrade program and not for use as base memory. DRAM manufacturers, however, may choose to actively support OEMs in this line of business, which may make it difficult for third-party manufacturers to compete.

During times of allocation, like 1994 and 1995, there is an opportunity for third-party manufacturers to supply DRAM modules for use in main memory, particularly with small OEMs. A synergistic relationship between certain third-party module manufacturers and system manufacturers occurs during these periods because of a common effort to obtain DRAM.

Point-of-Purchase Sales

Once a customer arrives in the store, a salesperson works to load the PC with additional memory, software, and other features to assure that the buyer spends as much as possible. As a result, there is a large percentage of DRAM sold at the point of purchase, rather than at the OEM base memory level.

Upgrades

The upgrade market supplies the memory needs of the installed base of PCs. As features and software are added to a PC, there is often a performance benefit from adding memory. Third-party module manufacturers offer a full line of memory modules to capitalize on this opportunity. One characteristic of this segment is the need to support memory modules for out-of-production computers. Although today's mainstream computers no longer use 30-pin SIMMs, there is a large installed base that does. Fringe products, like 30-pin SIMMs, offer third-party manufacturers higher margins to offset the low margins in the mainstream, standard module business.

Chapter 3

Annual Revenue History and Forecast

Table 3-1 shows Dataquest's estimate and forecast of the worldwide revenue for the third-party DRAM module market. Table 3-2, Dataquest's estimate and forecast of revenue from the shipment of DRAM ICs, is provided for comparison.

Table 3-1
Worldwide Third-Party DRAM Module Revenue, 1992 through 2000

	1992	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Third-Party DRAM Modules ($M)	2,000	3,100	5,200	6,941	6,133	6,997	8,120	11,090	15,550	17.5
Growth (%)		55.0	67.7	33.5	-11.6	14.1	16.0	36.6	40.2	-

Source: Dataquest (April 1997)

Table 3-2
Factory Revenue for Shipments of DRAM ICs Worldwide, 1992 through 2000 (Millions of U.S. Dollars)

	1992	1993	1994	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
64K Standard	11	5	3	0	0	0	0	0	0	-
256K Standard	189	109	54	55	20	1	0	0	0	-100.0
256K Video RAM	158	103	63	49	18	15	7	6	2	-45.6
1Mb Standard	2,392	1,618	1,542	1,851	723	321	260	195	78	-46.9
1Mb Video RAM	530	775	566	10	126	65	28	21	10	-0.1
2Mb Video RAM	0	237	410	581	421	358	330	139	58	-36.9
4Mb Standard	5,029	9,949	14,402	21,041	5,498	1,878	803	553	253	-58.7
4Mb Video RAM	0	15	111	522	581	693	1,023	771	398	-5.3
16Mb Standard	230	1,601	5,713	17,641	16,748	16,135	17,311	6,989	3,574	-27.3
64Mb Standard	0	0	0	4	1,059	6,402	9,355	22,913	29,482	484.0
256Mb Standard	0	0	0	0	0	0	307	12,254	28,726	-
Total	8,538	14,411	22,864	41,755	25,194	25,870	29,423	43,840	62,582	8.4
Growth (%)		68.8	58.7	82.6	-39.7	2.7	13.7	49.0	42.8	-

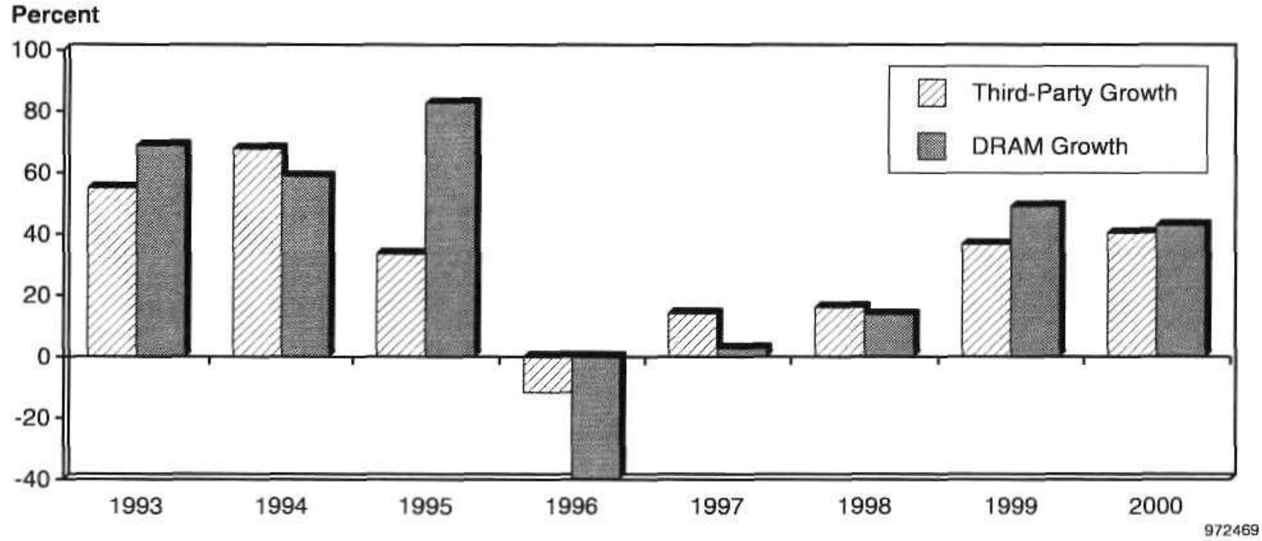
Source: Dataquest (April 1997)

Prior to 1996, the third-party module market enjoyed strong growth. In 1992, the worldwide third-party DRAM module market was an estimated $2 billion. By 1995, worldwide third-party DRAM module revenue approached $7 billion. The compound annual growth rate for this industry between 1992 and 1995 was 50 percent. Third-party industry revenue declined by 12 percent, to $6.1 billion, in 1996. While 1996's revenue decline was a rude awakening for the third-party manufacturers, 1996 was still a relatively successful year for them.

Comparison with DRAM Manufacturers

One way to gauge the success of third-party module manufacturers is to compare their industry revenue with DRAM manufacturers' industry revenue. Figure 3-1 graphs the growth rates of both industries from 1992 to 2000.

Figure 3-1
Third-Party DRAM Module and DRAM Industry Growth Rates, 1993 through 2000



Source: Dataquest (April 1997)

The total revenue of DRAM manufacturers was $41.8 billion in 1995 and $25.2 billion in 1996, a 40 percent decrease. Third-party DRAM module revenue was $6.9 billion in 1995 and $6.1 billion in 1996, a 12 percent decrease. A very strong year for DRAM manufacturers, 1995 was only a good year for third-party manufacturers. A bad year for DRAM manufacturers, 1996 was a down year for third-party manufacturers, but considerably better than for DRAM manufacturers.

Another way of looking at the data is to look at how much DRAM the third-party module market consumed. This is a good indicator of the relative importance of third-party companies. About 65 percent of third-party DRAM module revenue is spent on DRAM ICs. In 1995, third-party manufacturers consumed $4.5 billion or 11 percent of the DRAM manufactured in 1995. In 1996, third-party module manufacturers consumed $4 billion of DRAM or 16 percent of the DRAM manufactured in 1996. Even though third-party companies consumed more DRAM on a percentage basis, they are still a small part of total DRAM IC revenue.

The idea of DRAM passing through third-party companies is very important when comparing the differences between the two industries. Third-party module companies are middlemen for DRAM. They obtain the DRAM from DRAM manufacturers or on the spot market (also known as the gray market, this market is where excess DRAM inventory is bought and sold) and quickly turn around the assembled DRAM modules to aftermarket channels or OEMs. Third-party manufacturers simply pass dramatic shifts in DRAM price on to their customers. The value-add of a third-party module manufacturer stays relatively stable.

Revenue by Density

Tables 3-4 and 3-5 show the revenue and percentage breakout of third-party DRAM module revenue by density for 1996 and a forecast to 2000.

Table 3-4
Third-Party DRAM Module Revenue by Density, 1996 through 2000 (Millions of Dollars)

	1996	1997	1998	1999	2000
1 and 2 Megabytes	79	37	8	1	0
4 Megabytes	903	382	162	55	31
8 Megabytes	2,390	1,149	568	444	311
16 Megabytes	1,652	2,222	2,274	2,606	2,628
32 Megabytes	787	2,027	3,167	3,992	4,510
64 Megabyte	218	697	1,218	2,662	5,598
128 Megabytes	72	409	487	887	1,555
256 Megabytes	6	46	162	333	778
All Others	27	28	73	110	140
Total	6,133	6,997	8,120	11,090	15,550

Source: Dataquest (April 1997)

Table 3-5
Third-Party DRAM Module Revenue by Density, 1996 through 2000 (Percent)

	1996	1997	1998	1999	2000
1 and 2 Megabytes	1.3	0.5	0.1	0	0
4 Megabytes	14.7	5.5	2.0	0.5	0.2
8 Megabytes	39.0	16.4	7.0	4.0	2.0
16 Megabytes	26.9	31.8	28.0	23.5	16.9
32 Megabytes	12.8	29.0	39.0	36.0	29.0
64 Megabytes	3.5	10.0	15.0	24.0	36.0
128 Megabytes	1.2	5.8	6.0	8.0	10.0
256 Megabytes	0.1	0.7	2.0	3.0	5.0
All Others	0.4	0.4	0.9	1.0	0.9
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (April 1997)

Units by Density

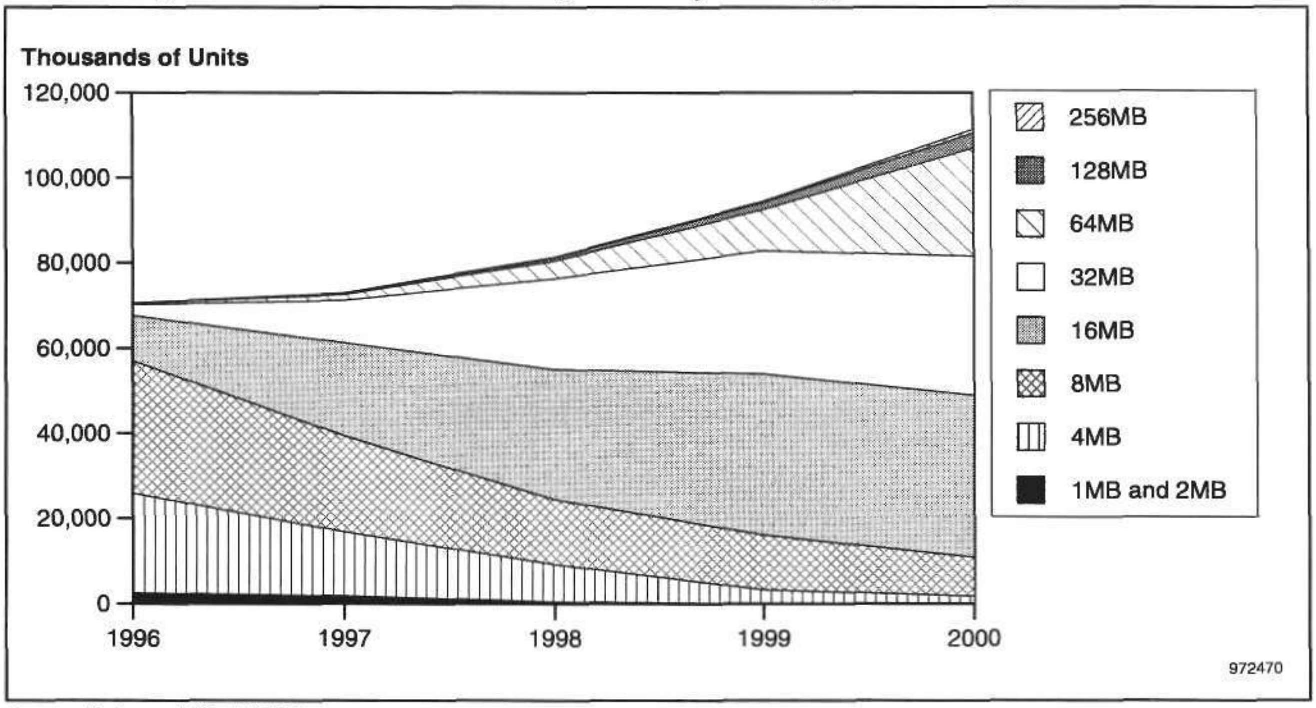
Table 3-6 and Figure 3-2 show third-party DRAM module unit shipments by density for 1996 and a forecast to 2000.

Table 3-6
Third-Party DRAM Module Unit Shipments by Density, 1996 through 2000 (Thousands of Units)

	1996	1997	1998	1999	2000
1 and 2 Megabytes	2,550	1,864	451	62	-
4 Megabytes	23,433	15,001	8,736	3,216	1,804
8 Megabytes	31,027	22,583	15,287	12,864	9,019
16 Megabytes	10,720	21,837	30,574	37,787	38,104
32 Megabytes	2,553	9,958	21,293	28,944	32,692
64 Megabytes	282	1,371	4,095	9,648	25,361
128 Megabytes	39	335	819	1,608	3,522
256 Megabytes	2	19	91	301	881
Total	70,605	72,967	81,346	94,430	111,382

Source: Dataquest (April 1997)

Figure 3-2
Third-Party DRAM Module Unit Shipments by Density, 1996 through 2000



Source: Dataquest (April 1997)

A small sector of the market needs the ultimate in density in the smallest form factor and is willing to pay a great premium for it. Enter companies like Dense-Pac Microsystems and Cubic Memory, which use direct die attach. This allows the stacking of chips to provide up to eight times as much DRAM on the same module. Simple Technology uses a more standard approach by stacking packaged DRAMs and connecting them by running sideways circuit cards alongside the stacked DRAMs.

Chapter 4
Supplier Overview

The single most striking division in the memory module market is that two very different types of manufacturers sell the exact same product to two different types of customers. On one side, we have the DRAM manufacturers, which manufacture modules using their own DRAM ICs and sell them almost exclusively to OEMs. On the other side are third-party DRAM module manufacturers, which procure DRAM ICs from others, manufacture the modules, then sell them almost exclusively to the aftermarket through retail and distribution and resale channels.

DRAM Manufacturers

DRAM manufacturers sell their modules primarily to system manufacturers or OEMs. DRAM manufacturers can choose customers that meet certain criteria, such as minimum order size. Dataquest knows of only one DRAM manufacturer that sells modules directly to end users and very few others that sell through any retail channels. By not selling to end users and retail channels, DRAM manufacturers are free from offering extensive product support. Once a DRAM manufacturer has qualified its product with an OEM, the level of support needed is minimal because the OEM clearly understands the product purchased. However, OEMs are willing to pay an adder for the module only over the price they would have paid for the individual DRAM chips via existing volume contracts.

Third-Party Manufacturers

Only 25 percent of third-party DRAM module manufacturer revenue comes from the OEM channel. The majority of their revenue is downstream in the channel, either from distributors, computer resellers, or, on a limited basis, directly to the end user. Third-party module manufacturers get price premiums in return for smaller orders requiring a high level of support. End users pay a premium that is highly volatile, gyrating on daily news flashes related to DRAM availability and price. In return for higher prices, customers get 24-hour technical support lines, a module source for out-of-production computers, and the ability to purchase single-unit quantities of devices over the telephone using a personal charge card.

There is currently an increased interest by OEMs in using third-party module companies, which has put the OEM channel business into a transition state. Third-party module manufacturers are not replacing DRAM manufacturers in providing the base memory needs for PC OEMs. What they are doing is helping OEMs manage their memory module upgrade business.

This transition is occurring because OEMs can leverage two positive attributes of a third-party company, flexibility and responsiveness, without paying a cost premium. It is costly for an OEM to run small production runs for discontinued computers or proprietary modules. Third-party companies gear their business model for this type of manufacturing. By using a third-party module manufacturer, the OEM profits from aftermarket sales to the installed base of its computers and it avoids the logistics nightmare of manufacturing hundreds of module variations.

Chapter 5
Third-Party Channel Profile

There are three distinct channels for third-party module manufacturers:

- Distribution and resale
  - Commercial, industrial, and specialized distributors—This group targets value-added resellers (VARs), large corporations, retailers, systems integrators, OEMs, and master distributors.
  - Master resellers/systems integrators (formerly known as aggregators)—This group has a split business model, operating half of its business as a distributor and half as a large corporate reseller/systems integrator.
- PC OEMs and other system OEMs
- Retail

Table 5-1 shows 1996 third-party DRAM module revenue by channel. The distribution and resale channel is where the majority of third-party modules are sold. There is no single approach for memory module manufacturers in this channel. Some specialize by product lines (for example, memory modules for printers), others concentrate on a type of distributor or reseller, and others champion service, quality, or price.

Table 5-1
Third-Party DRAM Module Revenue by Channel, 1996

	Revenue ($M)	Revenue (%)
PC and System OEMs	1,522	24.8
VAR	1,532	25.0
Distributor	1,339	21.8
Systems Integrator	1,017	16.6
Retail	515	8.4
Mail Order	85	1.4
End User (Business)	57	0.9
End User (Home)	10	0.2
Others	56	0.9
Total	6,133	100.0

Source: Dataquest (April 1997)

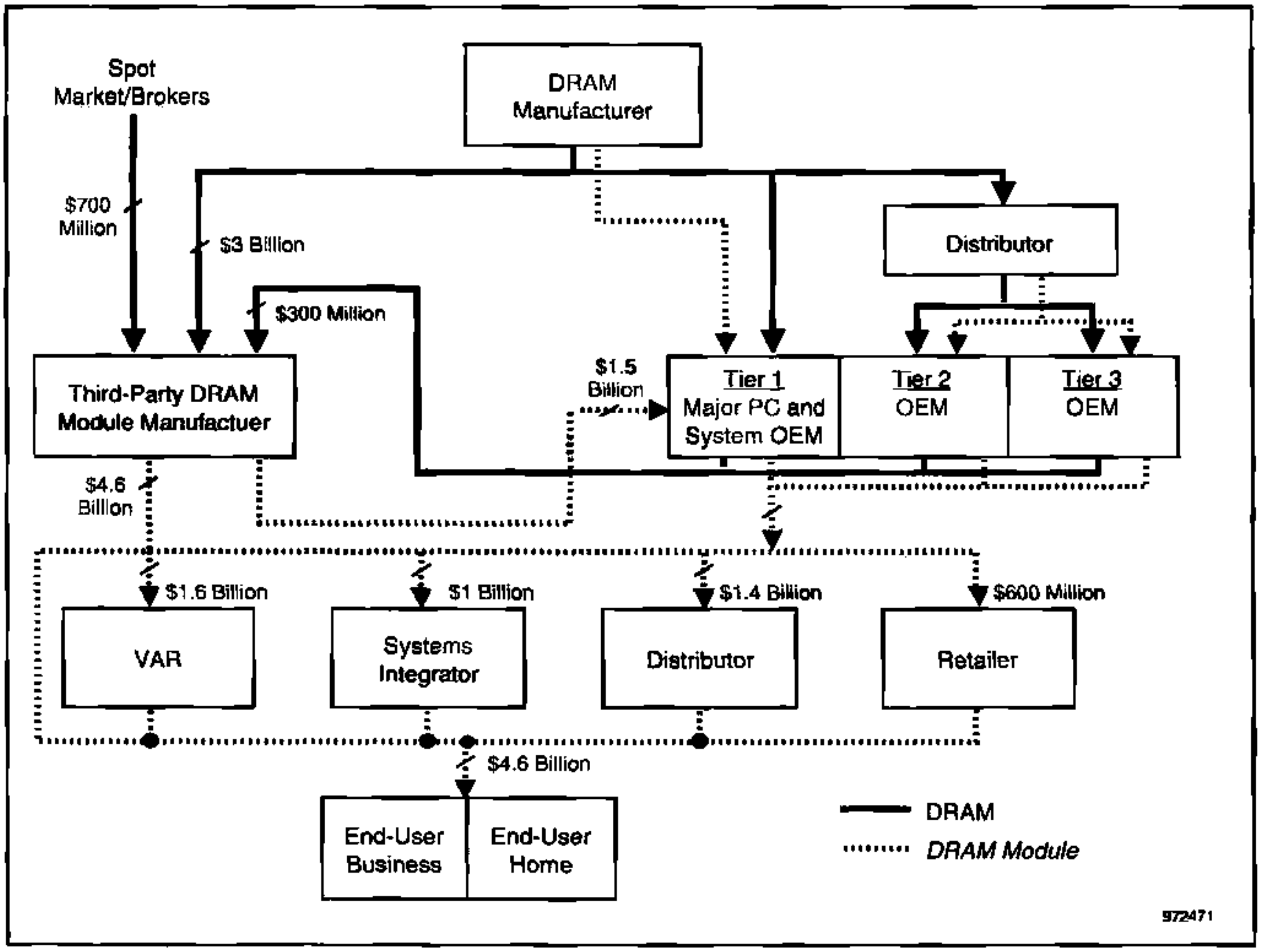
The PC OEM and system OEM channel is characterized by third-party module manufacturers specializing in providing contract module manufacturing services for OEMs. Smart Modular Technologies is an example of a module manufacturer that focuses on the PC OEM channel. The keys to success in this channel are quick and flexible manufacturing. One of the reasons this channel is attracting the interest of the larger third-party module manufacturers is the higher margins it offers.

Retail channel sales are through retailers, such as Wal-Mart and Best Buy, or directly to the end user, via mail order or the Internet. PNY Technologies and Centon Electronics are two memory module companies with significant retail presence. The retail channel is particularly harsh on module manufacturers because of price pressure. Payment methods, forced buy-backs, and stocking charges are all part of doing retail business. Because of the normal tendency of DRAM ICs to decrease in price, these attributes of the retail channel become very difficult to manage. There is also very little brand loyalty in this channel, aggravating the problem further. Because of these difficulties, the retail channel is not a popular target for growth.

Penetration Model

Figure 5-1 charts the path of DRAM and DRAM modules from the DRAM manufacturer to the end user. This figure shows how complex the module market is. A discussion of the overall module market structure, including information for modules supplied by DRAM manufacturers and OEMs, will be included in a Focus Report on modules manufactured by DRAM companies.

Figure 5-1
DRAM IC and DRAM Module Aftermarket Structure

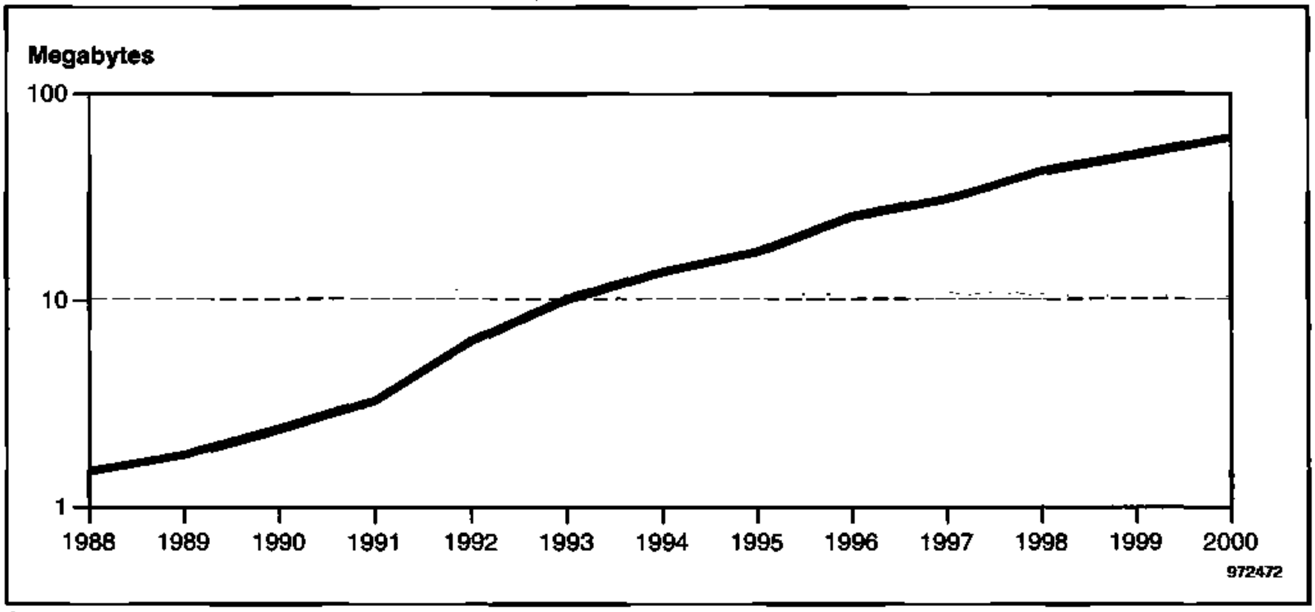


Source: Dataquest (April 1997)

Chapter 6
Main Memory Trends

Figure 6-1 shows Dataquest's estimates of main memory sizes from 1988 through 2000, from Dataquest's *DRAM Supply/Demand Quarterly Statistics*. Main memory size expands at a rate of 30 percent per year.

Figure 6-1
PC Main Memory Sizes, 1988 through 2000

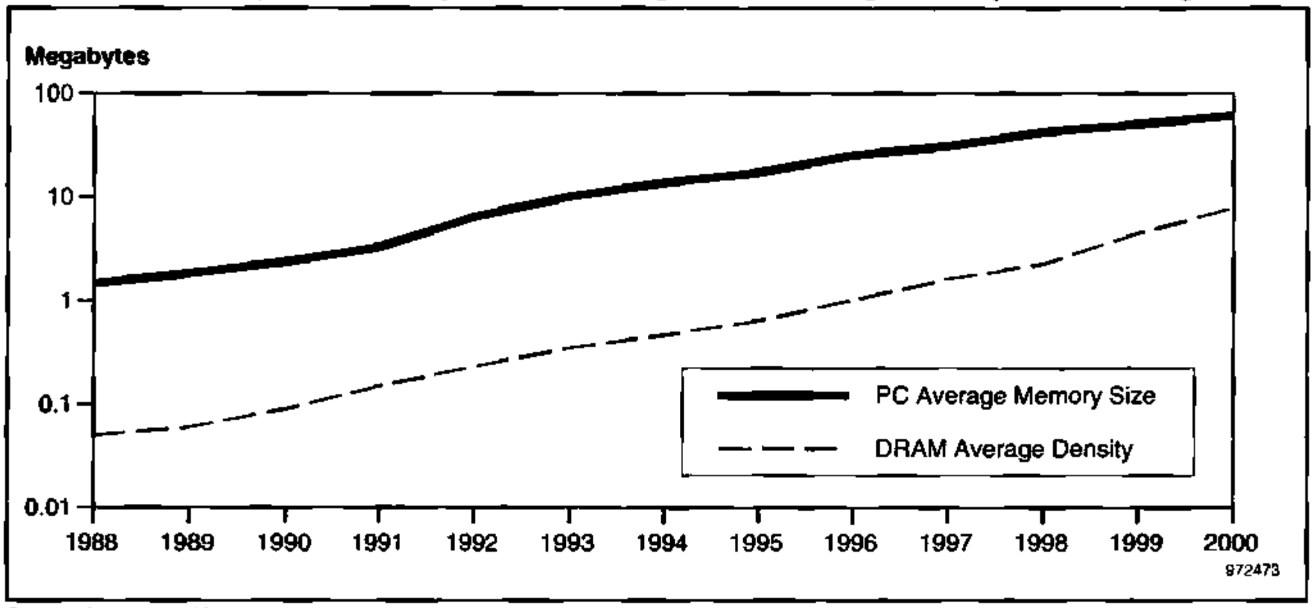


Source: Dataquest (April 1997)

Figure 6-2 shows the average density of DRAM ICs over the same period. As the main memory size increases at a rate of 30 percent per year, the rate of memory per IC increases far more sharply, at 56 percent per year. This means that the number of DRAM chips in a system should be expected to decrease slowly, at a rate of 17 percent over time, as shown in Figure 6-3.

This effect impacts the types of DRAMs required on the market. The first impact was felt in 1995, when the 16Mb DRAM was expected to start to displace the 4Mb part. This displacement was slowed because DRAM manufacturers had experience manufacturing only 1-bit-wide and 4-bit-wide DRAMs, and the version of the 16Mb density that was needed was a 16-bit wide device. The transition from a 4-bit to a 16-bit width was slowed for about a year because of manufacturing difficulties faced by most DRAM manufacturers.

Figure 6-2
PC Main Memory Sizes Compared to Average DRAM Chip Density, 1988 through 2000

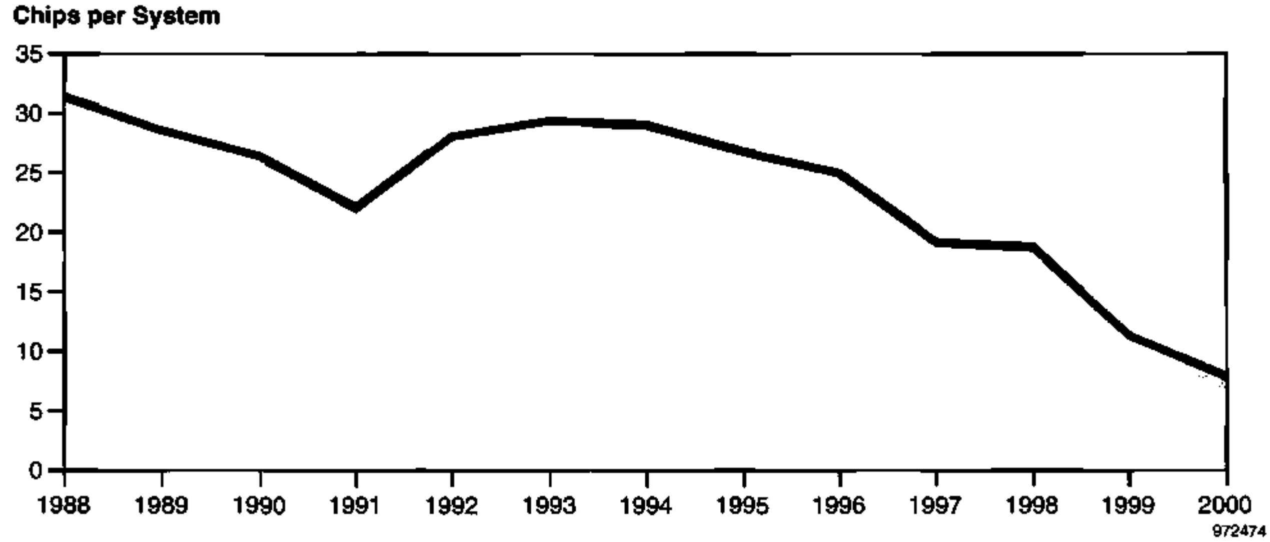


Source: Dataquest (April 1997)

The decrease in number of DRAM ICs used is coupled with a need for increased bandwidth, a problem that in past years was often approached through the use of more ICs, put together on a very wide bus. This approach is not feasible for the future because the number of DRAM ICs will be decreasing in the system. For this reason, approaches are being tried that will increase the data output rate of each DRAM chip without forcing the DRAM ICs to go to 64-bit-wide and 256-bit-wide buses.

Two approaches being considered are the synchronous DRAM (SDRAM) and the Rambus DRAM (RDRAM). Dataquest expects the SDRAM to become an important part of PC main memory shipments in 1997. The standard SIMM interface does not support SDRAM usage, but DIMMs do support SDRAM, so there will be a progression from the SIMM to the DIMM format. Intel's 430VX chipset already supports SDRAM, and Compaq, Dell Computer, Gateway 2000, and others are now using SDRAM. SDRAMs will be used in the majority of PCs when DRAM manufacturers provide SDRAMs at price parity with comparable extended data out (EDO) DRAMs.

Figure 6-3
Average Number of DRAM ICs Required in a PC, 1988 through 2000



Source: Dataquest (April 1997)

Personal Computers

Third-party module companies manufacture DRAM modules for any system that allows an upgrade, but PCs account for most of the market. Table 6-1 shows the 1996 third-party DRAM module revenue by platform, and Table 6-2 shows Dataquest's PC unit shipment forecast by product type. Dataquest's PC unit forecast provides a useful reference point for the potential of aftermarket DRAM modules.

Table 6-1
Third-Party DRAM Module Revenue by Platform, 1996

	Revenue ($M)	Revenue (%)
Desktop and Deskside PCs	3,982	64.9
Mobile PCs	1,254	20.4
Workstations	322	5.3
Servers	248	4.0
Printers	232	3.8
Others	95	1.6
Total	6,133	100.0

Source: Dataquest (April 1997)

Table 6-2
Shipments of Personal Computers to the World by Product Type

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Desktop and Deskside							
Units (K)	49,615	58,824	68,753	79,483	91,705	105,483	16.3
Unit Growth (%)	-	18.6	16.9	15.6	15.4	15.0	-
Mobile							
Units (K)	9,717	11,958	14,469	17,053	20,029	23,129	18.9
Unit Growth (%)	-	23.1	21.0	17.9	17.4	15.5	-
Server Marketed							
Units (K)	839	1,239	1,571	1,924	2,377	2,884	28.0
Unit Growth (%)	-	47.7	26.8	22.5	23.5	21.3	-
Total							
Units (K)	60,171	72,021	84,793	98,460	114,110	131,495	16.9
Unit Growth (%)	-	19.7	17.7	16.1	15.9	15.2	-

Source: Dataquest (April 1997)

Chapter 7

Technology

Module Form Factors

Memory modules plug into special slots on the system board. There are two mainstream modules today, the single in-line memory module and the dual in-line memory module. The major types of SIMM slots are 30-pin and 72-pin slots, and the dominant type of DIMM slot is 168 pin. The 30-pin SIMM was popular until local bus PCs arrived. VESA and PCI local bus systems generally use a 72-pin SIMM, although some also accommodate the older 30-pin variety. The shift to DIMMs offers a 64-bit bus on a single module.

Table 7-1 presents 1996 third-party DRAM module revenue broken out by the module form factor. Table 7-2 presents 1996 third-party DRAM module revenue broken out by module width.

Table 7-1
Third-Party DRAM Module Revenue by Module Type, 1996

	Revenue ($M)	Revenue (%)
30 SIMM	358	5.8
72 SIMM	3,540	57.7
72 SO DIMM	606	9.9
144 SO DIMM	269	4.4
168 DIMM	822	13.4
200 DIMM	59	1.0
Others	479	7.8
Total	6,133	100.0

Source: Dataquest (April 1997)

Table 7-2
1996 Third-Party DRAM Module Revenue by Width, 1996

	Revenue ($M)	Revenue (%)
x8	202	3.3
x9	267	4.3
x32	2,846	46.4
x36	1,146	18.7
x64	725	11.8
x72	304	5.0
Others	644	10.5
Total	6,133	100.0

Source: Dataquest (April 1997)

Parity/Nonparity

Parity checking once was a common feature of DRAM modules. This stems back to the original Wang 9-bit configuration and was driven in part by the parity checking supported by the Intel 486 microprocessor. One reason the 486 supports parity is the close relationship between Intel and IBM, a staunch believer in parity, in the middle 1980s, when the 486 was being defined.

Today parity is much less popular, although still supported in multiuser systems. Cost is more important to single-user systems purchasers than data integrity—the single-system user is willing to put up with a rare malfunction in order to save an appreciable amount of cost (13 percent off the price of main memory). Dataquest sees a continuing reduction in the market for parity modules, although the market is not expected to disappear altogether.

Another technology used instead of parity is error correction code (ECC). ECC corrects single-bit errors automatically and flags two-bit errors, which are exceptionally rare. Two-bit errors instigate a bad parity bit on the module's edge connector, signaling the need for the system to abort the current instruction stream.

Error correction of this kind is costly and is almost exclusively used in file servers, where errors cannot be tolerated. As one designer put it, "In a single-user environment, a bit failure will usually cause the system to lock up, whereupon the user reboots, usually enhancing the experience with colorful vocabulary. In a multiple-user system, the entire office has to wait around while a systems expert is called in to reboot the system."

Interfaces

There is a wide range of emerging DRAM interface alternatives. All of these emerging interfaces will cause some discussion when it comes to DRAM module support, but few look like sure winners. Today's interface standard for main memory applications is enhanced data out (EDO, also known as hyperpage mode), but SDRAM, which is a JEDEC-standard interface, should become the main memory standard by late 1997 or early 1998. EDO was a relatively simple change from the previous main memory standard, fast page mode (FPM), and it could be accommodated by the standard fast page mode module pinout. The switch to SDRAM is more difficult, requiring a transition to the DIMM module format and an SDRAM-enabled chipset.

In main memories beyond SDRAM, there are Rambus, a licensed technology; SDRAM II; double data rate (DDR) SDRAM; SyncLink; Enhanced Memories' enhanced DRAM (EDRAM); and MoSys' MDRAM. Intel recently embraced a Rambus-based solution to the main memory needs of computers in the year 2000.

From a module perspective, for nearly all of these interfaces, the pins of the memory module will have to be redefined to support special functions required to operate these parts. Rambus has taken the initiative and has issued a specification for a Rambus module that has all of the interface problems already solved. This is of key importance for the Rambus high-frequency bus, which communicates at a peak rate of 500 MB/sec on a byte wide bus. Rambus has realized that the only way to make its interface operate uniformly in all systems is to exert a very tight control over all aspects of the bus design, including the specifications for both motherboard layout and module layout.

Standard versus PC-Specific Parts

There are three classes of memory modules, standard, PC specific, and proprietary, or custom, memory.

- Standard modules: These are multisourced, non-PC-specific memory modules, with low value added in design or manufacture, and containing no proprietary architectures, components, or functions that constitute a barrier to entry. Standard parts tend to sell in extremely large volumes with thin margins.
- PC-specific modules: These constitute the typical modules sold by third-party companies. These modules are designed for a specific PC or small range of PCs from a single OEM and typically have no proprietary content and are multisourced, but sell in smaller volumes than standard parts. PC-specific modules typically have mechanical or performance specifications unique to that PC or class of PCs.
- Proprietary or custom modules: These modules are available only from the OEM or its designated licensee because of some proprietary attribute of the add-on memory module, such as a custom chip. Proprietary modules exist but on a very limited scale.

Many third-party module manufacturers advertise the thousands of PC-specific modules they support. The PC-specific approach enables a module to be optimized and tested for 100 percent compatibility with the intended PC. The standard approach offers near 100 percent compatibility with practicality, in that it is difficult and impractical for retailers and resellers to stock the thousands of module variations that exist.

Some third-party memory module manufacturers believe that SDRAM and next-generation DRAM-based machines will require PC-specific modules. They cite timing issues with these DRAM technologies that make designing a standard, PC-independent module difficult. Dataquest expects that a solution will be worked out that enables standard modules to exist in the future. In any case, because the third-party module industry is heavily dependent on the installed base of computers, there is no foreseeable end to a market for standard modules.

Chapter 8
Issues

The third-party module industry is constantly changing. Once-hotly contested issues, like software DRAM doublers and intellectual property infringement, are yesterday's news. There are, however, a number of issues that continue to be topics of interest.

DRAM Availability and Pricing

Almost all third-party module manufacturers Dataquest surveyed listed DRAM pricing and availability as the most important issues they face. DRAM pricing is important, but third-party companies can pass this cost on to their customers. Without a supply of DRAM, third-party module companies will have no customers.

The importance of DRAM availability is obvious. Third-party module companies offer a service, assembling DRAM memory modules. Everything they add to this basic task, such as managing distribution, providing technical support, and offering complete product lines, becomes irrelevant without a supply of DRAM ICs. DRAM availability is the lifeline of a third-party module company, and because of this it influences everything from inventory and cash management to the type of modules the company manufactures.

As dependent as third-party manufacturers are on DRAM availability, they have relatively little influence with DRAM manufacturers. A discussion of the relationship between DRAM manufacturers and third-party module manufacturers is included later in this document, in the business model section.

International Trade

International trade issues that impact DRAM pricing and availability are important to third-party manufacturers. A movement toward a worldwide zero tariff on semiconductors is occurring, but there are still regions where this is not the case. In the European Union (EU) there is a semiconductor duty for some devices from certain regions of 14 percent. Because SIMMs and DIMMs are classed as "computer parts" rather than ordinary semiconductors, memory modules imported into the EU are subject to a duty at a reduced rate of 3.8 percent.

The associated costs of importing DRAM and DRAM modules into the EU have resulted in two responses by DRAM manufacturers. One response is that some DRAM manufacturers have opened manufacturing facilities in the EU to avoid these costs. The second response is to ship DRAM into the EU in a module, rather than as DRAM chips, to avoid the higher duty. Dataquest believes these responses by DRAM manufacturers are the major reasons behind the lack of penetration of third-party module manufacturers in the EU.

Another trade issue is the fear of dumping. For example, late last year, Micron Technology announced that it had filed a request with the U.S. Department of Commerce to conduct a changed circumstances review that would investigate DRAM IC dumping by Hyundai and LG Semicon.

In the EU, an antidumping response is DRAM reference pricing. Reference pricing is a minimum price set to create a floor below which DRAM prices cannot go. Any manufacturer selling below the reference price is subject to penalties. In the past, Japanese manufacturers had one blanket reference price, but Korean manufacturers had individual reference prices based on the DRAM density. Because DRAM average selling prices (ASPs) were relatively high until early 1996, there was no need for antidumping legislation, so it was suspended until March 9, 1997. However, during the rest of 1996, DRAM IC prices crashed by about 80 percent.

Suspension of the antidumping measures was reviewed in response to claims that DRAM IC pricing was so low in the first quarter of 1997 that DRAM was being sold below cost and therefore dumped into the European market. As a result of this review, the EU announced on March 10, 1997, that reference pricing would be phased in on DRAM originating in Japan and Korea.

An interim period, during which reference pricing is to be reintroduced, is to run from April 1, 1997, until June 30, 1997. This means that no minimum price will be in force during March 1997 but, from July 1, 1997, full reference pricing will be in place. For the months of April, May, and June 1997, an increasing percentage of the full reference price will be applied.

The existing arrangements for calculating individual companies' reference prices are to remain. That means that Japanese vendors will have blanket weighted average reference prices, while Korean vendors will have individual ones. Also, during the interim period, Japanese vendors whose cost structure is lower than the average minimum price will be allowed to sell below that level.

DRAM reference pricing will have repercussions in both spot and contract pricing for non-EU-made product. If product cannot be brought into the EU below a certain price level, buyers will have to make sure their spot and contract pricing deals are above that threshold when they are taking ownership of the product in Europe. Likewise, vendors that do not have production facilities in the EU region may have to pay a duty on product being imported there. This gives suppliers that produce DRAM inside the EU a pricing advantage over suppliers that do not.

Historically, antidumping has not been proven to be an effective method of flattening the playing field. It provides some short-term relief but does not encourage the players to address the real cause of the problem, such as DRAM manufacturing over capacity.

Quality and Reliability

Interconnections on memory module signal sockets tend to be plated with either tin or gold. The differences between the two are not of a great importance unless the connector is exposed to a corrosive atmosphere, something which is unlikely for a PC. Generally, tin-plated connectors are adequate for most applications. Gold is more expensive and is used when higher reliability is needed.

Using gold was a certain mark of distinction for some system manufacturing companies. For a while Apple and IBM were using gold-plated sockets on their motherboards. This caused some concern that if tin-plated modules were inserted into the gold sockets, electrolysis would result, corroding the connection between dissimilar metals, and that this would cause the failure of the module, possibly also destroying the socket.

Those in the industry have assured Dataquest that the problem takes about 30 years to manifest itself, and that even if it were a shorter period, the life of the computer would be far, far shorter than the time it would take for corrosion to cause a failure.

However, some consumers still believe that the interconnection of tin and gold will cause problems, so module manufacturers carry inventory of both types of modules.

Use of Off-Specification Parts

There is a probability that some third-party module companies manufacture modules from off-specification DRAMs. During periods of DRAM oversupply, the use of off-spec DRAM is not much of a concern, but during DRAM allocation periods, this becomes an issue. In the case of nonfunctioning parts, one approach is to populate the module with more DRAM chips than required if fully functional parts were used. Programmable logic can then be used to overlay the nonfunctional sectors with equivalent-size working sectors from a spare DRAM chip.

The use of off-spec DRAM ICs allows the procurement of parts, when available, at deep discounts. The most blatant form of this is the manufacture of modules out of DRAMs that are not fully functional. Dataquest was not able to collect much data on this phenomenon, since no manufacturers were willing to admit that they indulged in such activity, yet some made allegations that their competitors do. This is probably not an important issue since the availability of off-spec parts is spotty, with low-volume availability.

Effects of DRAM Density Transitions on the Module Market

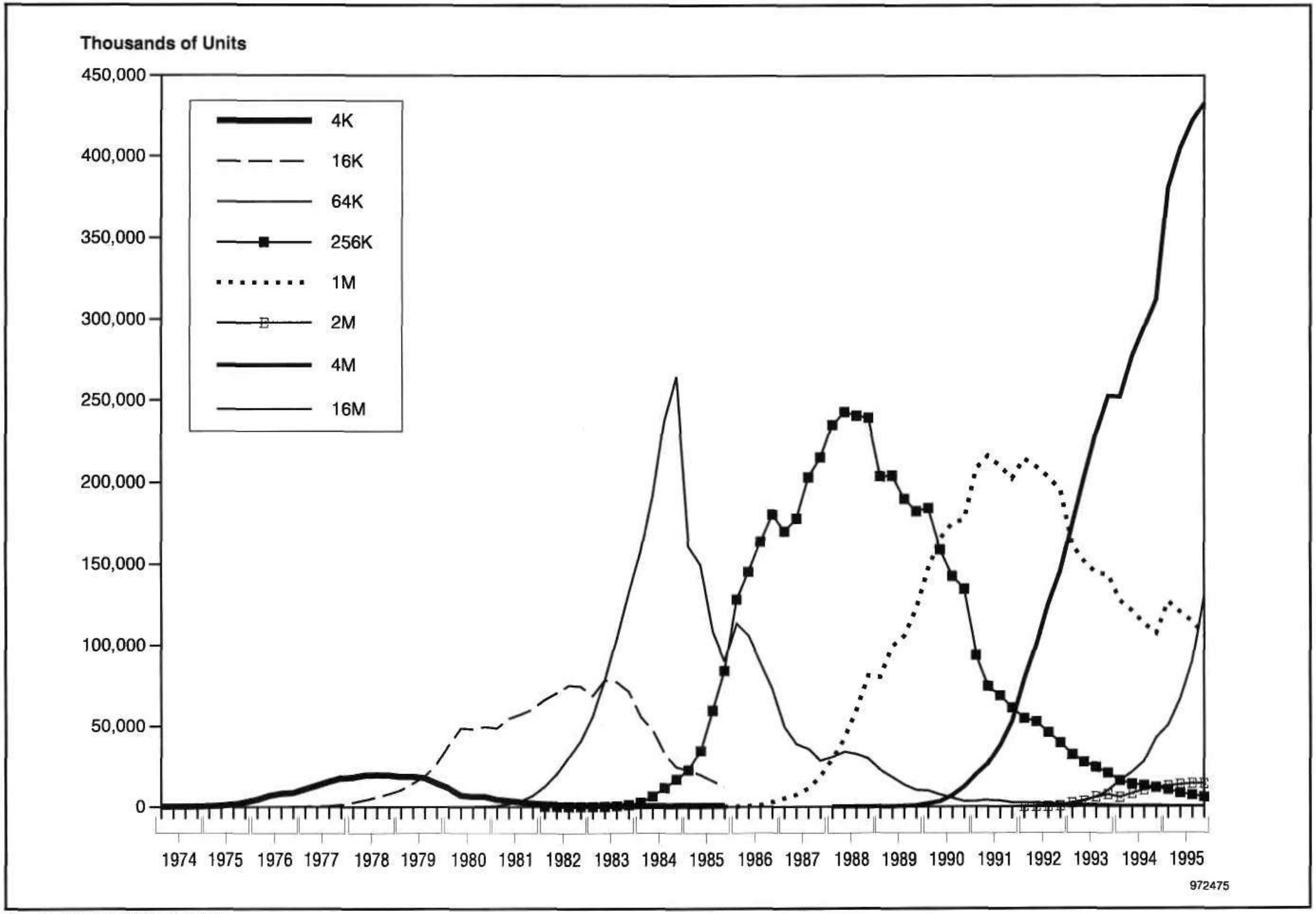
DRAM ICs follow a predictable trend, where the density of the leading chip increases by a factor of four every three years. In 1997, the majority of devices shipped will be 16Mb DRAMs, whereas three years earlier, in 1994, the leading density was 4Mb, and in 1991 the 1Mb DRAM was the sales leader. The shift from one density to the next is driven mainly by maturation of leading-edge DRAM production processes. This continual density increase drives down the price per megabyte of memory and has an interesting effect on the DRAM module market.

Figure 8-1 shows unit shipments of DRAM ICs by density from 1974 through 1995. Transitions from one density to another are relatively sharp, and a predictable life cycle repeats itself for each generation of DRAM. During the transitions from one density to another, adjacent densities compete with each other for the same sockets. For example, during the transition from the 4Mb to the 16Mb density in 1996, the two devices competed in price against each other. The 16Mb device has four times as many bits (or megabytes) as the 4Mb density, so any 16Mb price that is lower than four times the 4Mb's price makes the 16Mb chip more economical per megabyte. In 1994, when the manufacturing processes for the 16Mb chip were much less mature, the price per megabyte for 16Mb chips was significantly higher than that for 4Mb DRAMs, and the 4Mb chip had a cheaper price per megabyte than any of its predecessors, so the 4Mb was in a stable period in which it was the most cost-effective DRAM density.

These two phases in a DRAM's life, the one in which two densities compete for the cheapest price per megabyte and the one in which one density alone is the most cost-effective, are very important to the overall DRAM module market. During the phase in which one density is the most cost-effective, there is no reason for the base memory of a system to switch from one density to another, so PC OEMs design their motherboards to have the base memory configuration soldered directly onto the motherboard. Sockets are provided for upgrades, but the socket used for the base memory configuration is avoided, and cost savings can be realized.

During the transition phase in the DRAM life cycle where DRAM two densities are competing for lowest cost per megabyte, the PC OEM's purchasing department is confronted with a difficult situation of which DRAM to procure. The transition will take a number of quarters. In order for the OEM to be able to take advantage of the lower costs, modules are used during this time for the base memory configuration. This means that the OEM adds to the motherboard's cost by adding a socket, but this socket gives the purchasing department more flexibility, since they can purchase the least-expensive modules of a given density no matter which DRAM chips are used to populate these modules. At this point, there is a surge in module unit volumes, and most DRAM manufacturers ship the bulk of their product in modular form.

Figure 8-1
DRAM Quarterly Unit Shipments, 1974 through 1995



Source: Dataquest (April 1997)

Chapter 9
The Business Model

This section outlines the prevailing business practices of a successful third-party DRAM module manufacturer. One important point to remember when addressing the third-party business model is the idea that this is a service business and not a technology business.

Strategies

The strategies of third-party module companies are closely tied to the channels they choose to support. As described earlier there are three broad classes of distribution channels, distribution and resale, retail, and OEM. At this time, not one third-party manufacturer is a major influence in all three distribution channels.

In the distribution and resale channel, the strategy is to gain a foothold with distributors and resellers and then approach the corporate end user with a sales pitch to pull the product through the distributor or reseller. There are alliances among the resellers, distributors, and systems integrators and the third-party manufacturers, but these can change quickly because it really does not matter to the channel whose module they sell. The retail channel strategy is similar to the distributor and reseller channel strategy, with the exception that the target is now the home user and small business.

Alliances are important for companies following an OEM channel strategy. The value offered by the module company in this channel is logistics management and consistent manufacturing. In one sense, the OEM channel is the easiest to participate in because the OEM has a clear understanding of its memory modules needs. The difficulty in servicing this channel comes from the need to provide a very consistent, high-quality memory module.

In addition to channel development, design, and manufacturing capability, vendor relationships, diversification, and tight business management are important parts of a module company's business strategy.

Product diversification into nonmemory module products is another important part of a third-party memory module company's business strategy. Product diversification is important because third-party module manufacturers want to maximize their distribution and reseller channel relationships.

Inventory Management

Inventory management is arguably the most important part of the third-party business model because of the tight margins involved. The key to success is the ability to turn inventory as quickly as possible. Third-party companies keep the bulk of their inventory as DRAM ICs, enabling manufacturing flexibility. DRAM IC inventory is typically between one week and one month. Finished DRAM module inventory is kept very small, an amount between three to five days is common.

A module manufacturer has the majority of its value tied up in DRAM inventory. This creates a situation in which a well-managed inventory system becomes a differentiator. The DRAM price decline of 1996 is a good example of the importance of inventory management. Module manufacturers holding DRAM in inventory faced the potential loss of 10 to 20 percent of their inventory's value every month. Holding out hope for a short-term uptick in price is not an alternative because product needs to be sold to provide the capital necessary to purchase more DRAM.

One factor that eases third-party module manufacturers' inventory concerns is that third-party manufacturers are technology followers instead of technology drivers, and they do not need to precisely forecast DRAM technology shifts. DRAM manufacturers and PC OEMs need to be precise about forecasting the future mix of DRAM that the PC memory market will need. The memory aftermarket lags the leading-edge PC market. Whether this time lag is a month or a year, the third-party manufacturers have the opportunity to look at current PC memory configurations and use that information to forecast what type of memory they need to buy. This does not solve the problem of where to obtain DRAM, how much to buy, and when to buy it, but it does ease the concern of whether it should be EDO DRAM or SDRAM, for example.

Manufacturing Flexibility

One of the attributes of any module company is its manufacturing flexibility, which helps in its inventory management. Keeping inventory in DRAM chips allows the same 16Mb DRAMs to be used in a 4Mb, 8Mb, or 16Mb module, in a SIMM, DIMM, or proprietary module. The time needed to switch a manufacturing line over to a new module configuration is only a matter of hours.

An example of manufacturing flexibility using 16Mb chips to populate a x32 SIMM is as follows:

Typical configuration (megabytes): number of chips times (DRAM chip type)

- 1Mbx32 (4 megabytes): 2 x (1Mbx16)
- 2Mbx32 (8 megabytes): 4 x (1Mbx16) or 4 x (2Mbx8)
- 4Mbx32 (16 megabytes): 8 x (4Mbx4) or 8 x (2Mbx8)
- 8Mbx32 (32 megabytes): 16 x (4Mbx4)

Even though there are alternatives, module suppliers typically make the modules from the most standard DRAM. For 16Mb DRAM, the standard chips are the 1Mbx16 and 4Mbx4. The 2Mbx8 became "mainstream"' in the second half of 1995 when the Intel chipset finally supported it. Initially, it was used to make only 8MB modules, but in the second half of 1996, it was also used for 16MB modules when 4Mbx4 pricing soared in all markets because of a lack of supply. Thus, the 2Mbx8 acts as a useful barometer reflecting the start of the PC base memory transition from 16MB in the end of 1995 to 32MB in the end of 1996.

Cash Management

Cash management is closely related to inventory management and is another important attribute of a well-run module company. A module company with $200 million in annual revenue may have spent $160 million on DRAM in that year. This creates an environment that requires the use of cash from accounts receivable to pay off suppliers. If a module company does not have a well-run collection process, it is in a situation where one or two significant defaults could jeopardize its solvency.

Closely related to cash management is a clear understanding of labor requirements. Successful companies running their own manufacturing facilities need to do a labor cost analysis. Module manufacturers need a specialized labor force that is flexible and capable of dealing with hourly priority changes.

Capital Investment

The third-party module industry is filled with privately held companies that grow using their own retained earnings. This ability to grow from retained earnings is also why most of these companies have stayed private. Kingston Technology, a well-positioned company in the module market, is a good example. John Tu and David Sun, Kingston's founders, started with $7,000 in capital. From this starting point, they grew Kingston to a billion-dollar business without the help of a bank loan, capital infusion, or equity offering. Kingston even owns its company headquarters building outright.

Revenue growth stopped abruptly for this industry in 1996, and this may signify a turning point in how the industry looks to fund its growth. Again, Kingston is a good example. Softbank, a publicly held Japanese company, acquired Kingston in 1996. Kingston has very strong ties with DRAM manufacturers and solid penetration into the distribution and resale channels. Given these advantages, Kingston had a strong position in this market; however, its owners chose to sell their company.

The primary use for capital in this industry is to purchase DRAM. The sale of Kingston shows the importance of alliances and purchasing power. Kingston is now part of a large corporation, which strengthens its already strong purchasing power. The importance of purchasing power or alliances with companies that have purchasing power should not be overlooked. One of the few DRAM-dependent companies to show positive growth in 1996 was Smart Modular Technologies. Smart Modular has aligned itself with system OEMs and DRAM manufacturers, abandoning the traditional distribution and resale channels. It has positioned itself where, even if it does not have standalone purchasing power, it works with companies that do.

Vendor Relationships

It is important to elaborate on the relationship between the third-party module companies and the DRAM manufacturers.

Naturally, DRAM manufacturers have a relatively simple procurement procedure if they choose to manufacture modules in-house. The bulk of the parts used are manufactured in-house. These are transferred at a cost that reflects the manufacturer's internal accounting practices, where the internal transfer price is usually set to be one of three options: zero cost, cost, or prevailing prices. Preferential treatment is often given to the module producing division in decisions of allocation, costing, and slippage.

Third-party module manufacturers, on the other hand, must be nimble purchasers and have placed themselves in novel situations and partnerships. Some buy directly from the DRAM manufacturer and have good ongoing business relationships with major DRAM producers. Others purchase almost exclusively through brokers, putting themselves at the mercy of the availability of surplus devices. Sometimes this means cheaper DRAMs for the SIMM manufacturer, but at other times this means far more expensive DRAMs.

A typical memory module company's best approach to procurement is somewhere in the middle, which requires the ability to maneuver successfully among the minefields of both markets. Ideally, a module manufacturer has guaranteed access to a steady supply of low-priced, quality DRAM and access to the right memory technology at the right time. A blind devotion to either market would not offer this.

Module companies need to maintain relationships with DRAM manufacturers. Without these relationships, there is little chance a module company will be able to weather technology shifts and allocation periods without losing customers. However, during allocation periods, a module company faces the fact that the DRAM manufacturer has to prioritize accounts and it is likely to face an allotment cut. There is also a price penalty during oversupply periods when the spot market offers cheap DRAM.

Module companies that have grown too dependent on the spot market face even more difficulties. Although they have the opportunity for significant cost savings in oversupply periods, they pay a significant price penalty during allocation periods when spot market availability is poor. It is also true that spot market DRAM is of suspect quality and difficult to pedigree.

Customer Relationships

The majority of third-party module companies mention customer relationships as the backbone of their company's operations. Vendor relationships place a close second, but many companies pointed out that without customers, their vendor relationships become moot.

Outsourcing

Outsourcing has two meanings for third-party memory module manufacturers. One refers to third-party manufacturers that outsource their own module manufacturing to a contract assembler. The second refers to third-party manufacturers that offer their module manufacturing services to OEMs and DRAM manufacturers.

In-house manufacturing capability does not necessarily separate successful third-party memory module manufacturers from the rest. The decision to use contract assembly is dependent on where the module company sees its value-add. Companies that believe the value-add is in state-of-the-art manufacturing insist on running their own manufacturing facility. Companies that believe the value-add is in managing the logistics of purchasing, manufacturing, testing, and distribution may or may not manufacture their own modules.

Module companies do differentiate themselves by product quality and availability. If a company does outsource manufacturing, it must ensure it has a test program sufficient to guarantee the quality of its product. It also must maintain a close relationship with the contract assembler to oversee the day-to-day fluctuations in product mix and to deal with problems as they arise.

The second type of outsourcing mentioned, offering contract manufacturing services to other companies, is a growing area of interest. Third-party companies actively offering this service carefully align themselves between the DRAM manufacturer and OEMs. As mentioned earlier, top-tier OEMs procure their DRAM and DRAM modules directly from DRAM manufacturers. Because of this, third-party module companies offer contract manufacturing services to tier two and tier three OEMs that face difficulties obtaining DRAM. This scenario is undergoing a number of changes.

Top-tier OEMs are embracing third-party memory module manufacturers in a combined effort to run their upgrade business. This combined effort offers OEMs the ability to profit from the lucrative aftermarket while avoiding the pitfalls of managing their own program. This has created an environment where third-party manufacturers are scrambling to align themselves with OEM partners. One very public example was the 1996 teaming of Toshiba and Kingston. In this arrangement Toshiba's computer group will cobrand its modules with Kingston, while letting Kingston run the upgrade program.

On the flip side, third-party manufacturers are also teaming up with DRAM manufacturers. DRAM manufacturers run into situations where they need quick turnaround for key accounts. For unusual requests or short production runs, this level of support is costly. One cost-effective approach is to use a third-party module company in these situations. By doing so, the DRAM company leverages the flexibility and dedication of a third-party module company while cost-effectively meeting the needs of their key accounts.

Although the relationships mentioned above are beneficial to both parties, it may be best to look at them as marriages of convenience. OEMs and DRAM manufacturers control the power in these relationships, and they can easily exercise it by taking their business and their DRAM elsewhere or creating an in-house equivalent. Dataquest wonders how long it will be before an OEM or DRAM manufacturer purchases a third-party module company outright.

Barriers to Entry

This industry is not protected by high barriers to entry. The legion of small companies that participate in this industry and the relatively low value-add of placing DRAM on a module demonstrates this. Because manufacturing and test can be outsourced, a large part of start-up costs are tied to the initial purchase of DRAM. Once a company has entered the business, success is dependent on continually turning the last output into the financing needed for the next.

What barriers to entry are there? One is company reputation. This industry has a history of transient companies with questionable business practices. Companies that have established relationships and a strong reputation for fulfilling their promises are in a good position.

Another potential barrier is the economies of scale in procuring DRAM ICs. There is a definite pecking order to procuring DRAM. Top-tier OEMs will get their DRAM ICs before $100 million module companies. However, it is difficult for a DRAM manufacturer to ignore a well-capitalized, $500 million module company.

Terms and Conditions

Some third-party DRAM module manufacturers have fostered the habit of procuring DRAM ICs through brokers. During times of a supply/demand balance or an oversupply like that of 1996, this can play very much to the advantage of the spot market buyer. During an undersupply like the one experienced in 1994 and 1995, this can cause a lot of trouble for spot-market buyers. Shortages also spell survival of the fittest, where manufacturers thrive or perish by the relationships they have attained. DRAM manufacturers have made inroads into the territories held by third-party module manufacturers simply by their ability to exert control over their own production of DRAM ICs.

Service Issues

Third-party memory module manufacturers are in a service business, and success is dependent on providing a complete solution. Because module companies are in the middle, between DRAM suppliers and PC OEMs, they have to accommodate whatever directions both of these markets take. The type of service depends on what part of the channel the third-party manufacturer supports. Same-day shipping, lifetime warranty, tech support, and complete product lines are important in the retail and the distribution and reseller channels. The OEM channel is dependent on manufacturing flexibility and consistency.

Chapter 10
Regional Markets

Although the DRAM IC market is a global effort on a grand scale, regions still compartmentalize the third-party module market. A worldwide market does exist for third-party memory modules, but there is relatively little penetration outside the United States. Tables 10-1 and 10-2 show the regional breakout of DRAM module revenue by region. Table 10-3, which shows Dataquest's PC unit shipment forecast by region, is provided as a reference point.

Table 10-1
Third-Party DRAM Module Revenue by Region, 1996 through 2000 (Millions of Dollars)

	1996	1997	1998	1999	2000
Americas	3,966	4,387	4,872	6,432	8,864
Japan	650	742	934	1,331	1,866
Europe, Middle East, and Africa	844	1,086	1,340	1,885	2,644
Asia/Pacific	674	783	974	1,442	2,177
Total	6,133	6,997	8,120	11,090	15,550

Source: Dataquest (April 1997)

Table 10-2
Third-Party DRAM Module Revenue by Region, 1996 through 2000 (Percent)

	1996	1997	1998	1999	2000
Americas	64.7	62.7	60.0	58.0	57.0
Japan	10.6	10.6	11.5	12.0	12.0
Europe, Middle East, and Africa	13.8	15.5	16.5	17.0	17.0
Asia/Pacific	11.0	11.2	12.0	13.0	14.0
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (April 1997)

Table 10-3
Unit Shipments of Personal Computers to Each Region

	1995	1996	1997	1998	1999	2000	CAGR (%) 1995-2000
Americas							
Units (K)	27,040	31,626	36,415	41,910	48,499	56,624	15.9
Unit Growth (%)	-	17.0	15.1	15.1	15.7	16.8	-
Europe, Middle East, and Africa							
Units (K)	14,672	16,269	18,791	21,422	24,611	27,704	13.6
Unit Growth (%)	-	10.9	15.5	14.0	14.9	12.6	-
Japan							
Units (K)	5,695	7,987	9,799	11,352	12,985	14,553	20.6
Unit Growth (%)	-	40.2	22.7	15.8	14.4	12.1	-
Asia/Pacific							
Units (K)	6,822	8,705	10,749	13,432	16,998	21,161	25.4
Unit Growth (%)	-	27.6	23.5	25.0	26.5	24.5	-
Worldwide							
Units (K)	60,171	72,021	84,793	98,460	114,110	131,495	16.9
Unit Growth (%)	-	19.7	17.7	16.1	15.9	15.2	-

Source: Dataquest (April 1997)

Americas

The Americas account for approximately 65 percent of third-party revenue. While there are third-party manufacturers throughout the Americas, a significant number of third-party companies are located in Southern California. However, the location of manufacturing isn't a significant competitive advantage because DRAM modules are relatively small and large volumes are easily shipped over night.

Dataquest expects third-party DRAM module revenue to increase in the Americas, but with a decreasing percentage of the entire market. One reason behind this is that both U.S. and foreign manufacturers are looking to capitalize on the growing installed base of PCs outside of the United States.

Europe

Europe has become a hot area of interest for memory module manufacturers because of its close similarities to the U.S. market. U.S.-based companies such as Centon Electronics, Kingston Technology, PNY, Simple Technology, Smart Modular Technologies, Viking, and VisionTek dominate the European third-party module market. Some of these companies have established European manufacturing facilities in Europe, and most module manufacturers have at least one sales office in Europe. However, because the DRAM vendors themselves manufacture DRAM modules, in part to avoid paying a higher level of European Union import tariff, the third-party module manufacturers are competing for a relatively small slice of a much larger total market.

Europe produces about 20 percent of the world's PCs, and, in total, the PC industry in Europe constitutes more than 70 percent of the European DRAM market. It is this dominant PC element that drives the market for modules. Because European PC production is centered in the United Kingdom/Ireland and Germany, it is in these regions that the module manufacturers are most active.

Over the past 12 to 18 months, there has been a move by some of the larger module manufacturers that have a global presence to set up manufacturing in Europe, most notably in the United Kingdom/Ireland region. This increased presence in Europe, by U.S.-based memory module manufacturers in particular, is a move to tackle a number of challenges: warehousing, import duties, logistics, accounting differences, language barriers, and so on. Having local manufacture and warehousing in a significant PC manufacturing region gives a module manufacturer an edge in responsiveness and helps to drive cost reductions. Another strong motivator in the move to local manufacture is the avoidance of the import duties that apply in the European Union, which affect both DRAM chips and memory modules.

There are companies of European origin manufacturing memory modules and serving the European market, but these companies tend to focus on the local national marketplace rather than the pan-European market.

Japan

The Japanese market makes up about 11 percent of the third-party module business. Two Japanese companies, Melco and I.O. Data, dominate this region. Both of these companies are Japanese and do almost all of their business in this region. U.S.-based third-party companies almost completely ignore the Japanese region. The only U.S. manufacturer that has a significant presence in this market is Century Micro Electronics. However, Century's main manufacturing facility is in Japan, and more than half its revenue is from outside of the United States, which is unusual for a U.S.-based module company.

Based on Dataquest's discussions with U.S. module manufacturers, the Japanese region is not a targeted growth area. One reason behind this hesitancy is a fear that the approach these manufacturers have successfully implemented in the United States will not work in Japan. The only U.S. manufacturer that may have an immediate impact in this region is Kingston. Kingston's interest in this area was the seed that blossomed into Softbank's acquisition of Kingston. Because Softbank is a Japanese company, Kingston may have an easier time attacking this market.

Asia/Pacific

Korean DRAM manufacturers dominate this region, but there is an active third-party module market in Taiwan. In addition to the Korean and Taiwanese companies, there are emerging markets, such as China, that also offer worldwide and national manufacturers an avenue for growth.

The U.S. third-party structure of independent third-party memory module manufacturers does not seem to exist in Korea. Memory-related activity in that country is closely tied to Korean DRAM manufacturers. There are companies that manufacture memory modules in Korea; most seem to manufacture on a contract basis for the DRAM manufacturers, and the module is sold under a DRAM manufacturer's brand name.

The Taiwanese third-party DRAM module market is similar to the U.S. market in that the modules are sold to a worldwide base of distributors, computer resellers, and PC OEMs. The main differences are a heavier use of the spot market and a lack of branded product. The heavier use of the spot market is easy to understand, considering that the Taiwan DRAM spot market was the lowest-cost source of DRAM in the world in 1996. This enabled Taiwanese third-party manufacturers to purchase the lowest-priced DRAM chips, which in turn resulted in some of the most aggressively priced DRAM modules in the world.

Dataquest estimates that between $150 million and $230 million worth of unbranded modules were manufactured by Taiwan-based third-party module manufacturers in 1996. The Asia/Pacific market and the worldwide gray market are where most of this product was sold.

Dataquest believes that the low penetration of "branded" third-party modules in Japan and Asia/Pacific results from two influences—the strong presence of DRAM manufacturers in these regions and the lack of a large installed base of PCs. For the third-party company to offer value, it needs to leverage a large installed base. The installed base of computers outside the United States is relatively small. Without an installed base to leverage, a third-party company becomes dependent on OEM channel business. This creates a situation where the third-party manufacturer would infringe on the DRAM manufacturer's module territory. In effect, a third-party structure, as it exists in the United States, is difficult to replicate at this time in Japan or Korea.

Chapter 11
Third-Party DRAM Module Manufacturer Vendor Profiles

American Computer and Digital Components Inc.

ACDC
440 Cloverleaf Drive
Baldwin Park, California 91706
(818) 336-1388
http://www.acdcmemory.com/

American Computer and Digital Components was established in 1987 as a memory module manufacturer. ACDC operates a 120,000-square-foot facility in Southern California, where it manufactures over 2,000 different types of memory modules. ACDC is active in both the retail and the distribution and resale channels. Dataquest estimates ACDC's DRAM module revenue to be $480 million in 1996.

Celestica

Celestica Inc.
844 Don Mills Road
North York, Ontario
Canada
(416) 448-5790
http://www.celestica.com/

Celestica is a Canadian full-service contract manufacturer with total company revenue approaching $3 billion in 1995. Celestica can trace its history back 80 years as a manufacturing facility in Toronto. It has expertise in design, prototyping, manufacturing, and miniaturization of electronic assemblies. Celestica employs more than 2,500 individuals at its 900,000-square-foot facility in North York, Ontario. The company also has a subsidiary, Celestica Corporation, based in New York state.

Celestica was once part of IBM, but it is now independent of IBM and has manufactured memory modules for other parties on a contract basis for a number of years. In August 1996, Celestica entered into the distribution of computer memory products. Celestica has signed contracts with a number of computer and industrial distributors, like Ingram Micro, making their products immediately available throughout North America. Although Celestica is not a traditional third-party company, it should not be overlooked as a significant competitor with the other companies mentioned in this report.

Centon Electronics

Centon Electronics Inc.
20 Morgan
Irvine, California 92718
(714) 855-9111
http://www.centon.com/

Centon Electronics was founded in 1978 by Gene Miscione, its president and CEO. Originally a distributor of DRAM, Centon began the transition to memory module manufacturer in 1990, and completed it in 1993. Centon's 1996 company revenue is estimated to be $220 million. Although revenue was impacted by 1996's DRAM price declines, 1996's profit margin was double 1995's level, and DRAM module unit shipments grew.

The company's goal is to be "a worldwide supplier of memory add-on solutions through leadership in the design and marketing of new products to all segments of the market." Strategic partnerships and long-term relationships with its customers, qualified contract manufacturers, and suppliers are the keys Centon has identified to meeting its goals.

OEM relationships account for the lion's share of Centon's business—50 percent, the distribution and reseller channel accounts for 30 percent, and the retail channel makes up the remaining 10 percent. Centon believes that once all true costs are considered, each of the channels offers similar margins. Retail, however, is cited as the most difficult channel in which to participate. Centon maintains its presence in retail through very tight management.

Centon is shipping about an equal number of FPM and EDO modules, but it is moving quickly toward EDO. Centon's most popular products are 8MB and 16MB EDO SIMMs. DIMMs are growing in significance but are still considered a differentiator at this time.

Centon believes in emphasizing its operating strengths, which it believes to be managing the logistics involved in manufacturing memory modules, not the actual physical assembly of the module. Centon manages its own planning, procures its own parts, inventories its own components, tests its own parts, and manages the inventory and distribution of finished goods. What Centon is content to outsource is assembly.

Four to five subcontract assembly houses are used by Centon at any given time to manufacture its memory modules. Centon provides complete assembly kits to its subcontractors and maintains a support engineering staff on site. The engineering support is to deal with problems as they arise and to ensure that proper manufacturing principles are followed. Before working with an assembler, Centon does a full team review of the facility and processes used. Centon is also in the process of becoming ISO 9001 certified.

Centon uses both the contract and spot market, at about equal levels, to obtain its DRAM supply. The split between contract and spot market usage varies depending on market conditions. Centon uses the spot market more than many of its competitors, leveraging its experience as a distributor. Even though Centon chooses to use the spot market more than many of its competitors, it also works to maintain strong relationships with its contract DRAM suppliers. Centon maintains an inventory level of raw material and finished goods of about two weeks.

Centon believes the entire third-party memory module market is still growing, and because of this, it expects to grow in size and revenue without having to grow its market share. International, OEM, notebook, and workstations are all areas targeted by Centon for growth. Centon already has an international presence, with 20 percent of its sales coming from outside of the United States, but it hopes to expand this area.

Century Micro Electronics

Century Micro Electronics Inc.
4800 Great America Parkway
Santa Clara, California 95054
(408) 748-7788
http://www.century-micro.com/

Century Micro Electronics was founded in 1989 by principals from Japan and Hong Kong. Dataquest estimates Century's 1996 worldwide company revenue to be $400 million. Century did enjoy a higher profit margin in 1996 and an increase in DRAM module unit volume. Century supports all three distribution channels. About 60 percent of Century's revenue comes from the distribution and reseller channel. The OEM channel accounts for a little over 30 percent of revenue. The retail channel and contract manufacturing make up the rest. Century's product line includes modules from 1MB to 128MB, with 8MB and 16MB being the most popular in 1996.

Manufacturing is split among Japan, Hong Kong, and the United States. Fifty percent of Century's 100 employees are devoted to manufacturing. Century's main manufacturing facility is located 35 miles southwest of Tokyo, where Century operates five fully equipped surface-mount technology lines. In the United States, Century uses contract assembly for quick turnaround situations to avoid heavy inventory exposure. Decentralized manufacturing allows Century to provide just-in-time service to its worldwide customer base.

Century's Japanese plant features test equipment with the capability of performing full printed circuit board (PCB) timing analysis, wave form measurement, and complete parametric testing. Environmental and reliability testing, including operational life test, burn-in, and insertion testing, is also performed.

Century differs from many of its competitors in that more than half its revenue is derived from outside the United States. The United States is the largest single region, accounting for 40 percent of Century's sales. The Japan and Asia/Pacific regions account for about 50 percent of sales, which is not surprising considering this is where most of Century's manufacturing is located.

Century uses both the spot market and contract arrangements with DRAM suppliers to purchase its DRAM. The dependency on either source varies considerably, depending on market conditions. Taking advantage of 1996's falling DRAM prices, Century augmented its direct allocation DRAM with product from the spot market. This action assured Century's cutomers a consistent supply of product at competitive prices.

I-O Data

I-O Data
24 Gaiku-1, Sakurada-machi
Kanazawa City 920
Japan
http://www.iodata.co.jp/

I-O Data is the second-largest third-party module manufacturer in Japan. It was founded in 1976 and became a publicly held company in 1991. I-O Data first started manufacturing memory enhancement products in 1980. In addition to DRAM modules, I-O data manufactures and sells a full line of PC peripherals. Dataquest's estimate of I-O Data's 1996 DRAM module revenue is $177 million.

GoldenRAM

GoldenRAM
8 Whatney
Irvine, California 92618
(714) 460-9000
http://www.goldenram.com/

GoldenRAM's product line includes various memory modules for main memory, graphics and cache applications, CPU upgrades, and hard drives and CD-ROM kits. Its sales have nearly doubled almost every year since it first began manufacturing in 1988. Company revenue in 1996 is estimated to be $180 million. GoldenRAM distributes its product primarily through the distribution channel, where 60 percent of its modules are sold. The OEM channel accounts for the remaining 40 percent.

GoldenRAM sources all of its DRAM through contracts with DRAM suppliers. GoldenRAM manufacturers between 6,800 and 7,200 modules a day and maintains a centralized finished goods and DRAM inventory of two to three weeks. GoldenRAM expects to be registered to the ISO 9001 standard by June 1997. GoldenRAM's Ramcharge dealer support program and its Goldenserv corporate end-user support service are aimed at differentiating GoldenRAM-brand modules from generic memory modules. These programs are aimed at ensuring repeat business. GoldenRAM also repurchases modules from customers to encourage upgrading. GoldenRAM breaks even on these purchases.

Kingston Technology

Kingston Technology Corporation
17600 Newhope Street
Fountain Valley, California 92708
(714) 435-2600
http://www.kingston.com/

In 1987, Kingston Technology was formed to support the emerging market for memory upgrades. Today, Kingston's objective is to be the OEM of memory throughout the computer industry. Kingston is by far the largest of the third-party memory module manufacturers, with estimated company revenue of $1.3 billion in 1996. Kingston has an image and strategy of supporting the high-end, machine-specific memory module market and avoiding generic, commodity modules. Kingston also sells processor, networking, and storage upgrades, but these products are completely overshadowed by memory modules, which account for over 80 percent of Kingston's revenue. Although company revenue was flat, Kingston experienced a threefold increase in DRAM module unit shipments in 1996.

Kingston's prominence among memory module manufacturers comes from its domination of U.S. distribution channels. Kingston's dominant position in distribution is in contrast to its position in the PC OEM and retail channels, where it has little or no presence. Kingston had a first mover advantage in the distribution channel, having entered this channel before there was any significant competition. This allowed Kingston the opportunity to develop tight working relationships with its distribution and reseller customers, without having to worry about cutthroat price competition. Because Kingston is already so well positioned in the U.S. distribution channel, it is difficult to forecast above-average growth in this channel. This constraint explains why Kingston has targeted international expansion as the best way of expanding this line of business. It also explains why Kingston is interested in expanding its presence in the OEM channel. Kingston recently made a public entrance into the OEM channel when it announced it will supply the memory modules for Toshiba America Information Systems' memory upgrade program.

Kingston has traditionally sourced 100 percent of its DRAM through contract arrangements with DRAM manufacturers. Even in 1996, when the spot market provided the opportunity for significant cost savings, 95 percent of Kingston's DRAM was purchased through contracts. Kingston avoids relying on the spot market for a number of reasons. The most important is the need to maintain strong relationships with DRAM manufacturers. Kingston fears opportunistic use of the spot market would alienate its suppliers, creating the potential for problems during allocation periods. Kingston's size also prohibits it from relying heavily on the spot market.

Ma Laboratories

Ma Laboratories
1972 Concourse Drive
San Jose, California 95131
(408) 954-8188
http://www.malabs.com/

Ma Laboratories was founded in 1983 as a PC maker but moved into the PC upgrade market. Dataquest's estimate of Ma Labs' 1996 DRAM module revenue is $182 million. In addition to DRAM modules, Ma Labs sells other PC peripherals, such as CPU upgrades and motherboards.

Melco

Melco Inc.
Kamiya Bldg., Ohsu 4-11-50, Naka-ku
Nagoya 460, Japan
81-52-251-6891
http://www.melcoinc.co.jp/

Melco is the leading third-party module manufacturer in Japan. Melco is a publicly held company, with 357 employees, that manufactures memory modules and PC peripherals. Dataquest's estimate of Melco's 1996 DRAM module revenue is $268 million. Approximately 60 percent of Melco's total company revenue is derived from DRAM modules.

Melco considered 1996's DRAM price decline as an opportunity for it to expand its add-on memory board business. To capitalize on this opportunity, it offered stock compensation of about $26 million to dealers so that lower module prices for Melco memory modules would become effective in the marketplace immediately. Melco also promoted an advertising campaign targeted at dealers and end users, addressing the opportunities affordable add-on memory offered. These initiatives had a positive impact on Melco's DRAM module revenue, which increased 45 percent in 1996.

MGV Memory

MGV Memory
29 B Technology, Suite 100
Irvine, California 92618
(800) 440-4648
http://www.mgvgroup.com/

MGV maintains its company headquarters in Irvine, California, and a manufacturing facility in Huntsville, Alabama. MGV's 45,000-square-foot manufacturing facility is ISO 9001 compliant and can produce over 50,000 memory modules per day. MGV sells its memory products through facilities in Europe, Asia, and North America. Dataquest's estimate of MGV's 1996 DRAM module revenue is $113 million.

MGV is active in all three distribution channels, but it concentrates on the retail channel, which accounts for the largest portion of its business. MGV Memory products are available at more than 2,000 retail outlets, including computer and office product superstores, consumer electronics stores, and mass merchants in the United States, Canada, Mexico, and Europe. In 1996, MGV's retail strategy included proactive pricing actions for its retail partners to help manage the DRAM price decline, a just-in-time manufacturing system to ease inventory exposure, and a special order program for proprietary products for notebook and printer memory upgrades.

PNY Technologies

PNY Technologies Inc.
200 Anderson Avenue
Moonachie, New Jersey 07074
(201) 438-6300
http://www.pny.com/

PNY Technologies was founded in 1985 as a memory chip broker. In 1991, PNY made the transition to third-party memory module manufacturer, and since then, PNY has progressed from a company with a manufacturing mind-set to one with a design mind-set. PNY operates three manufacturing facilities, one at its headquarters in Moonachie, New Jersey, a second U.S. facility in Santa Clara, California, and a third facility in Bordeaux, France. PNY will soon move its headquarters to a new 165,000-square-foot facility in Parsippany, New Jersey. PNY's annual sales have virtually doubled every year since its transition to manufacturer in 1991. Company revenue was flat in 1996, approaching $500 million. However, DRAM module unit volume increased 400 percent in 1996.

PNY sells its memory modules through the three dominant channels and is the leading third-party manufacturer in the retail channel, which includes mail order, where its memory modules are available at over 7,500 retail locations and 22 mail-order catalogs. PNY is as dominant in the retail channel as Kingston is in the distribution channel. The retail channel accounts for about 60 percent of PNY's sales.

PNY also provides contract assembly services to semiconductor manufacturers and OEMs. PNY's high-volume production lines and automated testing equipment in America and Europe result in a combined surface-mount placement capacity of more than 200,000 components per hour. In December of 1994, PNY's New Jersey operation became ISO 9001 certified.

PNY sources its parts primarily through contract arrangements with DRAM suppliers. The spot market is used for about 10 percent of PNY's DRAM needs.

PNY's approach to the thousands of potential combinations of memory modules is its UNIMEM asset management program. Fewer than 45 UNIMEM products replace over 1,000 OEM part numbers. PNY uses this approach to dramatically reduce the amount of inventory its resellers need to carry. In 1996, PNY favored FPM as its dominant module type, with a 60/40 split between FPM and EDO. A significant part of PNY's EDO modules are being packaged as DIMMs. By the end of 1997, PNY estimates 10 percent of its modules will be SDRAM.

Simple Technology

Simple Technology Inc.
3001 Daimler Street
Santa Ana, California 92705
(714) 476-1180
http://www.simpletech.com/

Founded in 1990 by the Moshayedi brothers as a memory module manufacturer, Simple Technology expanded its product line in 1993. Simple now offers a number of PC-directed products, including small form-factor memory cards, high-density portable storage devices, and mobile networking and communications products. Memory modules are Simple's primary business, accounting for about 70 percent of Simple's sales. Simple's 1996 company revenue is estimated to be $165 million. Although Simple's revenue was impacted by the dramatic DRAM price slide of 1996, its unit shipments grew over 100 percent when compared to 1995. Twenty percent of Simple's business is international.

Simple concentrates on the distribution and OEM channels. Simple does have a retail channel presence, but it is minimal and not a key business area. The OEM channel accounts for 30 percent of Simple's business, and the distribution channel accounts for most of the remaining 70 percent. Simple deals with five or six major OEMs, providing turnkey products for drop shipping. When dealing with distributors and resellers, Simple maintains a same-day shipping policy at a 96 percent success rate.

Simple takes pride in being one of the memory vendors that designs, engineers, produces, and tests each memory module in-house. Simple maintains manufacturing plants in the United States, Scotland, and Canada, with an additional plant planned for the Pacific Rim. The combined manufacturing space Simple has is about 130,000 square feet. Simple Technology is undergoing the final qualification procedures for ISO 9001 standards. Simple expects certification will be completed within the first quarter of 1997.

About 90 percent of Simple's DRAM is obtained via contact arrangements with Japanese manufacturers. Simple's inventory level has been worked down from 45 days to around 21 days. Inventory is maintained in a mix of finished goods and raw material.

Simple expects growth to come from a number of areas, including expanded OEM sales and an increased international presence. Simple, like most module manufacturers, expanded as quickly as its monthly cash flow would allow, but it has made the big jump to strategically growing its OEM business. Simple's presence in the OEM market was helped greatly in the allocation years of 1994 and 1995. Simple hopes to expand the OEM channel to 40 or 50 percent of its total module business in 1997.

Smart Modular Technologies

Smart Modular Technologies Inc.
4305 Cushing Parkway
Fremont, California 94538
(510) 623-1231
http://smartm.com/

Launched as an independent memory module maker in 1988, Smart Modular Technologies offers its products under the Smart and Apex Data brand names to leading OEMs and distribution channels in the computer, printer, networking, and telecommunications industries. Smart is made up of three divisions: the Memory Products division, the Embedded Computer division, and the Apex Data Products division.

Smart's company revenue for 1996 was a little over $400 million, an increase of 46 percent from 1995's revenue of $275 million. Smart's success in 1996 may seem odd when compared with its third-party competitors, most of which had negative revenue growth, and with DRAM manufacturers, whose revenue dropped almost 40 percent. One reason behind Smart's success is the OEM channel. One of the most visible trends in 1996 regarding third-party module manufacturers was the move to establishing OEM relationships. Smart was already well established in this channel and has leveraged its position to continue its strong growth pattern. Smart, however, is aware of the pitfalls of unmanaged growth, citing a concern about adding customers faster than capacity.

Smart is unusual for a third-party memory module manufacturer because it is one of a few that is publicly held (Nasdaq: SMOD) and its memory modules are targeted 100 percent at the OEM channel. Smart's strength is in its manufacturing capability. This area is where Smart provides value-add to its customers. The benefits Smart offers to its OEM customers are speed and flexibility in manufacturing. Typically, large computer OEMs are slower to turn around their production lines to new product variations than a focused company like Smart. Smart leverages its capability to offer quick turnarounds to OEM customers when needed and then drop ship the product with the OEM brand name to the desired location. Because of its strengths, Smart is service oriented and not intent on owning the technology it manufactures. In fact, in some instances, Smart's customers provide their own parts and design.

Over 90 percent of Smart's business comes from DRAM modules. Right now, the modules are about equally split between EDO and FPM DRAM, with SDRAM starting to make its presence felt. Sixteen megabyte and 32MB are the most popular densities, while 8MB modules are being shipped at an increasingly slower rate.

Smart runs three manufacturing facilities: a 90,000-square-foot facility in Fremont, California, a 25,000-square-foot facility in Puerto Rico, and a 50,000-square-foot facility in Scotland. To facilitate round-the-clock design service, the company operates an additional design center in Bangalore, India. At this time, Smart ships more than 1.2 million units a month and is in the process of becoming ISO 9001 certified.

Southland Micro Systems

Southland Micro Systems
7 Morgan
Irvine, California 92718
(714) 380-1958
http://www.southlandmicro.com

Southland Micro Systems designs, develops, manufactures, and markets RAM, cache, and video memory upgrades for personal computer systems. The majority of Southland's DRAM module revenue comes from the distribution and resale channel, but memory module contract manufacturing for OEMs is growing in importance. Historically, European sales account for the largest part of Southland's sales, but Southland expects to expand its market recognition and presence in the United States.

Dataquest's estimate of Southland's 1996 DRAM module revenue is $218 million. Southland, like most of its third-party competitors, significantly increased unit volume in 1996, even though company revenue decreased. Southland expects 1997 to be a strong year, and to capitalize on this opportunity, it is planning on expanding capacity by 400 percent in 1997.

TechWorks

Technology Works Inc. (TechWorks)
4030 W. Braker Lane
Austin, Texas 78759
(512) 794-8533
http://www.techwrks.com/

Founded in 1986, TechWorks manufactures add-on performance products for personal computers, laser printers, and workstations. TechWorks manufactures modules for all types of computers, but it specializes in the Apple platform. In addition to DRAM modules, TechWorks sells other PC peripherals, such as 3-D graphics accelerators. Dataquest's estimate of TechWork's 1996 DRAM module revenue is $120 million.

TechWorks has more than 140 employees worldwide and distributes its products in more than 15 countries. The company's worldwide headquarters are in Austin, Texas, with European sales and service headquarters located in the United Kingdom.

Unigen Corporation

Unigen
45388 Warm Springs Blvd.
Fremont, California 94538
(800) 826-0808
http://www.unigen.com/

Unigen was founded in 1991. Originally, Unigen concentrated on the distribution and reseller channel, but in 1996 it changed its business strategy to focus on the OEM channel. Dataquest's estimate of Unigen's 1996 DRAM module revenue is $80 million. Although 1996 was a difficult year, Unigen did increase its unit volume by 300 percent.

Unigen operates a 40,000-square-foot manufacturing facility in Fremont, California. There are currently 55 employees and four operating manufacturing lines at this facility. This facility can produce up to 25,000 modules per shift. In addition to Unigen's U.S. facility, it maintains a design center in Taiwan. Unigen is considering expanding its Taiwan facility to full production capability and possibly opening a new facility in Europe.

Viking Components

Viking Components
11 Columbia
Laguna Hills, California 92656
(714) 643-7255
http://www.vikingmem.com/

Viking Components was founded in 1988 by President and CEO Glenn McCusker. Originally, Viking was a memory sales and distribution company, but Mr. McCusker decided that the best way to grow his company was to invest in on-site design and manufacturing capability. In addition to memory upgrades, Viking's product line has also expanded to include PC Cards and connectivity products.

Viking's business plan focuses on the reseller part of the distribution channel. The OEM channel accounts for a small part of Viking's business, and it is an area Viking is interested in expanding. In 1996, Viking's company revenue remained flat at an estimated $260 million, and the company experienced a 400 percent increase in the number of units shipped. However, it was a challenging year from a customer service point of view, with customers increasingly looking for price protection.

Viking is in the process of preparing to move to a new company headquarters in Rancho Santa Margarita, California. The new facility will be 130,000 square feet, with 25,000 square feet devoted to manufacturing. The move is expected to occur in the second quarter of 1997. To better serve the European market, Viking has also opened a manufacturing facility in Dublin, Ireland.

Inventory control and quality management are keys to Viking's business model. DRAM is primarily sourced directly from Japanese and Korean manufacturers. Most product is maintained in an unfinished state to increase flexibility. At this time, inventory is turned twice a month.

VisionTek

VisionTek
1175 Lakeside Drive
Gurnee, IL 60031
(847) 360-7500
http://www.visiontek.com/

VisionTek was founded by Chairman of the Board Allen J. Sutker and Chief Executive Officer Mark Polinsky in 1988. The company's mission is to "consistently deliver first to the market, value-added peripheral and memory products that meet the highest standards for quality and value." VisionTek's 1996 company revenue is estimated to be $300 million, and it experienced unit volume growth of three to four times 1995's level. The distribution channel accounts for approximately 70 percent of VisionTek's business, with OEM relationships accounting for the remainder. VisionTek has no presence in the retail channel.

In addition to memory modules, VisionTek offers a full line of peripheral products such as fax/modems, PC Cards, and hard drive and processor upgrades. To help its resellers and corporate customers, VisionTek offers an inventory buyback program and various "Tek" support programs.

VisionTek's memory modules are designed and manufactured on-site, at the company's 60,000-square-foot corporate headquarters in Gurnee, Illinois. VisionTek also designs and manufactures on an OEM and contract basis. In the OEM channel, VisionTek considers itself a logistics partner, helping with the ups and downs of inventory management. DRAM is sourced primarily through contract relationships with DRAM suppliers, with little spot market use. Inventory levels are measured in the number of days, with no huge stockpiles of any one memory module.

Growth in 1997 is expected to come from an enhanced sales program targeting major accounts. VisionTek's own direct salesforce will target the accounts, fulfilling the order through the most convenient distribution or reseller channel for the customer.

Wintec Industries Inc.

Wintec Industries Inc.
4280 Technology Drive
Fremont, California 94538
(510) 770-9239
http://www.wintecind.com/

In 1988, Wintec Industries established a flexible manufacturing environment dedicated to designing and manufacturing high-performance memory modules. In addition to modules, Wintec distributes CPUs, cache memory, hard disk drives, multimedia hardware, and motherboards. Company revenue approached $700 million in 1996, with an estimated $395 million coming from DRAM modules. DRAM revenue was flat, but there was over a threefold increase in unit volume. Wintec's primary target for its memory modules is the distribution and reseller channel, with little OEM and retail channel presence.

Wintec designs its products to provide cost-effective solutions that meet the highest standards of compatibility and quality. Price and turnaround time are two important competitive concerns for Wintec.

Other Third-Party Memory Module Manufacturers

In addition to the companies included in the vendor profile section, there are many other companies involved in manufacturing and supplying third-party memory modules. A nonexhaustive list of those companies follows.

1st Tech Corp.
12201 Technology Blvd., Suite 130
Austin, Texas 78727
(512) 258-3570

Acculogic
13715 Alton Parkway
Irvine, California 92718
(714) 454-2441

Admor Memory Ltd.
217 Technology Dr., Suite 100
Irvine, California 92718
(714) 789-7292

All Components
14990 Landmark Blvd.
Dallas, Texas 75240
(972) 248-1027

AMT International
2393 Qume Dr.
San Jose, California 95131
(408) 432-1790

Anacapa Micro Products Inc.
2465 Portola Rd.
Ventura, California 93003
(805) 339-0305

Bettencourt Enterprises
1725 De La Cruz Blvd., Suite 3
Santa Clara, California 95050
(408) 986-8056

BJS Electronics Incorporated
2161 Del Franco St.
San Jose, California 95131-1570
(408) 435-2888

Cambex Corporation
360 Second Ave.
Waltham, Massachusetts 02154
(617) 890-6000

Camintonn/Z-RAM Corporation
22 Morgan Street
Irvine, California 92718
(714) 454-1500

Champion Memory Products
749 Miner Rd.
Cleveland, Ohio 44143
(216) 646-2500

The Chip Merchant
4870 Viewridge Ave.
San Diego, California 92123
(619) 268-4774

Computer Peripherals Inc.
7 Whatney
Irvine, California 92718
(714) 454-2441

Data 1 Inc.
6416 Parkland Dr.
Sarasota, Florida 34243
(941) 751-3336

Dataram Corporation
P.O. Box 7528
Princeton, New Jersey 08543
(609) 799-0071

Delkin Devices Inc.
3245 Greyling Drive
San Diego, California 92126
(619) 586-0123

Elkco Corp.
41-A N. Main St.
North Grafton, Massachusetts 01536
(508) 839-2111

Enhance Memory Products
18730 Oxnard Street, #202
Tarzana, California 91356
(818) 343-3066

First Source International Inc.
7 Journey
Laguna Niguel, California 92656
(714) 448-7750

Flash Electronics
48607 Warm Springs Blvd.
Fremont, California 94539
(510) 440-2840

G & G Assemblers
15561 Producer Lane, Suites I & J
Huntington Beach, California 92649
(714) 373-6767

GEE Technical Co. Ltd.
4F-4, No. 351, Sec. 2, Chung Shan Rd.
Chung Ho, Taipei, Taiwan, ROC
(886) 2-225-2716

H Co Computer Products Inc.
16812 Hale Ave.
Irvine, California 92714
(714) 833-3222

Hypertec Pty. Ltd.
61 Talavera Rd
North Ryde NSW 2113
Sydney, New South Wales, Australia
61 2 805 0111

K. K. Adtech
Meguro-Higashiyama Building
1-4-4, Higashiyama, Meguro-Ku
Tokyo, Japan
03-3710-9591

K. K. Hagiwara Syscom
Nishiki-Park Building
2-4-3, Nishiki, Naka-Ku
Nagoya City, Aichi Prefecture, Japan
052-223-1301

Kaga Electric K. K.
1-26-1, otoha, Bunkyo-Ku
Tokyo, Japan
03-3942-5228

Kai Fu Electronic Ltd.
Room 1103, Conic Investment Building,
Hok Yuen St.
Hung Hom, Hong Kong
(852) 2774 4668

KT Technology
H&M Minami-aoyama E. 301
5-11-14 Minami-aoyama
Minata-Ku, Tokyo 107, Japan
(81) 3-5485-8494

Marco International Inc.
9 Parklawn Dr.
Bethel, Connecticut 06801
(203) 830-8000

Memory Card Technology
141 Duesenberg Dr., Suite 12
Westlake Village, California 91362
(805) 494-1395

Memory Corporation
Dalkeith Palace
Dalkeith, Edinburgh, EH22 2NA
0131 654 2576

Memory Experts International Inc.
7750 Henri Bourassa West No. 102
Montreal, PQ H4S 1W3, Canada
(514) 333-5010

Micro Memory Inc.
9540 Vassar Avenue
Chatsworth, California 91311
(818) 998-0070

Mobel Electronics
477A Ave. Delmar
Pointe-Claire, PQ H9R 4A5, Canada
(514) 426-5588

Nevada Computer
684 Wells Rd.
Boulder City, Nevada 89005-1717
(702) 294-0204

Nitronic
Aalsmeerderweg 191
1432 CL Aalsmeer
The Netherlands
31 297 347-706

Pacific Force Technology Ltd.
1605 W. El Camino Real
Mountain View, California 94040
(415) 968-9685

PIICEON Inc.
1996 Lundy Ave.
San Jose, California 95131
(408) 432-8030

PMC
17702 Mitchell N.
Irvine, California 92714
(714) 851-8242

Princeton Technology Inc.
2552 White Rd.
Irvine, California 92714
(714) 851-7776

Quadrant Components Inc.
4378 Enterprise St.
Fremont, California 94538
(510) 656-9988

SIMMSaver Technology Inc.
1820 E. First St.
Wichita, Kansas 67214
(316) 264-2244

Sphinx Computer
Brunntalerstr. 2
D-85649 Hofolding
Germany
49 8104 66 33 0

Stracon Inc.
1672 Kaiser Ave. No. 1
Irvine, California 92714
(714) 851-2288

Telecomputer Inc.
17481 Mount Cliffwood Circle
Fountain Valley, California 92708
(714) 438-3993

Transcend Information Inc.
1645 N. Brian St.
Orange, California 92667
(714) 921-2000

U S Modules
1435 McCandless Dr.
Milpitas, California 95035
(408) 946-9105

Workstation Direct
55 Holly Hill Lane
Greenwich, Connecticut 06830
(203) 661-1600

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105 Cecil Street
#06-01/02 The Octagon
Singapore 069534
Phone: 65-227-1213
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Dataquest ALERT

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Which Way Is Up?

Micron Technology Inc. announced earnings for the first quarter of fiscal year 1998, which ended November 27, 1997. Net income for the quarter was $9.6 million ($0.04 per fully diluted share) on net sales of $955 million. This compares to net income of $72 million ($0.33 per fully diluted share) on net sales of $946 million for the fourth quarter of fiscal 1997.

Micron's performance last quarter shows how difficult the DRAM market continues to be. As many consider Micron to be the industry cost leader for 16Mb DRAM, one must wonder how poorly Micron's competitors are doing. Key results include the following:

- Micron experienced an average selling price (ASP) decline of 25 percent to just under $5 for the quarter. This compares with a decline of 13 percent for the previous quarter and 75 percent for fiscal 1997.
- Gross margin on semiconductor products declined from 44 percent in the fourth quarter of fiscal 1997 to 32 percent for the first quarter of fiscal 1997.
- Capital spending for fiscal 1998 is still expected to be in the range of $600 million to $1 billion, depending in a large part on the pricing situation.

From an operations perspective, Micron revealed that test, particularly for synchronous DRAM (SDRAM), remains a bottleneck. Micron made headway addressing the assembly problems it faced last quarter but said that test may take three to six more months to correct. The test bottleneck limited Micron's bit growth to 6 percent for the quarter. Micron believes that without this bottleneck, bit growth may have been an additional 10 percent. Micron believes the test bottleneck will continue to limit bit growth, most likely to low double digits per quarter for the fiscal year.

The test problem is primarily due to the technology transition to SDRAM. Next year's expected transition to PC/100-compliant SDRAM only adds to this burden. Micron may find some solace in the likelihood that many of its competitors are faced with the same difficulty. Micron said that SDRAM accounted for about 70 percent of its shipments and that for the past two months, more than 70 percent of its wafer starts have been synchronous DRAM. It seems that the year-long anticipated SDRAM transition has finally occurred—a reported 100 percent of contract purchasing by Micron's original equipment manufacturer (OEM) clients is SDRAM.

The spot market/contract mix remained steady at 15 percent/85 percent. Although it is difficult to find any comfort in DRAM pricing, Micron's ability to move away from the spot market over the last year has saved it quite a bit of additional discomfort. Micron stated that it is selling 16Mb DRAM at around $3.50, but with downward price pressure toward current spot market pricing, which ranges from $2.50 to $3.00, depending on speed and organization. The $3.50 price most likely includes a 10 to 20 percent adder that Micron mentioned it is getting for SDRAM. The 10 to 20 percent price adder probably adds little to the profitability of SDRAM, considering the increased test cost associated with the technology.

Micron continues to ramp 16Mb production, but it expects the bit crossover with 64Mb devices to occur in the second half of calendar year 1998. This represents an aggressive ramp for Micron's 64Mb DRAM because it is now shipping only small volumes of this device. Micron's current 64Mb production is around half a million units per month, with prices from $15 to $18.

Dataquest Perspective

Based on the questions asked of Micron during the conference call, two financial industry concerns stand out: What impact will the financial crisis in Korea have on the DRAM market? Is it possible for Micron to be profitable next quarter?

Micron's take on the Korean currency crisis is that it really doesn't impact the company or the cost of DRAM significantly. Dataquest disagrees. The difference of opinion is rooted in the currency denomination of Korean DRAM manufacturer debt and variable cost. Micron believes that most of Korea's debt, material, and factory equipment cost is denominated in U.S. dollars and yen. In this case, while Korean DRAM manufacturers would enjoy added sales revenue in national currency terms as the won depreciates against the dollar, they are also paying out more won to get dollars to service their dollar-denominated costs and heavy debt. The result is a push. Micron also believes that, with the current rapid price depression, if a cost advantage does exist, it spells relief only for a very short time, possibly a week.

Dataquest believes that a significant amount of Korean DRAM manufacturer debt is internally obtained in local currency. In this case, the Korean government and national banks are subject to the exchange rate risk. The relative cost to the Korean DRAM companies decreases as the won depreciates because they get more won per dollar in sales transactions outside Korea, but the cost of internally derived debt remains the same. The same is true for labor and any materials purchased in Korea. The impact to Micron and other non-Korean DRAM manufacturers is the potentially lower cost basis for Korean DRAM manufacturers if there is sustained local currency depreciation. This would make a difference in a dumping case, because cost plus 8 percent is regarded as the floor for acceptable pricing.

The profitability question depends on where pricing goes in the next quarter. Micron and all its competitors, including Korean DRAM manufacturers, would be helped by a slowing in DRAM price depreciation. Unfortunately, as long as there is industrywide overcapacity, too many manufacturers would need to restrain their production to affect this immediately--a very unlikely scenario.

The currency situation should eventually help Micron and other DRAM companies in more stable financial environments. It will become increasingly difficult for Korean DRAM companies to find new financing to add capacity and to make technology improvements to existing fabs. This eventually will allow the market to catch up to the supply of DRAM and allow a return to a more profitable DRAM market.

By George Iwanyc

Dataquest ALERT

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Motorola to Phase Out of DRAM Business

In a decision deemed consistent with its new focus, Motorola Incorporated announced today that it will phase out its limited participation in the DRAM market. According to Motorola, this decision will have no impact on employment or on long-term relationships with Toshiba and Siemens.

- Motorola's second quarter 1997 results will be negatively impacted by this action, with a charge of about $170 million against pretax second quarter earnings related to the write-down of both technology development costs and manufacturing equipment.
- Motorola will work closely with its DRAM customers to assure that they obtain other sources of supply, in a market that has abundant capacity.
- Motorola's DRAM resources will be allocated to other technologies, including proprietary fast SRAM and integrated flash and EEPROM.
- Motorola will maintain its joint-venture partnerships with both Toshiba and Siemens but will convert its share of production capacity to other products over time.
- Motorola's joint venture with Toshiba, Tohoku Semiconductor's newest facility, which now produces 16Mb DRAMs, will gradually shift operation to logic products, including leading-edge microprocessors and application-specific integrated circuits (ASICs). Motorola's production of 16Mb DRAMs in that facility will cease by year's end; the DRAM capacity for Toshiba will be maintained until the logic conversion is completed in 1998.
- The Motorola/Siemens White Oak Semiconductor joint-venture facility under construction in Richmond, Virginia, will use DRAMs to ramp to volume production, with Siemens selling both companies' share of output. After volume production is reached, Motorola will convert its share of the facility's capacity to produce proprietary fast SRAMs.

Motorola reminded Dataquest that it has purposely maintained limited participation of less than 5 percent in the DRAM market since the mid-1980s, principally through the company's joint-venture production partnership with Toshiba. During the past three years, Motorola's share of the DRAM market has been less than 2 percent.

Dataquest Perspective

Rumors have indicated for a while that something was afoot here. About a month ago, Motorola backed out of its development joint venture with IBM, Siemens, and Toshiba. There were rumors over a week ago that the White Oak facility was going to be stopped midstream. Members of Motorola's management have been touring the country briefing analysts and the press that they planned to restructure the company to play a decreasing role in markets that did not easily fit within the overall company's direction.

The spirit of this move was stated simply by Motorola to be the "redeployment of resources to higher-value technology, especially fast SRAMs and flash memory, a market in which Motorola is committed to become a market leader."

Motorola followed this announcement with a conference call to give additional detail:

- The $170 million in anticipated charges will comprise two parts:
  - An advance payment of technology fees that Motorola agreed to pay Siemens for the development of the 64Mb DRAM technology. Rather than pay this fee over the scheduled five years, Motorola has elected to pay over 50 percent of the fee this quarter and to pay the balance over the next two years.
  - The write-off of the book value of DRAM development and test equipment at the Tohoku joint venture fab. This equipment will not be used by Motorola after 1997.
- Motorola will produce 64Mb DRAMs from the beginning of production at the White Oak facility (mid-1998) until the middle of the year 2000.
- Siemens will sell Motorola's share of the 64Mb output from the White Oaks fab. Motorola will pay Siemens a distribution fee for this service. During this time, Motorola will have no visible presence in the DRAM market.

Despite Motorola's candor, there are still several interesting points to consider. If the company stops manufacturing 16Mb DRAMs at the end of this year, yet doesn't start to produce 64Mb DRAMs until the middle of next year, will it at all be able to maintain a standing in the market? It appears that Motorola is planning to take advantage of the wide availability of product on the market to move customers to its former competitors' DRAMs. (Toshiba and Siemens will have an easy job recovering Motorola's business, since there should be little, if any, requalification needed for OEMs to switch from a Motorola part to its equivalent from Motorola's partners.)

Given that Motorola's DRAM revenue and SRAM revenue last year were both about $500 million and assuming that the revenue per wafer for Motorola's kind of SRAMs is considerably higher than that for commodity DRAMs, can Motorola find a market for all of the SRAMs it intends to produce?

Another question that comes to mind is why Motorola would push to get out of the DRAM market altogether just when all other DRAM manufacturers seem to be moving toward developing embedded DRAM technology for their ASIC processes.

Motorola's current presence in the flash memory market is negligible. Can the company ramp its business quickly enough to take advantage of all the capacity that is freeing up? Many other companies have similar goals, including Motorola's flash partner, Mitsubishi, yet these companies all seem to stumble over the technical difficulties of producing flash memories.

Some equipment manufacturers will be pleased to hear that this move should cause the company's capital investments to increase, as the company purchases equipment to convert its DRAM lines to logic processes. Motorola committed to stay on schedule for its capital investments at the White Oak facility, apparently the only facility in which the company was investing in DRAM capital equipment.

So is this a good move or a bad move?

Dataquest anticipates that the move from DRAMs to SRAMs, flash, and logic will be costly in the short term, with increased capital costs, the mentioned one-time charges, difficulties in finding room to expand in certain markets, and the difficulties in changing processes, especially flash memory. Despite the short-term troubles, this looks like a move in the right direction for the long term.

Wall Street analysts have made favorable comments in news reports, saying that the company had not shown a commitment to the market for several years and that the capital costs were significant enough that participation represented a poor use of this resource for a company with such a limited market share.

We are forced to wonder whether upper management at the company didn't look at the DRAM business that Motorola was doing and say, "Why are we doing this to ourselves?"

By Jim Handy and George Iwanyc

Dataquest ALERT

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Korean Manufacturers Further Cut DRAM Production

In an announcement carried by the Dow Jones News Service, South Korea's three major semiconductor makers announced on Tuesday, July 1, that they will temporarily suspend DRAM production this summer as a part of their effort to prevent further price declines.

Samsung said it will shut down the lines from July 26 to August 1. It will also stop purchases of raw and basic materials for the chips. Hyundai and LG Semicon said they will take similar actions, making the lines idle for five days.

Dataquest Perspective

Dataquest has been waiting and watching for this announcement for about a month now, and we are a little surprised at the small size of the steps taken. A five-day closure over the course of a quarter amounts only to under 6 percent of the days in the quarter, and a similar percentage of the output of these plants. Because Korean manufacturers make only about 30 percent of the world's DRAM, this amounts to a production cut of less than 2 percent of the world's capacity.

At the end of January 1997, much coverage was given to a production cutback by Korean DRAM producers, done to try to stabilize the then seemingly uncontrolled DRAM market. Although the suppliers were hazy in terms of unit cutbacks, this threat of action was enough to push the red panic button of shortages in many markets. It did result in short-term DRAM price increases in both the contract and spot market channels.

However, by the end of February, spot market prices started to drop, fueled by the combination of better-than-anticipated product availability and lower-than-expected customer demand. Likewise, buyers in the contract segment reported that their Korean suppliers had no trouble in satisfying customer upsides, regardless of size. By the middle of second quarter contract prices started to drift south, although little media attention was given to this trend! At the time of writing this article, trading of DRAM product in the spot market remained lighter than usual despite excellent availability and ever-declining prices. This would lead many to believe that, despite the cutback announced in January, there was still more product produced than demanded by customers. Many would deduce that either the production cutback was negligible or that it never really occurred. Is this announcement of a complete production freeze for five days going to be any different?

Returning to the theme of inventory, many ask where the excess product is coming from. OEMs continue to maintain their policy of minimal in-house inventory, so it is clearly not coming from this channel. This means that the excess product must originate from further back in the supply chain (that is, from the suppliers themselves or their trading companies). This would tie in with the rumors abounding of certain suppliers holding on to large inventories. This is the DRAM that they continue to produce, despite a lack of customer orders. If the rumors are to be believed, the inventory holdings are on the order of three to eight weeks. Although Dataquest doubts that suppliers are really holding up to two months of inventory across the board, it does believe that most suppliers are holding more than a week's worth of product. Thus, a production shutdown of five days in the slowest quarter for DRAM sales should have no impact on the market.

To summarize, this announcement needs to be viewed from a larger perspective. The market is currently oversupplied, the third quarter is always sluggish for sales, numerous technology transitions are occurring, prices are falling again (albeit in a controlled manner in the spot market). Thus, this should be seen as one more step, with many more to follow, by manufacturers to try to stabilize the DRAM market.

By Jim Handy and Evelyn Cronin

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An End to DRAM Antidumping Legislation in Europe

After three months of equivocating, the European Union (EU) is to lift the DRAM antidumping legislation currently imposed on Japanese and Korean vendors.

On March 10, 1997, the EU announced the phased reintroduction of DRAM antidumping legislation after a period of suspension. However, Dataquest understands that, in a U-turn, the EU will announce the lifting of its legislation on June 25, 1997, when its antidumping committee next convenes. At that meeting, nevertheless, the European Electronic Components Association (EECA) is expected to propose that the EU continue to demand a price undertaking from Korean and Japanese DRAM manufacturers, citing the European disclosure document of March 18, 1997, that confirmed a threat of further commercial damage to the European DRAM market because of DRAM dumping in Europe.

At the same time as the EECA's representations, however, the Korean and Japanese manufacturers will offer to commit themselves to a voluntary price-monitoring framework. This framework is thought likely to involve an industry-to-industry "gentlemen's" agreement among the various trade bodies and industry associations representing the interested parties. The EECA considers it inappropriate for the European Commission (EC) to recommend such industry agreements, hence the Association's request for a continuation of the current DRAM legislation in Europe. Nevertheless, Dataquest understands that no opposition to the joint Japanese/Korean proposal is anticipated from any individual EU member state, so the EU antidumping committee will recommend acceptance of this proposal to the EC, which then will formally ratify the decision. Antidumping measures could be lifted officially by August 1, 1997.

Dataquest Perspective

It would be harsh to suggest that this decision by the EU acknowledges the failure of its DRAM reference pricing measures in Europe. In fact, DRAM vendors themselves pulled back from a prolonged DRAM bloodbath in the second half of 1996 by regulating production levels when it became obvious that the industry was experiencing global DRAM oversupply. This action caused DRAM prices to rise from less than $4 per megabyte to nearer $5 per megabyte, effectively circumventing any European DRAM reference price. Recently, however, after several months of stability, DRAM prices have started to decline once more, and reference pricing could have started to play a role in the European market. Could this be the motivation behind the Japanese and Korean companies' move?

The EECA, which perhaps is being bullied into accepting the Japanese and Korean companies' proposal, obviously is concerned about the consequences of a lack of legislation. In the meantime, the proposed agreement will have to be taken at face value; its true worth will become apparent only when DRAM market forces inevitably drive prices down in the future.

By Richard Gordon and Edmund Gemmell

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Micron Announces Earnings—Now We Know What Happened in May

Micron Technology Inc. reported net income of $97 million on net sales of $965 million for the third quarter of fiscal year 1997, ended May 29. This compares to the reported net income of $143 million on net sales of $876 million for the second quarter of fiscal year 1997. (Micron's net income for the fiscal second quarter benefited from a $200 million-plus gain from the sale of subsidiary stock, so net income comparisons are less useful.) By contrast, net income for the third quarter of the prior fiscal year was $58 million on net sales of $771 million. Also, Micron's operating income rose to $169 million during the third quarter of fiscal 1997. The means improvement over $77 million for the second quarter of fiscal 1997 and $98 million for the third quarter of fiscal 1996.

There were two parts to a conference call between Micron and analysts on June 16, with the first part covering Micron Electronics (PC and other manufacturing) and the second part on Micron Technology (semiconductors). Overall, the Micron Electronics call seemed defensive, while the Micron Technology call was more upbeat but with some concerns. This report focuses on semiconductors, especially DRAM.

Micron revealed the following information during its earnings conference call:

- Net sales of the company's semiconductor memory products were $511 million in the third quarter of fiscal year 1997, compared to $402 million in the second quarter and $416 million in the third quarter of the prior fiscal year.
- Gross margins on sales of semiconductor memory products improved to about 49 percent in the third quarter of fiscal 1997, compared to 32 percent in the second quarter and 38 percent in the third quarter of fiscal 1996.
- Megabit production of semiconductor memory increased by 31 percent in the third quarter of fiscal 1997 over the second quarter of fiscal 1997.
- Micron's average selling price (ASP) for the fiscal third quarter was $8.25, which is a mild increase over the fiscal second quarter 1997 price. Pricing fell somewhat during the last month of the quarter. Micron's current contract price as of June 1997 is in the low-to-mid-$7 range, and its spot price is just below $7.

Dataquest Perspective

Micron's semiconductor recovery continued in the third fiscal quarter, and the company benefited from both higher DRAM ASPs and increased DRAM production. Micron continues to improve its production process through shrinks. For 16Mb DRAM, Micron currently produces about 450 gross dice per wafer, but it expects this to increase to 600 gross dice per wafer by the end of the year. For synchronous DRAM (SDRAM), gross dice per wafer is expected to be about 650 by the end of the year. Micron reports that 16Mb SDRAM yields are similar to those of extended data out (EDO) parts.

Micron is changing its image of waiting for high-volume economic returns before ramping the next DRAM transition device. Although Micron is not abandoning its business model, it will produce viable devices in the same time frame as its competitors. The results of this effort can be seen in the recent steep ramp of SDRAM in the fiscal third quarter and the start of 64Mb production in this fiscal quarter. Fiscal third quarter SDRAM production was 1.3 million units, with 1 million of that coming in the last month. Micron expects to manufacture 10 million SDRAM units in the fiscal fourth quarter. Production of 64Mb is expected to be a few hundred thousand units.

During the fiscal third quarter, Micron shifted its business away from the spot market, which accounted for 30 percent of its business. The spot market typically accounts for 40 to 50 percent of its business. Micron acknowledged some seasonal summer slowdown in DRAM demand (that is, modules). Micron noted that this slowdown did not occur last year. The company also expressed a belief that its focus on contract business will sustain it for the next several months in terms of demand and avoidance of a sharp DRAM price drop.

Two areas of concern are a growing inventory level and, as indicated, a recent DRAM price slide. Finished goods inventories grew from two or three days at the end of the fiscal second quarter—late February—to about three weeks at the end of the third fiscal quarter—late May. Although bit production grew some 31 percent, taking into account the inventory growth, Dataquest estimates that Micron's actual bit shipments to the market grew between 8 and 12 percent. As mentioned earlier, DRAM pricing softened during May 1997. Micron said that the price decline is in part to blame for the growing inventory level. Micron choose to stay away from low-priced spot market business during late May because of concern that the low spot prices would mean pressure for contract prices.

The company generates about 15,500 8-inch wafers per week using a 0.35-micron process. Effort is just starting on a 0.3-micron process. Capital spending should total just over $600 million for fiscal year 1997 and $1 billion for fiscal 1998. Near-term spending will focus on test equipment (including Lehi, Utah, fab activity) and not on extra silicon out. With wafers remaining at the level of 15,000 per week, Micron will count on improved yields and the next 16Mb shrink to grow bit production. The conservative goal for this quarter is 20 percent DRAM bit production growth.

The overall tone of the Micron Technology call was that the semiconductor business continues to improve and that the company should do all right despite lurking summer doldrums. Micron could do well quite well later this calendar year and early next year, especially if 16Mb SDRAM demand surges.

By George Iwanyc and Ron Bohn

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A Confusing Picture in DRAMs: The Oversupply that Many Call an Undersupply

Along with the most recent semiconductor forecast, Dataquest has just published an update of the *DRAM Supply/Demand Quarterly Statistics* report (DSDR-WW-MS-97Q1, April 1997), and the results of the supply and demand analysis present a confusing picture. This Dataquest Alert aims to clarify exactly what is happening in the DRAM market.

Data from Supplier Surveys

Our DRAM supply and demand outlook has changed from prior expectations largely because of a recent, abrupt change in 16Mb shipment patterns. Led most visibly by Korean-based suppliers, some DRAM companies managed, starting in February 1997, to decrease their supply of 16Mb DRAM. The suppliers managed to control 16Mb DRAM shipments more skillfully than expected. The result? The worldwide DRAM market has moved, at least for the short term, closer to supply and demand balance than originally forecast. For example, Dataquest had expected DRAM bit shipments to exceed demand by more than 5 percent during the second and third quarters of 1997. By contrast, we now expect relatively close balance between DRAM supply and demand during these quarters.

In order to control the market this way, production has had to be fine-tuned to avoid building swelling inventories. If DRAM suppliers do successfully manage 16Mb DRAM inventory levels, the market should remain relatively balanced during midyear 1997. Dataquest's latest semiconductor forecast is based on this assumption. If 16Mb DRAM inventories do not decrease during second quarter 1997, however, a large supply of 16Mb devices might flow into the market during the late second quarter or early third quarter. (The latter scenario would mean a supply and demand more consistent with our prior expectations.)

The DRAM market remains as volatile as ever, so we view today's supply and demand balance as a fragile balance. The impact of reduced 16Mb shipments varies across world regions, with sharper impact in Asia/Pacific, Japan, and Europe. The word "shortage" to date sounds more frequently in those regions than in the American region.

The recent dramatic market change has centered mostly on the so-called spot market. The large oversupply of 16Mb abruptly disappeared from the spot market by the end of February 1997—with concomitant strong upward pressure on spot pricing. Highlighting the turbulent nature of the market at the time of writing this article, 16Mb DRAM spot market prices have decreased.

A Convergence of Pricing

The easiest way to frame the current "shortage " pricing trend is to rank DRAM purchasers or sales channels into three tiers. At the bottom is the spot market, at the top are OEM contracts (with top-tier system manufacturers), and sandwiched somewhere in the middle are "contract" purchases made by module manufacturers. We use the term "contract" with caution, as these agreements often bear little resemblance to the OEM version. The former concentrates almost exclusively on the lowest buying price, the latter on reducing total cost of ownership. The former is short-term gain oriented, the latter long-term forward looking. The three tiers can be characterized by three words: stability (the OEM tier), volatility (the module manufacturers), and opportunism (the spot market).

Generally, the OEM tier has priority in the event of new product releases—allocation situations, among others. Also, most memory suppliers aim to ship the majority of DRAM through this channel. The OEM channel leads in terms of technology adoption and implementation, while the module manufacturers tend to lag somewhat. The spot market just redistributes whatever is available.

At the end of 1996, spot market buying prices were considerably lower than OEM prices. Many vendors used the spot market as a product redistribution channel, causing pricing and availability to remain excellent. However, by the beginning of February, it became clear that certain suppliers were consciously de-emphasizing the spot market. Deliberately, product was no longer sold in that channel, and the desired affect was achieved. Almost overnight, availability reduced dramatically, and prices started to soar. It would appear that the spot market had dried up as a repository for cheap product.

At almost the same time, Dataquest began to hear of price rises from the module channel. The memory suppliers began to impose pricing structures resembling the OEM segment on the module manufacturers channel.

So the middle-tier (the module manufacturers) prices are rising to meet the prices seen in the major OEM contracts, and, because of rising spot-market prices, these companies are forced either to pay up or take their business elsewhere.

Usually, one of the characteristics of an undersupplied DRAM market is that spot market DRAM prices are consistently higher than contract prices. Even though this is occurring at the moment, Dataquest does not believe that it symbolizes an allocation or undersupplied market. Supplier production cutbacks (whether fact or fiction) have created this situation, not increased user demand. This is the crucial point. There continues to be more than enough DRAM production capacity to meet supply.

It is clear that the suppliers' moves have been directed at the less stable sales segments, namely the spot market and the module manufacturers. These channels remain volatile, and it takes little for prices to come down (as was seen in mid-April when a number of sources deposited 16Mb product in the channel—prices plummeted by up to 20 percent over two days). Some brave companies are beginning to try to increase OEM contract pricing, but the reasons are less straightforward and are linked to synchronous DRAM release plans and 16Mb-to-64Mb migration, among other reasons. It is also worth emphasizing that, while prices may rise, they are nowhere near prices of a year ago.

An Abundance of Capacity

The definition of "supply" that Dataquest uses in the *DRAM Supply/Demand Quarterly Statistics* report is not to be confused with actual DRAM manufacturing capacity—it is manufacturers' shipment forecasts. DRAM supplier shipments, production, and capacity are three different numbers today. There is plenty of DRAM capacity that could be brought on line at a moment's notice. For this reason, we are referring to today's balance as "fragile."

From a capacity perspective, Dataquest estimates that we are in 20 to 25 percent overcapacity today, lessening to an overcapacity of 10 to 15 percent by year-end 1997. We expect to be passing over equilibrium by the fourth quarter of 1998 and entering undercapacity in 1999. Tight supply should last 15 to 24 months before overcapacity re-emerges later in 2000. This scenario is reflected in Dataquest's current capital spending forecast.

Equipment and material companies should be aware that today's fragile balance will not create a new need for capital spending. Although it is true that some capacity is trying to be redirected to other processes and devices, this is a slow process. Further, through a pricing survey just completed in the foundry industry and through discussions with companies, we are starting to hear confirmation of oversupply in the logic sector, even at the leading-edge 0.35-micron technology.

For further information and discussion on industry capacity and capital spending plans, please refer to *Year-End 1996 Forecast: Capital Spending, Wafer Fab Equipment, and Silicon Markets* (SEMM-WW-MT-9603, March 17, 1997). For information from the foundry area, please refer to several reports available from the Semiconductor Contract Manufacturing Services Worldwide program on supply and demand and pricing trends.

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Pentium II: Intel's Modular Approach to Restraining Cache SRAM Competition

Now that the Pentium II has been officially announced, Dataquest can discuss what we have found from Intel and others about the processor. More important, we can discuss the effects that the Pentium II will have on the cache SRAM market. In brief, the approach Intel is taking should raise cache SRAM average selling prices (ASPs) for a few suppliers but will harm those that count most on the PC cache SRAM market.

Intel's Modular Processors

The Pentium II is a relatively large module (although, according to Intel, the proper name is "single-edge contact cartridge," or SECC) containing the CPU and a secondary cache for a PC or other high-end x86 system. The processor is an extension of the Pentium Pro, which, according to Intel, was not a multichip module.

The Pentium II is not the first processor module Intel has pioneered. Earlier this year, the company introduced a module aimed at the notebook PC market. Both of these assemblies contain two SRAM chips in addition to the processor and some other logic. The approach is a middle ground between the external caches that have been used in PCs exclusively, so far, and the multichip module used in the Pentium Pro processor. The approach is sound from a technical standpoint, as current interface and test standards limit the maximum bandwidth of chip interconnects unless a modular approach is used.

The Chosen Few

As does any major consumer of ICs, Intel appears to have decided to limit the number of sources it uses for its chips. Rumors indicate that only three or four sources will be used.

A rumor that circulated last year was that Intel was guided in making this decision by input from major SRAM manufacturers. According to this rumor, these manufacturers told Intel that they would cease supporting cache chips for Intel processors because the roots of the current cache SRAM oversupply appeared to lead back to Intel. When faced with the possibility that Intel modules would be supported with SRAMs from second-tier and third-tier manufacturers, Intel agreed to severely limit the number of sources it would use, cutting competition and assuring participants of at least a small profit.

Although we do not have an official list of the vendors Intel has chosen, we do know that:

- Intel showed off a Pentium II board containing Mitsubishi SRAMs.
- Intel has shown portable modules based on NEC SRAMs.
- Dataquest would guess that other suppliers might include Hitachi, Samsung, Sony, and Motorola.

Intel's normal strategy is to ramp new processors quickly in order to deter attempts by its competitors to catch up. Dataquest's processor forecast shows slot 1 (Pentium II) and mobile P6 processors to account for the majority of processors shipped in 1998. This indicates that there will be a rapid displacement of those processors that can use cache procured through independent sources of supply.

Dataquest Perspective

This promises to be a difficult time for many SRAM vendors. At one point, Dataquest counted 45 manufacturers of PC cache SRAM chips. Many of these vendors are smaller fabless companies that took advantage of the low barriers to entry in the market and the lack of vendor loyalty at many PC OEMs. Many of these companies sold nothing except SRAM chips for the PC cache market.

Soon this market will disappear, and these vendors will be forced into markets where sales are based on more than simply price and availability or into markets for which the barriers to entry are not quite so low. Assuming that the number of suppliers to the PC cache SRAM market will gradually erode to four, the other 41 or so suppliers have a lot of planning to do in order to stay in business.

By Jim Handy

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Flash Companies Have Slow First Quarter

The major flash companies recently released financial results that show a slowing trend in the flash memory market. Except for Advanced Micro Devices, all of the selected companies had lower revenue for first quarter 1997 than fourth quarter 1996. There is a glimmer of hope in the future with product introductions just happening now that should give better pricing strength.

Intel

Intel Corporation is, of course, is the world's largest semiconductor supplier. It is also the largest flash memory vendor, but the results of this division do not affect the overall Intel numbers much. Dataquest estimates that Intel's 1996 flash revenue was about $1 billion, or an average of $250 million per quarter. Compare that to the $6,448 million in total first quarter 1997 revenue shown in Table 1 and it is clear that from a financial standpoint flash memory is not that significant to Intel. But it was important enough for the company to say in its press release that "flash memory units shipped during the quarter set a record; however, pricing pressure continued, resulting in sequentially slightly lower revenue." This is somewhat puzzling, because the company also says that it is capacity constrained (or "sold out"), which usually means pricing stability. Dataquest believes that Intel was more interested in market share than revenue and profit and was making this its priority and driving it via pricing. Perhaps its new read-while-write boot-block chip will give the company a better pricing structure now.

Table 1
Intel Quarterly Revenue and Income (Thousands of U.S. Dollars)

	Quarter Ended March 29, 1997	Quarter Ended December 28, 1996	Quarter Ended March 31, 1996
Revenue	6,448,000	6,440,000	4,644,000
Net Income	1,983,000	1,910,000	894,000

Source: Intel

AMD

Advanced Micro Devices Inc. had its overall sales grow 11 percent from fourth quarter 1996, and AMD said that "revenue growth was led by flash memories." This gave the company an unexpected profit, compared to Wall Street estimates. Intel, in contrast, had flat sequential total revenue and decreasing flash revenue. AMD discloses its sales of nonvolatile memory (NVM), shown in Table 2. Nonvolatile memory sales at AMD are mostly flash memory. Because AMD has been having trouble fielding a competitive processor to Intel, the NVM group has been the largest revenue source for AMD, making it much more important for AMD than for Intel. In first quarter 1997 and fourth quarter 1996, NVM revenue was 33 percent of AMD's total, down from 39 percent in first quarter 1996.

Table 2
AMD's Quarterly Revenue and Income (Thousands of U.S. Dollars)

	Quarter Ended March 30, 1997	Quarter Ended December 29, 1996	Quarter Ended March 31, 1996
Revenue	551,999	496,868	544,212
NVM Revenue	184,000	162,000	210,000
Net Income	12,951	-21,243	25,327

Source: AMD

Atmel

Atmel Corporation's first quarter 1997 results, as seen in Table 3, were disappointing because of "strengthening of the dollar, pricing pressure in the nonvolatile business, and delays in the qualification of our new flash products," according to the company. Atmel says that its new 49 Series flash, Data Flash, and AVR Flash Microcontrollers are now being sampled to customers. Atmel's NVM focus is mostly on lower-density flash and EEPROM devices, which have seen price erosion that was rapid in the past but is moderating now. If the new products come up as they should, cautious optimism for the future would be appropriate.

Table 3
Atmel Quarterly Revenue and Income (Thousands of U.S. Dollars)

	Quarter Ended March 31, 1997	Quarter Ended December 29, 1996	Quarter Ended March 31, 1996
Revenue	252,946	281,112	240,096
Net Income	38,738	53,644	44,909

Source: Atmel

SanDisk

SanDisk Corporation is the largest independent supplier of flash storage systems, mostly PCMCIA flash cards, using proprietary flash chips manufactured for it with foundry agreements; it is a fabless flash company. It is also making a name for itself in intellectual property licensing, as can be seen in Table 4. SanDisk is a company in transition, from the industrial/commercial sector serviced with PCMCIA to a consumer market satisfied with the CompactFlash form factor. Product revenue has been decreasing both sequentially and on a year-to-year basis. CompactFlash needs to be successful to bring sales back up, and this could be an uphill battle because its competition is the Intel/AMD Miniature Card and the

Toshiba/Samsung Solid-State Floppy Disk Card. But SanDisk *is* winning this battle, based on design-wins to date. Stay tuned, this will be an interesting story to follow.

Table 4
SanDisk Quarterly Revenue and Income (Thousands of U.S. Dollars)

	Quarter Ended March 31, 1997	Quarter Ended December 31, 1996	Quarter Ended March 31, 1996
Revenue	21,444	26,250	20,739
Royalty Revenue	3,250	4,250	1,250
Net Income	2,125	4,383	3,054

Source: SanDisk

SST

Silicon Storage Technology Inc., a fabless flash chip company, had a bad quarter. It lost $2.5 million, which is sequentially down from last quarter and a *really* big drop from a year ago. A large factor in this was a charge of about $3.2 million to reduce the carrying value of inventory to its approximate replacement cost, which, if ignored, would have given the company an operating profit. For the future, it has negotiated lower costs with its foundry partners, including one with Taiwan Semiconductor Mfg. Co. that will give it 0.5-micron lithographic capability now and 0.35-micron and smaller further down the road. Another company story to keep a watch on.

Table 5
SST Quarterly Revenue and Income (Thousands of U.S. Dollars)

	Quarter Ended March 31, 1997	Quarter Ended December 31, 1996	Quarter Ended March 31, 1996
Revenue	17,092	23,491	23,023
Net Income	-2,519	737	4,199

Source: SST

By Bruce Bonner

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Six SRAM Companies Report Mixed Quarterly Sales/Profits

Profitability Depends on Focus Markets

While the DRAM market continues to absorb the bulk of the world's attention, owing mainly to its superior size, the SRAM market had a much worse 1996, and some companies appear to be on a recovery track, while others are still suffering the effects of a very dramatic price decrease. This Dataquest Alert compares the most recent quarterly results of six publicly traded SRAM manufacturers and compares the winners' strategies against the losers'. In general, companies that depended highly on cache memories did poorly, and companies that had portfolios more focused on telecommunications were able to move into marginal profitability.

The Winners: Cypress and IDT

Two companies that posted profits in the first calendar quarter were Integrated Device Technology Inc. and Cypress Semiconductor Corporation. What differentiates these two companies? Both focus on differentiated SRAMs for use mainly in telecommunications applications. IDT, in fact, has such a focus on telecommunications that the company has recently decided to split its market definition of telecom into two parts: telecom and datacom, which together accounted for 51 percent of the company's most recent quarter's revenue. Cypress announced that the company had made first revenue shipments of a proprietary first in/first out (FIFO, mainly used in telecom applications) and a data separator IC, although the company is still heavily invested in PC cache chips, as is evidenced by its showcase HyperCache chipset and first revenue shipments of the ill-fated 32Kx32 SRAM.

Cypress posted a net income of nearly $5 million, up 280 percent from the prior quarter, on sales of $126 million, up 11.4 percent from last quarter's revenue of $113.1 million. Despite lower average selling prices in the March quarter, the company says that it increased unit volume and improved its gross margin by 1 percent, from the 33.5 percent reported last quarter to 34.6 percent. IDT's sales rose 9.2 percent, from $131 million the prior quarter to $143 million in the first quarter, and moved from a $43 million net loss in the prior quarter to a $2 million net income in the quarter ended March 30.

The Losers: Alliance, ISSI, Logic Devices, and Paradigm

All of the companies that lost money are far more reliant on the cache memory market than on the telecommunications market. In general, this means that the companies make fast 256K and 1Mb SRAMs, mainly in the 32Kx8, 128Kx8, and 32Kx32 configurations. Paradigm Technology Inc. differs a little in that the company specialized in a 32Kx18 synchronous cache SRAM that commanded extremely high average selling prices (over $25) until the cheap 32Kx32 came along. This $3 alternative was too attractive to pass up for many system designers, even if system throughput suffered a bit when the x32 part was used. Paradigm's market suddenly shifted to the cheaper alternative, and this has been a difficult obstacle to overcome.

All these manufacturers performed extremely well during the PC cache SRAM shortage of 1995, but when the serious 32Kx32 oversupply started late in that year, those companies that were highly focused on the PC cache SRAM market lost much of what they had.

Alliance Semiconductor Corporation increased sales by nearly 20 percent, from $25.2 million in the December quarter to $30.1 million last quarter, but still posted a net loss of $2.8 million, about double the prior quarter's $1.3 million net loss. Alliance has tried to get away from its overreliance on the PC cache SRAM market by expanding into DRAMs. Now 60 percent of its revenue comes from DRAMs, but both markets are oversupplied, and the company is still highly reliant on the PC market for its sales. Alliance is making no apologies and sees the loss this quarter as a step toward profitability in the next quarter.

Integrated Silicon Solution Inc. had a modest revenue increase—last quarter's revenue was $25.8 million, up 9 percent from the prior quarter's revenue of $23.6 million, trimming losses to $1.5 million from a loss of $1.7 million in the prior quarter. Although Paradigm Technology's revenue for the first quarter totaled $3.6 million, 16 percent higher than the $3.1 million the company achieved in the previous quarter, the company still posted a net loss of $2.6 million. Paradigm moved from being a fab-owning company to a fabless company in the prior quarter, a move that caused the company to post a $13 million loss in that quarter. Although this trimmed its operating expenses, it makes it tough to compare this quarter's loss to that of the prior quarter.

From a revenue standpoint, Logic Devices Inc. was the worst-hit company of the lot, with revenue of $2.0 million, down a whopping 40 percent from the prior quarter's $3.4 million in revenue. LDI ended up posting a 0.3 million loss for the quarter, which it attributed to a number of causes, including order cancellations, tooling costs, and difficulties in ramping down its foundry commitments. We should note that the most recently posted earnings for LDI were those of the December quarter, which the company announced nearly three months after the quarter's close.

Dataquest Perspective

Most companies take pains to assure that they are not overreliant on one particular customer, geography, technology, or end market. The quarterly financial results examined here attest well to that point. Companies overly vested in the PC cache SRAM market had a poor quarter, whereas those with a more diverse product offering were able to come back into profitability. We will look at these same companies next quarter to see what changes management has made to improve their situation.

By Jim Handy and George Iwanyc

Dataquest ALERT

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Intel Teaches Flash the Three Rs

Intel Corporation has introduced a new flash memory that uses a hybrid hardware-plus-software approach to allow concurrent reading and writing in a single flash chip. The notable features of the new Smart 3 Advanced Boot Block chips are:

- Faster "write suspend" timing
- Development tools that allow near simultaneous read and write operation
- Improved blocking organization
- 1.8V interface compatibility with 2.7V minimum supply voltage
- Read access time of 120ns
- 4 Mb, 8 Mb, and 16Mb densities
- 48-lead TSOP and micro-BGA packaging

Dataquest Perspective

This introduction continues the saga of the Intel-Advanced Micro Devices Inc. voltage slugfest. AMD recently brought out a 2.2V part (read and write) that has a 150ns read access speed. Now Intel responds with a part that is compatible with 1.8V but still requires 2.7V, which gives it a better access time of 120ns. Both companies have high-volume kickoff customers for their parts, which validates a market demand and need for their respective approaches. Obviously there is no one "right" answer here. Also, we can look forward to an AMD rejoinder in the future.

The reason that these parts can coexist in the market is that their customers, digital cellular handsets and two-way pagers, are desperate for system voltage reductions. Lowering system voltage extends the run time and shrinks the size of their batteries, and they will accept anything that helps. Also, these systems are so full of "bleeding-edge" technology anyway that a sole-source flash chip is not a large problem. The AMD part fills the need of a system that uses a slow processor, so the reduction to 2.2V is all positive. The Intel part keeps the access time down to 120ns while allowing the rest of the digital logic to go to 1.8V, which will make other designers happy. Dataquest expects a wide range of vendors to eventually have

1.8V-only parts (probably with tunneling erase, as opposed to the current hot electron technique used in NOR flash); this introduction is on the road to the 1.8V holy grail.

But the bigger news here is the concurrent read-while-write solution. Bill Howe, the vice president and general manager of the Intel flash division, says his strategy is "do not solve something in hardware [the flash chip] when you can do it in software." While this is not a new idea, its application to memory is novel. It also avoids a 10-to-12 percent cost increase for duplicate control circuitry in a hardware-only implementation. But why does someone want a design like this anyway?

The Intel product will be attractive to portable equipment manufacturers that need to store both a small amount of data *and* a larger amount of code that might need to be updated in the future. Today, solving this puzzle requires two chips: a flash memory and an EEPROM. With the Intel hardware-plus-software approach, the EEPROM can be removed from both the design and the cost of the product. Intel will not charge extra for this feature, but all vendors *do* have a price adder for the lowest-voltage offerings. So Intel is teaching flash memory the three Rs (reading, writing, and arithmetic). Its strategy is to allow a flash chip to read and write, with the software doing the arithmetic. Dataquest believes this is a well-thought-out and well-executed product offering that includes some great development tools that will allow it to compete effectively with hardware-only solutions.

By Bruce Bonner

Dataquest ALERT

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Intel Reenters DRAM Market—NOT!

Intel Corporation and Samsung Electronics Co. announced yesterday that Intel is making an unspecified size equity investment in Samsung Electronics' $1.3 billion advanced semiconductor memory fabrication plant now under construction in Austin, Texas. When it begins operation later this year, it will be able to produce 25,000 8-inch (200mm) wafers per month with a 0.35µm lithography. The fab is capable of building either 16Mb or 64Mb dynamic random access memory (DRAM) chips.

Intel executive vice president Dr. Gerhard Parker said in a press release, "Intel believes that an adequate supply of memory components that maximize the system performance of the PC platform is important for the future growth of the PC industry. ... We have taken an equity position in Samsung's advanced memory manufacturing plant to help assure a stable supply of these advanced memory products."

In an interview with Dataquest, an Intel spokesman characterized the investment as a "minority position" in the plant, meaning it is less than $650 million. He also said that Intel has a "right, but not obligation" to purchase the product, which will be 64Mb packaged devices.

Dataquest Perspective

Unless you just got back from a year-long vacation on Mars, you know that there is no shortage of DRAM manufacturing capacity in the world this year or next, and so you have to wonder why Intel made any investment in this area. Dataquest believes that Intel did it to lock in a supply of synchronous DRAM for the second half of 1997. Intel fears that the performance of its new Pentium (P55C) and P6 (Klamath) designs with MMX may be constrained by memory bandwidth, and the incremental performance of 66 MHz SDRAM over 66 MHz EDO may be needed to unlock these processors' performance potential. There's little incentive for end users to upgrade if the new machines do not run any faster than the old ones, and limits on memory bandwidth might create just such a situation. It doesn't make any sense for Intel to re-engineer the CPU, core logic and motherboard, and then to discover there's not enough SDRAM to go around, just when it's needed to maintain the flow of system-level products to end users. So, if an SDRAM shortage were to emerge, Intel (and its friends) want to be first in line for limited supplies.

A recent Dataquest analysis of the DRAM market came to the conclusion that the PC market will quickly switch to SDRAM from EDO DRAM in the second half of 1997. This will cause a serious shortage of synchronous devices and a serious oversupply of EDO in the fourth quarter of 1997 and the first quarter of 1998. Currently Samsung, NEC, Toshiba, and Hitachi are shipping SDRAM in volume.

Of course, Intel could have solved this problem by ordering huge quantities of SDRAM at current prices for delivery later in the year. In fact, this was precisely the path Intel followed in 1995 when it feared an EDO shortage. Intel locked in a good position in 4Mb EDO DRAMS at only $13.50 per chip. The shortage never materialized, and Intel took a bath when it unloaded its position at $10.00 per chip, resulting in a $100 million writedown in the fourth quarter of 1995. The new arrangement with Samsung basically provides an option on all these devices, but Intel won't have to exercise the option if the market doesn't develop in the manner Intel anticipates today.

By Bruce Bonner and Nathan Brookwood

January 16, 1997 MEMORIES Preliminary Market Share TELEBRIEFING SCRIPT

Welcome to Dataquest's Memories Preliminary Market Share Telebriefing. In the room are representatives of the Memories Worldwide service, Bruce Bonner, George Iwanyc, and myself, Dataquest's Semiconductor Supply and Pricing Service, Mark Giudici and Evelyn Cronin, and Clark Fuhs of Dataquest's Semiconductor Equipment, Materials and Manufacturing Service.

We will be recording this call for possible later transcription. To protect your identity, the operator has given each participant an identification number. This number is the only way you will be identified during the call. We will proceed according to the following format. After a review of Dataquest's 1996 Preliminary Market Share rankings and a short discussion about the reasons we believe that each company has moved from their 1995 position, which should last approximately 20 minutes, the floor will be opened to questions. Follow the keystroke sequence the operator will give you to get in queue to ask a question. When your number is called, you will be placed on the conference line, and you may ask your question and receive your answer. Due to the high number of anticipated questions, we ask that each person limit themselves to a single question after which we will proceed to the next caller. And now to our Preliminary Market Share numbers.

##

Dataquest's ranking of Semiconductor manufacturers occurs in two phases: Preliminary and Final. Our Preliminary Market Share exercise is a "First Estimate" at the size of the different semiconductor markets, based upon surveys from manufacturers tempered with a modicum of sanity checks. The surveys were performed in November, so no companies were yet aware of their year-end numbers.

Over the course of the following three months, Dataquest will be reconciling the numbers we collect from semiconductor suppliers with numerous inputs from other industry barometers, suppliers' own financial statements, competitive information, trend analysis, and a myriad of other sources. These new numbers, our "Scrubbed" estimates, will then be taken back to the manufacturers for their comments, and, after a final pass, will be released as our Final Market Share numbers in May.

The data we will share in this teleconference is that "First Guess" - our preliminary market share. We expect to see certain changes occur when our final version is released, up to, and including, changes in rank. Still, we have heard from most of our clients that they would rather have a rough estimate early in the year instead of having to wait until we finalize our market share statistics. This is why we are releasing preliminary numbers this week.

By Dataquest's preliminary estimates, the 1996 MOS memory market dropped more than 32 percent from 1995 revenues, an $18 billion drop from 1995's $55.3 billion to 1996's total market of $37.3 billion. Dataquest's preliminary estimate of the 1996 DRAM market is $25.6 billion, down from $42.2 billion in 1995. DRAM revenue growth had been the major factor in the memory market's revenue upswing from 1992 through 1995, but as DRAM revenue declined in 1996 by nearly 40 percent, with average selling prices dropping by three-fourths, the entire MOS memory market followed it down. Even excluding DRAM, other factors like a severe SRAM oversupply and dramatically reduced mask ROM demand made the non-DRAM 1996 memory market decline by 10 percent, even in spite of a 46 percent increase in the size of the flash memory market. This represents a major change from the past three years of growth that exceeded 40 percent per year. Our preliminary estimate is that the SRAM Market in 1996 was $4.7 billion down 24% from 1995's $6.3 billion. Nonvolatile memories are estimated to have been $6.5 billion last year, a 4% increase from 1995's $6.2 billion. This, added together with our "Other MOS

Memories" category, shows a total MOS memory market for 1996 of $37.3 billion, down 33% from 1995's $55.3 billion.

DRAM is where the biggest changes occurred. The highly profitable 1995 DRAM market had a relatively measured descent over the whole of 1996. When we compare the drop in DRAM prices to the drop in PC cache SRAM prices, the DRAM drop is considerably slower, even though it was extremely painful for suppliers. The 40% drop in revenues of the overall market was matched by some suppliers, beaten by others, and avoided to a degree by the rest. In general, there was very little change to the ranking of DRAM suppliers from 1995 to 1996, with the only exception being that LG Semicon revenues dropped less than the company's nearest competitors, Toshiba and TI, allowing LG to skip ahead of thost two companies to move from Number 7 in 1995 to number 5 in 1996. Here is the preliminary 1996 DRAM market Ranking for the top-ten DRAM manufacturers:

1996 Rank	
1	Samsung
2	NEC
3	Hitachi
4	Hyundai
5	LG Semicon
6	Toshiba
7	Texas Instruments
8	Micron Technology
9	Mitsubishi
10	Fujitsu

Moving on to SRAM, the PC cache SRAM segment, the largest identifiable segment in the widely scattered SRAM market, lurched suddenly from a 1995 shortage to a late-1995/Q1 1996 oversupply of unheralded proportions. The result was a sudden drop of 15ns 3-Volt 32Kx8 prices from $2.50 to as low as $0.60. 32Kx32s, which until November of 1995 maintained prices just below $30 dropped to prices just above $3. The effect of this drop was to dramatically reduce the sales of all of those SRAM firms who heavily depended on PC cache SRAMs for their revenues. Prices for other SRAMs, like the large slow SRAM market and the "extremely high-speed SRAM" niche market, were far more stable, and followed more typical price declines. Samsung and Hitachi, by Dataquest's preliminary 1996 estimates, maintained their first-rank and second-rank positions, respectively. Both of these firms are broad-range SRAM suppliers. The lower eight firms in the top ten SRAM suppliers list were in the top-ten list for 1995, but their positions were dramatically shuffled. The following is Dataquest's preliminary rank of the top ten SRAM manufacturers for 1996:

1996 Rank	
1	Samsung
2	Hitachi
3	Toshiba
4	NEC
5	Motorola
6	Mitsubishi
7	Cypress Semiconductor
8	Sony
9	Integrated Device Technology
10	Winbond

For this telebriefing, we will examine nonvolatile memories as a whole, since the entire nonvolatile memory market is approximately the same size as the SRAM market. Interestingly enough, the top six suppliers of nonvolatile memories are also the top six suppliers of flash memories. This attests to the strength of the flash memory market and to that market's growing importance to all of nonvolatile memories. Intel maintained the first-place ranking in the nonvolatile memory market for the second year in a row even though flash memory is the only nonvolatile memory technology Intel makes. Although the top six companies' flash memory ranking is usually different from their nonvolatile memory ranking, this is simply because many of these companies have other nonvolatile revenue streams in the mask ROM, EPROM, and EEPROM markets.

By Dataquest's preliminary analysis, the top ten nonvolatile memories manufacturers for 1996 were:

1996 Rank	
1	Intel
2	SGS-Thomson
3	Advanced Micro Devices
4	Atmel
5	Sharp
6	Fujitsu
7	Macronix
8	NEC
9	Texas Instruments
10	Samsung

Although Sharp had a dramatic loss of business in the mask ROM market, which the company continues to dominate, Sharp's flash sales increased, keeping the company in the top five nonvolatile memory suppliers worldwide. SGS-Thomson expanded all of its nonvolatile memory businesses (EPROM, EEPROM, and flash) to move ahead to the No. 2 position from 1995's No. 4 rank. A significant drop in Toshiba's mask ROM revenue moved that company out of the top 10 to make way for Samsung, a more stable contributor to the mask ROM market and a new entrant to the flash memory market.

Please recall that these are preliminary numbers, and that there may be changes in ranking when our final market share numbers are announced in the second quarter.

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This concludes our introductory statement. We will now accept questions from our callers.

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Dataquest's Preliminary 1996 Memories Market Share: Trouble on Many Fronts

Dataquest's preliminary compilation of the 1996 MOS memory market shows more than a 32 percent revenue decline when compared to 1995 revenue; the result is an $18 billion revenue drop to a total market of $37.3 billion. DRAM revenue growth had been the major factor in the memory market's revenue upswing from 1993 through 1995, but as DRAM revenue declined in 1996 by nearly 40 percent, with average selling prices dropping by three-fourths, the entire MOS memory market followed it down. Even excluding DRAM, other factors like a severe SRAM oversupply and dramatically reduced mask ROM demand made the non-DRAM 1996 memory market decline by 10 percent, even in spite of a 46 percent increase in the size of the flash memory market. This represents a major change from the past three years of growth that exceeded 40 percent per year.

Table 1 shows Dataquest's preliminary 1996 memory market sizing for DRAM, SRAM, and nonvolatile memories worldwide.

Table 1
1995 and 1996 Memory Markets—Preliminary (Millions of U.S. Dollars)

Category	1995 Revenue	Preliminary 1996 Revenue	1995-1996 Growth (%)
DRAM	42,234	25,599	-39
SRAM	6,257	4,729	-24
Nonvolatile	6,239	6,459	4
Other MOS Memory	534	523	-2
Total MOS Memory	55,264	37,310	-33

Source: Dataquest (January 1997)

Top 10 DRAM Suppliers of 1996

Dataquest's preliminary ranking of the top 10 worldwide suppliers of DRAMs in 1996 is shown in Table 2. Samsung maintained its No. 1 position, mostly because of the company's 4 percent superiority over next-ranked NEC. The top four manufacturers have retained the same rankings as last year, despite the troubles in the market. Our preliminary results show LG Semicon moving ahead two positions to displace Toshiba and Texas Instruments. This appears to be a benefit of reduced consumption by Hitachi of products manufactured under the LG Semicon/Hitachi manufacturing alliance that Hitachi declined to market this year. Mitsubishi and Fujitsu maintained their No. 9 and No. 10 positions, respectively.

Table 2
Preliminary 1996 Rankings and Market Shares for the Top 10 DRAM Suppliers

1996 Rank	1995 Rank		Preliminary 1996 Market Share (%)
1	1	Samsung	17
2	2	NEC	13
3	3	Hitachi	10
4	4	Hyundai	8
5	7	LG Semicon	7
6	5	Toshiba	7
7	6	Texas Instruments	7
8	8	Micron Technology	6
9	9	Mitsubishi	5
10	10	Fujitsu	5

Source: Dataquest (January 1997)

1996's Top 10 SRAM Suppliers

Dataquest's preliminary 1996 ranking of the top 10 worldwide suppliers of SRAMs is shown in Table 3. As with DRAMs, Samsung maintained its No. 1 position and grew revenue in a market in which most suppliers' revenue declined. Hitachi, which had been SRAM market leader for every year that Dataquest studied the market until displaced by Samsung in 1995, maintained its No. 2 ranking by more than three percentage points of market share above next-ranked Toshiba. Below Hitachi was considerable turbulence, yet all of the top 10 manufacturers from 1995 are on our preliminary top 10 list for 1996.

Nonvolatile Memories

In nonvolatile memories, Dataquest's preliminary ranking of the top 10 worldwide suppliers is shown in Table 4. The top six suppliers of nonvolatile memories are also the top six suppliers of flash memories, although the companies' flash memory ranking is different, owing to these companies' varying contributions to the mask ROM, EPROM, and EEPROM markets. This attests to the strength of the flash memory market and to that market's growing importance to all of nonvolatile memories. More important, Intel, whose sole nonvolatile memory offering is flash memory, maintained the first-place ranking in the nonvolatile memory market for the second year in a row. Although Sharp had a dramatic loss of business in the mask ROM market, which the company continues to dominate, Sharp's flash sales increased, keeping the company in the top five nonvolatile memory suppliers worldwide. SGS-Thomson expanded all of its nonvolatile memory businesses (EPROM, EEPROM, and flash) to move ahead to the No. 2 position from 1995's No. 4 rank. A significant drop in Toshiba's mask ROM revenue moved that company out of the top 10 to make way for Samsung, a more stable contributor to the mask ROM market and a new entrant to the flash memory market.

Table 3
Preliminary 1996 Rankings and Market Shares for the Top 10 SRAM Suppliers

1996 Rank	1995 Rank		Preliminary 1996 Market Share (%)
1	1	Samsung	15
2	2	Hitachi	13
3	6	Toshiba	10
4	5	NEC	9
5	3	Motorola	8
6	8	Mitsubishi	6
7	9	Cypress Semiconductor	5
8	4	Sony	5
9	10	Integrated Device Technology	4
10	7	Winbond	3

Source: Dataquest (January 1997)

Table 4
Preliminary 1996 Rankings and Market Shares for the Top 10 Nonvolatile Memory Suppliers

1996 Rank	1995 Rank		Preliminary 1996 Market Share (%)
1	1	Intel	15
2	4	SGS-Thomson	12
3	3	Advanced Micro Devices	11
4	5	Atmel	11
5	2	Sharp	8
6	8	Fujitsu	7
7	10	Macronix	5
8	7	NEC	4
9	9	Texas Instruments	4
10	11	Samsung	4

Source: Dataquest (January 1997)

It should be noted that these are preliminary revenue estimates and rankings. Dataquest will finalize the market share and product data during the second quarter of 1997, at which time we will issue more detailed data.
By Jim Handy, Memories Worldwide

Dataquest

Perspective

Memories Worldwide

Market Analysis

Dataquest's Tactical Memories Newsletter —Vol. II, No. 26

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Korea's DRAM Costs: What a Difference a Low Won Makes

With the significant depreciation of the Korean won against other world currencies, there has been concern about the effect of the won's slide on worldwide DRAM prices. We at Dataquest find that there is a misconception about the magnitude of the effect of the depreciation of the won on the DRAM. Many think that prices will not be affected significantly by the won's recent 50 percent devaluation against the dollar. This is as far from the truth as it could be. The won's devaluation should be expected to have a phenomenal near-term effect on the asking price for a 16Mb DRAM in today's oversupplied market. Figure 1 shows a DRAM cost breakdown.

Current DRAM prices are cost-based. This means that most manufacturers are selling their DRAMs at the minimum prices they can justify. The bottom price of DRAM sales to the United States and Europe is limited by antidumping legislation—in order to protect local suppliers, DRAMs are not allowed to be sold into these markets at prices below their cost to manufacture.

The natural question to ask, then, is what effect the falling won will have on the cost to manufacture a 16Mb DRAM. The following is an estimate of the percentage breakdown of these costs, along with each components'

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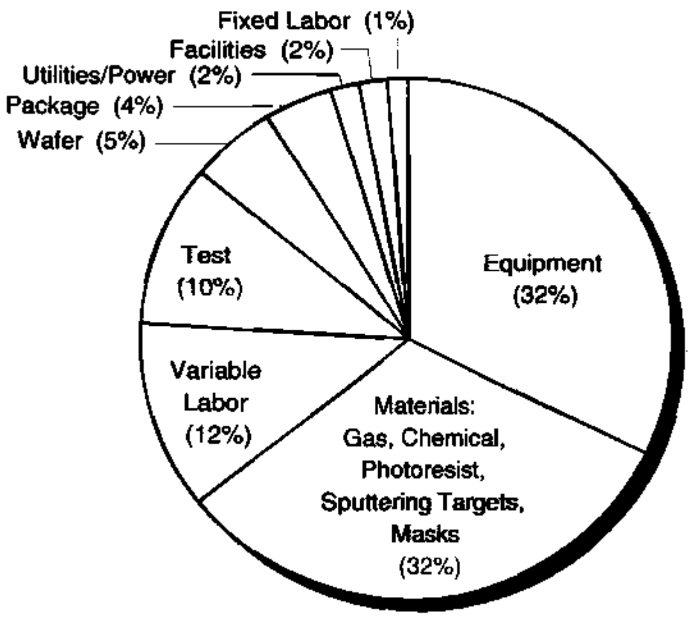
sensitivity to the exchange rate. Transactions based in won are likely to become extremely inexpensive to the world market, while Korean transactions carried out in foreign currencies are likely to move very little.

- Equipment: Equipment costs account for about 32 percent of the cost of a DRAM chip. Although some in the United States believe that Korean DRAM manufacturers' cost of equipment is realized in foreign currency, this is only true in the rare cases in which an equipment manufacturer leases its product to the fab. In most cases, the capital equipment is purchased with a bank loan. Many of these loans are guaranteed by the Korean government and are drawn on Korean banks in won.
- Materials: Materials consume about another one-third of the cost of the DRAM. They can be broken down into several components, the majority of which are won-based, thus likely to impact the foreign cost of a DRAM when translated to a foreign currency:
    - Gas: Gases tend to be locally produced, either through an on-site plant or at the chemical manufacturer. Because very little in the way of bulk gases is likely to be imported, these transactions tend to be in local currency. Only a few, more exotic specialty gases are imported.
    - Chemicals: With the exception of certain exotic chemicals, Dataquest finds that the chemicals used in Korean wafer fabs are from the chemical-producing arms of Korean conglomerates. Once again, these would be purchased in won, and prices would not fluctuate much during this sort of devaluation.

Figure 1
Breakdown of Costs of a DRAM IC



Source: Dataquest (December 1997)

- Photoresist: Photoresist is one material likely to be purchased from a foreign supplier, such as Shipley, TOK, Hoechst, or others. These prices would increase in a devaluation of local currency.
- Sputtering targets: A high percentage of sputtering targets is produced by non-Korean suppliers such as Tosoh and MRC. These transactions are most likely to be conducted in foreign currencies at depreciated won exchange rates.
- Masks: There are mask shops in Korea that are probably used by all Korean manufacturers. Further, some of the large manufacturers have captive maskmaking operations. Payment to these shops would be in won; however, the raw glass used to make these masks will be procured from foreign suppliers using foreign currencies.

- Labor: The cost of labor (fixed plus variable) usually accounts for only 13 percent of the overall processing costs of the DRAM.
- Test: The 10 percent or so of a DRAM's cost involved in test follows much of what has been said here about equipment and labor. Workers are paid in won. Bank loans are made in won. These costs will follow the depreciation of the won against foreign currencies.
- Wafers: Raw wafers are produced in Korea for LG Semicon by LG Siltron and for Samsung by Posco-Huls. Wafer cost accounts for about 5 percent of the cost of a DRAM. The only Korean manufacturer that would need to purchase a significant portion of its raw wafers from a foreign source would be Hyundai. With the exception of Hyundai, this cost is likely to fall with the falling won.
- Packaging/assembly: The 4 percent attributed in Figure 1 to packaging is a particular strength of Korean companies. As such, it is a business that is most likely to be conducted in won, and packaging costs should fall with the fall of the won.
- Utilities/power and facilities: Combined, these two categories account for about 4 percent of the cost to manufacture a DRAM. All of these are won-based in Korea and will fall with the falling won exchange rate.

There is some issue about the equipment costs. Some point out that any increases in capital expenditure will need to be transacted in dollars or yen. Although this is true, capital expenditure made in the current year is generally slated for use in production one or two years in the future. This means that any equipment being used to produce today's DRAMs was purchased before the won's slide.

Even so, there is some question of how the equipment is carried on the books. Korean tax laws allow the depreciation of fab capital equipment within 18 months to two years. Although the internal bookkeeping for these companies for the purposes of Korean tax laws may have already completely depreciated the equipment used in the fabs, there is the likelihood that the U.S. Department of Commerce or the European Commission will require a new set of books to be drawn up using a less aggressive depreciation schedule for use in any antidumping suit.

If a Korean DRAM manufacturer is paying for its equipment in won, then who bears the burden of a currency devaluation? The banks are shouldering this, and this is part of the reason why an International Monetary Fund bailout was needed early in December.

The upswing of this entire argument is that the costs to produce a DRAM in Korea are, at a minimum, 55 percent linked to the won and are quite likely more sensitive than that to the won's fluctuations. This implies that other countries are a very long way from seeing the bottom of 16Mb DRAM prices. Dataquest would not be surprised to see 16Mb DRAMs contracts drawn at prices below $2.50 by the middle of 1998.

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Cypress' Surprising Road to a Lower Fourth Quarter

Cypress Semiconductor Corporation announced that it would fail to meet analysts' expectations for the fourth quarter, ending December 29. The analysts' revenue estimates for Cypress are $152 million to $155 million, versus the company's current estimates in the range of $140 million to $143 million.

Cypress has given two causes for the lower sales numbers: a $5 million shortfall in wafer-foundry revenue because of lower orders from its foundry customers and a $10 million shortfall in SRAM revenue because of a timing problem in ramping up the production of SRAMs at Cypress' Round Rock, Texas, fab. This fab has previously produced nonvolatile memories, programmable logic, and data communications products, but not SRAMs.

DQ Take

At first blush, it seems really peculiar that Cypress would have had trouble both selling its excess fab capacity and needing more fab capacity to produce SRAMs. Whatever the trouble, this promises to be a short-lived problem but one that flies in the face of Cypress' "no excuses" management style.

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WSTS Revises DRAM Numbers for Entire Year to Date

For those who track World Semiconductor Trade Statistics DRAM statistics closely, we provide a friendly note that all 1997 DRAM statistics, with the exception of seven months of sales to Japan, have been corrected. This includes all unit shipment figures, some of which changed by as much as 7 percent. Revenue corrections stayed at or below 6 percent. A call to the Semiconductor Industry Association revealed that revised inputs were submitted by one or more of the participants. We do not wonder, based on the locale of the changes, where these companies are headquartered.

Jim Handy, Memories Worldwide, jim.handy@dataquest.com

DRAM Corner

Rumors, Rumors, and More Rumors!

Perhaps the two most spectacular rumors that have crossed our desks lately are that Texas Instruments Inc. and Nippon Steel Semiconductor will be getting out of the DRAM business. The former was a story carried in an electronics trade magazine out of the United Kingdom and the latter came straight out of Nikkei.

The TI rumor has actually been around for a while. About a month after Motorola announced its departure from the DRAM business, this rumor surfaced in Japan. The correspondent who wrote the TI story also happens to be in Japan. Both then and now, it was refuted immediately by TI, which appears to still be actively increasing its staffing levels in spite of today's challenging business environment. Nippon Steel Semiconductor has also told us that there is no truth to the rumor that it is abandoning this business and that not only will the company proceed in its DRAM business, but it also plans to expand its business to include a logic foundry business. Dow Jones quoted one spokesman as saying, "We're not getting out of the DRAM business, we're just adding the logic business." It appears that Nippon Steel Semiconductor will be delaying its entry into the 64Mb market for the time being and will redirect the capacity slated for the 64Mb DRAM to produce logic.

Hyundai appears to be the sole company about which some of these rumors may be true. According to one British newspaper and the *Washington Post*, Hyundai is mothballing its Dunfermline, Scotland, fab for up to 12 months. The company has recently announced that it has opened phase 2 of its Eugene, Oregon, facility but appears ready to postpone construction of phase 3 until things get better in the DRAM business.

DRAM Fab Delays in Japan

The *Nihon Keizai Shimbun* has quoted the following announcements of DRAM fab construction push-outs by Japanese manufacturers:

- Hitachi Ltd. will postpone the opening of its new Naka plant by a year.
- Toshiba Corporation plans to delay building a ¥130 billion plant in Iwate.
- Mitsubishi Corporation and Fujitsu Ltd. may cut capital spending in the next fiscal year by 10 percent to 20 percent.

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Dataquest's Tactical Memories Newsletter
251 River Oaks Parkway, San Jose, California 95134

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Perspective

Memories Worldwide

Market Analysis

Dataquest's Tactical Memories Newsletter —Vol. II, No. 25

- *Korean Monetary Crisis*
- *AMD Introduces 1.8V Flash and New Package*
- *DRAM Corner*

Korean Monetary Crisis

South Korea and the International Monetary Fund (IMF) have agreed to a rescue package totaling $57 billion. South Korea agreed to implement IMF-recommended measures to revitalize its faltering economy in return for accepting the bailout fund. Even with the agreement, there are fears that the bailout may not succeed and that Korea's links to other Asia/Pacific countries may endanger those countries, as well.

DQ Take

With the stringent management and restructuring requirements of the IMF bailout, the Korean semiconductor industry is planning to cut next year's capital investment by 30 to 50 percent, compared to this year. Korean DRAM manufacturers fear that their cutbacks could result in a drastically dwindling share of the world market, with market share lost particularly to Japanese and Taiwanese companies. The threat of shrinking market share is something Korean DRAM manufacturers haven't been accustomed to; they have enjoyed steady market share growth since 1990.

Samsung, currently the world's leading DRAM producer, is expected to implement a 30 percent cut in overall investment and is considering further cuts in coming weeks. Samsung's plans are to earmark W800 billion to W900 billion for semiconductor and LCD investment next year and W400 billion to W500 billion on research and development. LG Semicon and

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Hyundai are also cutting back investment. LG Semicon plans to lower investment by 30 percent, or W1.05 trillion to W1.10 trillion for next year, while Hyundai is considering a 40 percent cut. As with Samsung, both LG Semicon and Hyundai have yet to make their investment plans final.

What impact will these cutbacks have on projects already under consideration? LG Semicon is expected to delay the construction of its second LCD plant in southern Korea. LG Semicon and Hyundai are re-examining their plans to construct DRAM fabs in the United Kingdom, although both expect to go ahead with plans as scheduled. Most expansion plans for DRAM fabs in the United States by Samsung, LG Semicon, and Hyundai are expected to be suspended. Dongbu, which earlier this year announced plans to enter the semiconductor industry, decided to postpone this indefinitely, citing difficulties in borrowing money.

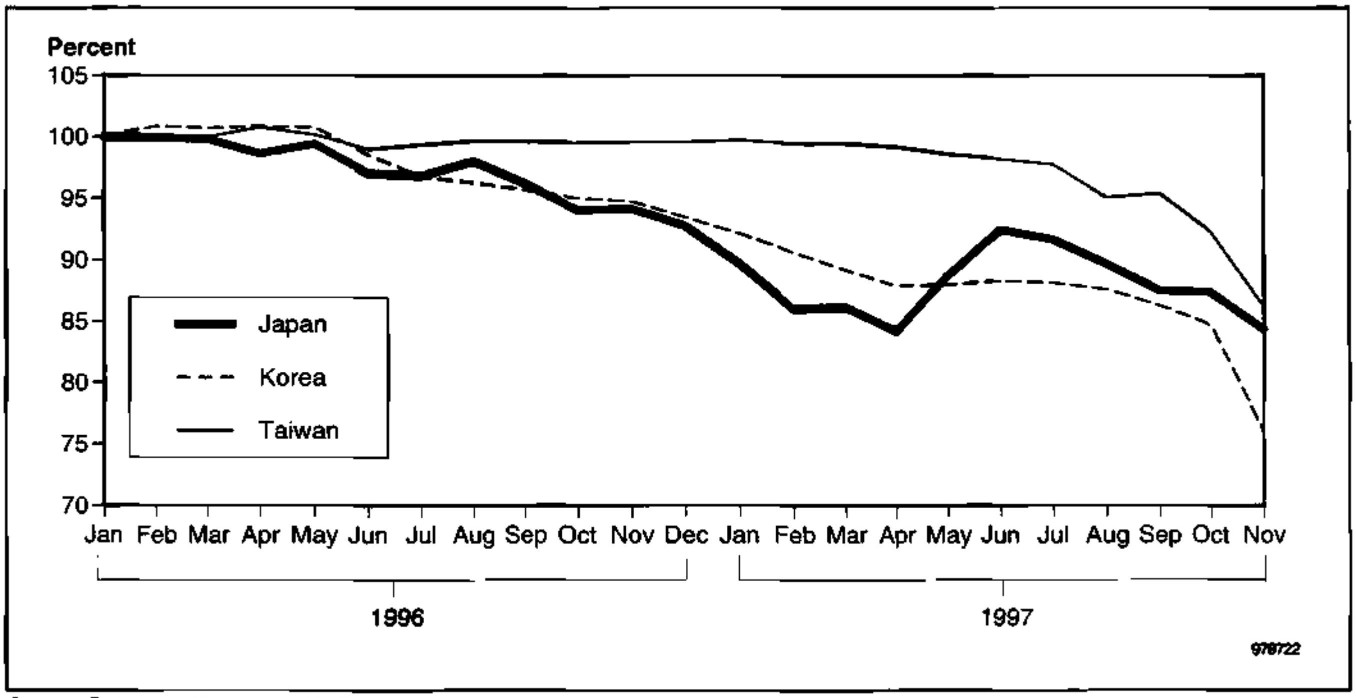
It will take one to two years for next year's cutbacks in Korean investment to make a significant impact on company market share and DRAM industry capacity. There is more than enough capacity already to support current demand, and as all manufacturers continue to shrink their 16Mb and 64Mb devices, industry overcapacity will continue through most of 1998 and possibly into 1999. To put device die size into perspective, the average die size of 16Mb DRAM at the end of 1998 will be 60 percent of the average die size of 4Mb DRAM at the end of 1995.

Taiwanese DRAM manufacturers will have a significant impact on when the market comes into balance. If Taiwanese companies continue with their aggressive expansion, the equilibrium point may be pushed out three to six months, well into 1999. Before the IMF actions, the Taiwanese companies planned to increase capital spending in local currency (NT$) by 10 percent. In U.S. dollar terms, this may actually represent declining capital spending because of currency devaluation (more on this later). The Korean cutback in spending may encourage Taiwanese DRAM vendors to accelerate investment in an effort to take market share away from the Koreans. If Korean companies cut their capital spending as indicated and if Taiwanese companies continue with their capital spending plans for foundry, memory, and joint ventures, Taiwan may surpass Korea in capital spending in 1998. However, not all Taiwanese DRAM vendors are expected to increase capital spending—at this time, Mosel Vitelic and Powerchip are expected to decrease their capital spending in 1998, and others may follow.

Dataquest believes there is a good possibility that Taiwanese manufacturers won't implement their aggressive capital spending plans. The Taiwanese companies are newcomers to the DRAM industry and haven't experienced prior industry downturns. As they gain experience in the current downturn, they may decide to stop DRAM spending abruptly. This will come with the realization that, while aggressive expansion will buy market share, it will also lengthen the DRAM industry downturn.

On top of all the changes in Korea's financial situation and the long-term effects of the IMF bailout plan, there is also the short-term phenomenon of a currency devaluation adding to the problem. Korea, Taiwan, and even Japan have seen the value of their currencies slide dramatically in relationship to the U.S. dollar as well as against European currencies (see Figure 1).

Figure 1
Foreign Currency Purchasing Power Relative to the Dollar



Source: Dataquest (December 1997)

This chart has been normalized to January 1996 to show that an item with a fixed local currency price that could be purchased in the United States for $1 in January 1996 could be purchased in November 1997 for $0.84 if it came from Japan, $0.86 if it came from Taiwan, and $0.76 if it came from Korea. Of course, DRAM per-megabyte prices descend at a relatively steady rate (28 percent per year), but the effects of currency rate changes layer on top of this. If the manufacturing cost, measured in won, of a Korean DRAM drops at 28 percent per year over the course of 1997, and if in that same time the won dropped 20 percent (which it did), then the minimum price that could be charged for that DRAM in the United States without triggering antidumping measures would have dropped 42 percent! This implies that there should continue to be exceptional price slides for DRAMs from Japan, Korea, and Taiwan into the United States and Europe. This has a great impact on the worldwide market because, in 1996, Japan, Korea, and Taiwan had a combined share of 77 percent of the DRAM market, and DRAM consumption in the United States and Europe accounted for 56 percent of the world market.

This, though, is not the end. The November average tells only a part of the story. As of December 10, when this was being written, the won had dropped to 54 percent of its January 1996 level. The end of the drop is not in sight today. Korean manufacturers accounted for only 34 percent of 1996 DRAM sales, so the impact of the price slide will not perfectly match the exchange rate drop times normal DRAM price declines. The effect will be less than this; however, it will be important!

In short, DRAM prices, which have been falling at a rate based largely upon the cost of manufacture, should continue to fall faster than this rate as long as Korean, Taiwanese, and Japanese currencies continue to slide against European and American currencies.

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AMD Introduces 1.8V Flash and New Package

Advanced Micro Devices Inc. has released an 8Mb flash memory that requires a sole supply as low as 1.8V. The device's initial access time is 170ns, but it will be available in 100ns and 120ns versions next quarter. The package options are 48-pin TSOP or 48-ball fine-pitch ball grid array (FBGA). The Am29SL800-170 is priced at $8.70 for the industrial temperature range and $8.35 for commercial temperatures. AMD's flash partner, Fujitsu, will also sell the part.

DQ Take

This part has a number of firsts and twists. The most notable first is it is fully 1.8V powered, pulling out in front of Intel in the continuing horse race between AMD and Intel. The twist is that AMD broke ranks with Intel on some joint technical agreements concerning packaging and interface; this marriage didn't even last through the honeymoon!

The 2.0V supply specification (plus or minus 0.2V) is a key item for the target market—next-generation digital cellular handsets. Dataquest expects 22 million of these handsets to ship in 1998, and 43 million in 2001. The 100ns speed at 1.8V is impressive, especially with an industrial temperature range of negative 40° to 85°. AMD said that its main technical innovation for the SL is an improved peripheral transistor with higher gain and lower turn-on threshold voltage, achieved by thinning the gate oxide from 150 to 100 angstroms. In addition, the company continues to use negative gate erase (NGE) and wordline boost techniques, allowing it to obtain the fast speed at low voltage. An on-chip charge pump supplies the higher voltages required for programming and erase, but because current requirements are small, its size can be minimized, reducing the impact on die size. The device consumes much less energy than comparable 3V flash chips from AMD.

AMD has decided to abandon the micro-BGA packaging approach it at first appeared to be doing with Intel. The company said it did not allow for easy density upgrades in designs because micro-BGA requires a unique ball pattern matched to die size, meaning it would potentially change with product design refinements and density increases. Instead, AMD has adopted the Japanese FBGA package that Sharp and Fujitsu are using for flash. This is another key cellular telephone area because of the competitive drive by handset vendors to shrink size (Dick Tracy "wristwatch" models are now being discussed!). A future advantage of micro-BGA over FBGA, however, is the ability to apply packages on an intact wafer, so perhaps micro-BGA may only be ahead of its time, instead of dead. AMD *was* also walking hand in hand with Intel on the common flash interface (CFI) specification. This was in response to ATA mass-storage suppliers such as SanDisk that do not require system changes for increasing density, much as rigid disk drives do not require them in PCs. Because the SL is not aimed at the mass-storage market, CFI was not required. An interesting tidbit from the press conference was that AMD is developing a mass-storage flash technology that is a mixture of NOR and NAND, so that it is the device that must be concerned with those standards.

The bottom line is that flash memory continues its awesome rate of technical innovation, spurred by large cellular phone customers and their fear of competitors nipping at their heels. AMD has opened the 1.8V hunting season for flash.

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DRAM Corner

Melco Inc., a Japanese computer peripherals and memory module manufacturer, said it will acquire a 68.1 percent stake in TechWorks Inc., a Texas-based module manufacturer. Melco said that it plans to use the affiliation with TechWorks to expand its production and sales to the U.S. and European markets. Before this acquisition, less than 10 percent of Melco's DRAM module revenue is believed to come from outside Japan.

Third-party module companies have merged or been acquired in the past, but Dataquest wonders whether this acquisition will be the symbolic start of a wave of acquisitions. Melco adds strategically with this acquisition. Other large third-party manufacturers may be considering similar actions. Expanding sales channels, adding design, manufacturing, and test capability (particularly for SDRAM), gaining vendor and customer relationships, adding a regional presence, and growing revenue are some reasons that companies may choose to acquire other module companies. Smaller module companies may choose to merge with each other, hoping to become more competitive with their larger competitors. There is also a possibility that some DRAM manufacturers are considering a third-party acquisition to add a low-volume, quick-turn, flexible manufacturing capability to complement their current capabilities.

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Dataquest's Tactical Memories Newsletter —Vol. II, No. 24

- *WSTS September Figures: DRAM's Big Drop*
- *COMDEX—PC100 or Bust?*
- *Intel Sues SST over Flash Memory Patents*
- *Another Taiwanese Company Licenses DRAM Technology*
- *DRAM Corner*

WSTS September Figures: DRAM's Big Drop

Figure 1 shows the latest World Semiconductor Trade Statistics (WSTS) figures for DRAM sales, expressed in dollars per megabyte. The drop in September is bigger than any month-to-month drop since August of 1996. This brings about the question: Are prices falling below where they should be? Dataquest thinks not.

DQ Take

Look at the trend line (the smooth one). This line shows the average 28 percent-per-megabyte decline Dataquest has noted during the past 23 years. Although DRAM prices have fallen to this line—and perhaps a little below it in January and February—in general, the market is falling at a normal and predictable rate (about 28 percent per year). Dataquest expects this trend to continue until demand catches up with today's capacity, which is expected to be seen in late 1998. After that, prices should raise above this line, as they have in previous times of market firmness. Why do they not drop below the line? The main reason is that antidumping provisions assure that manufacturers do not sell significant quantities of a product below their cost to manufacture. Manufacturing costs descend at a predictable rate, and the lowest contract prices will follow this trend. Since the bulk of the DRAM

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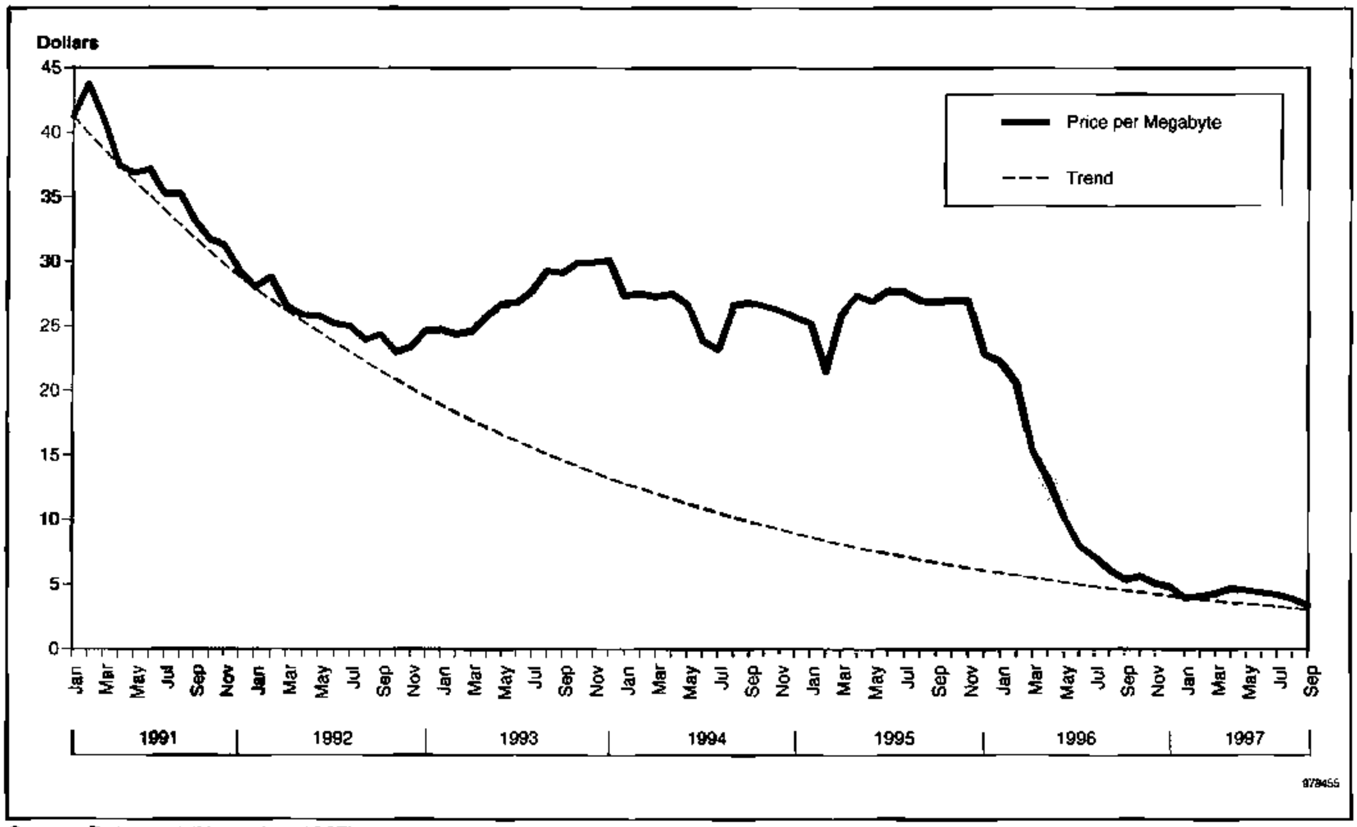
business is contract, rather than spot market, business, prices on average will not drop significantly below the trend line.

Figure 1
WSTS DRAM Price per Megabyte versus Trend Line



Source: Dataquest (November 1997)

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COMDEX—PC100 or Bust?

COMDEX may not be the biggest event for DRAM companies, but the volume of announcements made during COMDEX indicates it wasn't just a week of fun in Las Vegas, either.

- Hyundai Electronics Company Ltd. announced plans to introduce both 16Mb and 64Mb SDRAM designed for PC100. In addition to its PC100 announcement, Hyundai unveiled before COMDEX a working SLDRAM test chip.
- LG Semiconductor Ltd. announced what it believes is the first 64Mb concurrent RDRAM and unveiled plans to be the first to supply Direct RDRAM for PC main memory in mid-1998. LG Semiconductor also announced its fifth-generation 16Mb SDRAM, which operates at 133 MHz and a chip-scale package design that uses a patented bottom-leaded plastic technique.

- Micron Technology Inc. announced that it is sampling 125-MHz 64Mb SDRAM.
- NEC Corporation unveiled the technical specifications of Virtual Channel Memory.
- Samsung announced that it manufactured 64Mb SDRAM that meets the PC100 specification. Samsung also announced that it achieved functioning first prototypes of 64Mb DDR SDRAM and working samples of 16Mb and 18Mb concurrent RDRAM. Samsung's stated goal for its concurrent RDRAM is to lead the industry into volume production early in 1998.
- Siemens announced the availability of PC100-compliant 64Mb DRAM samples.

DQ Take

It doesn't take a genius to figure out what DRAM companies are thinking about—PC100-compliant SDRAM and what will follow. The question that remains is when will chipsets that support 100-MHz SDRAM, DDR SDRAM, and Direct RDRAM be available? The answer is today for the first two, and possibly the second half of 1998 for the third, based on LG Semiconductor's timetable for direct RDRAM.

Ali/Acer Labs said they have demonstrated a chipset (currently available for sampling) at COMDEX, the Aladdin V, that supports 100-MHz SDRAM. The Aladdin V also supports FPM, EDO, and four DIMM sockets. VIA showed its Apollo VP3 chipset that supports DDR SDRAM, as well as FPM, EDO, and SDRAM. It is worth noting that the VP3's DRAM interface is 66 MHz for both SDRAM and DDR SDRAM.

What about Intel Corporation? Well, its 100-MHz SDRAM-capable chipset is still expected in the first half of 1998 and should be in volume production by the middle of next year. The Ali and VIA chipsets support socket 7, so they are not an option for Intel's Pentium II, which comes in the modular slot 1 format. It will be interesting to see if the availability of competing chipsets that support DDR SDRAM will make a difference to Intel and its memory road map.

The availability of Intel's chipsets is critical for enabling DRAM technology transitions. Intel primed DRAM manufacturers to expect 66-MHz SDRAM in early 1997, but demand really didn't start to ramp until the 440LX chipset became available in the second half of 1997. Next year's 100-MHz SDRAM transition is a tougher challenge from a technology standpoint, but it offers interesting possibilities for both DRAM companies and third-party module vendors. The fear from Intel's and a PC manufacturer's point of view is that the tight PC100 timing parameters will make it difficult to bounce between different DRAM vendors.

If this compatibility problem materializes, it may be a saving grace for the DRAM manufacturers that get qualified with top PC OEMs. It looks as though 1998 will be another oversupplied year, but qualified PC100 SDRAM vendors may be able to enjoy a little price protection. The same should hold true for third-party module companies looking to develop OEM relationships. The companies that can prove they have the manufacturing and testing capability for PC100-compliant SDRAM modules will benefit.

Dataquest expects that one unfortunate by-product of the PC100 effort will be the availability of untested 100-MHz SDRAM modules in the aftermarket. Intel is making detailed module design guidelines available to all interested parties, which will help small third-party module vendors compete. Unfortunately, these vendors may not be able to afford the test equipment needed to fully test these modules.

The transition from FPM to EDO to SDRAM all occurred with chipsets that could handle more than one memory type. The transition to direct RDRAM is expected to come with a chipset that only supports direct RDRAM. It's unclear how this will impact direct RDRAM's acceptance. Lack of flexibility combined with Intel's less-than-sterling track record in managing DRAM transitions may lengthen the transition. There is also the possibility that having only one choice will result in a much quicker acceptance. Either way, if the 1999 direct RDRAM timetable is met, next year's COMDEX may be where the first PCs implementing this technology are publicly unveiled.

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Intel Sues SST over Flash Memory Patents

Intel has filed suit against Silicon Storage Technology, alleging patent infringement of its flash-memory designs. SST plans to countersue and said it will report Intel to the Federal Trade Commission, which began a broad inquiry into Intel's practices in September involving three Intel patents.

DQ Take

Boys, boys, can't you get along at all? The flash memory industry is becoming known for both fast growth and fast lawyers, with the latest salvo fired by Intel toward small flash memory vendor SST, which responded with cries of angst that big, bad Intel is being a bully, picking on someone much smaller than itself. And besides, SST says, it is not infringing Intel's patents.

The real motivation here is that SST is something of a competitive iceberg for Intel because of its aggressive technology licensing program. SST has done deals with SANYO, Taiwan Semiconductor Mfg. Co., ISD, Winbond Electronics Corporation, Seiko-Epson, and Analog Devices, either for producing embedded flash memory or as a manufacturing partner for SST. What this means is that SST is teaching many companies how to make its flavor of flash (so-called "Super Flash"), even if, theoretically, it is limited to be included in multifunction chips. The most worrisome companies for Intel are the ones in Taiwan, since they will try to win business using low price as an incentive. This lowers the market prices for other companies, including Intel, which is scrambling to make money with flash right now. We expect Intel to keep the pressure on SST because of the large shadow it casts.

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Another Taiwanese Company Licenses DRAM Technology

Macronix International Company Ltd. entered the DRAM market through a technology alliance with Matsushita Electric Industrial Co. Ltd. Matsushita licensed its 16Mb and 64Mb DRAM technology to Macronix, which will manufacture 16Mb DRAM on a foundry basis and then sell the output to Matsushita. Macronix expects to begin manufacturing of 64Mb DRAM in 1998. Macronix's long-term goal is not to be a commodity DRAM manufacturer, but to use its own logic process with Matsushita's DRAM technology to develop and sell a line of embedded memory devices under Macronix's brand name.

DQ Take

Macronix's agreement with Matsushita will help in two ways. The immediate benefit is that adding standard 16Mb DRAM to Macronix's product mix will help increase the utilization rate for its new 8-inch fab. The long-term benefit is that it adds strategically to Macronix's intellectual property portfolio. Companies with the most reusable intellectual property should have an advantage in the embedded memory market. Macronix already has experience with mask ROM, EPROM, and flash memory technologies, and it is adding DRAM capability with this agreement. It should be possible for Macronix to use its logic capability to add SRAM technology. When combined, this gives Macronix the building blocks needed for embedded memory.

Having the building blocks, however, doesn't ensure success. Many DRAM, SRAM, and nonvolatile memory companies are looking at ways to improve their own revenue stream and fab utilization with embedded memory products. From the logic side, ASIC and ASSP vendors are adding memory technology to their product portfolios. The embedded memory market promises to be very crowded. Success will depend not only on having all memory technologies and a process that optimizes for both logic and memory, but an ability to get design-wins. The design-win mentality may ultimately be the hardest addition for most memory companies because of their experience selling standard, commodity products.

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DRAM Corner

Rambus Seeing Encouraging Results

Hambrecht & Quist analyst Robert Chaplinsky was recently quoted as saying that Rambus Inc.'s efforts with Intel were "well ahead of plan" in their work together to develop a Rambus-compatible chipset.

Success has been a long time coming at Rambus, and it appears now to be at the brink of arrival. The initial Rambus concept appears to have been devised about 1989, and since then, the company has persevered for a number of years driving the world toward its vision of increased PC

performance. Despite threats from DDR and SLDRAM, both of which had announcements at COMDEX, the PC market appears to be moving with strong inertia toward the adoption of the Rambus standard.

Nan Ya Expands DRAM Capacity

Nan Ya announced that it will begin construction on January 1, 1998, of an 8-inch wafer fabrication plant at a total cost of NT$45 billion. The plant will produce 64Mb and 256Mb DRAM using 0.18-micron technology. With this addition, Nan Ya is expected to experience the largest amount of capacity growth among Taiwanese DRAM vendors next year. Nan Ya is also offering foundry capacity, but it lost an opportunity to gain foundry business from United Microelectronics Corporation after UICC's fire, which Holtek consumed.

In addition to the new fab construction, there is a rumor that Nan Ya's technology agreement with Oki may end. There is no evidence indicating that Nan Ya is looking for another partner. It looks like Nan Ya is taking the same approach as Vanguard, another Taiwanese DRAM manufacturer. One difference, however, is Vanguard is forced to manufacture only memory (DRAM especially) by one of its major investors, the Taiwanese government. This limitation is in force for three years after Vanguard's inception. However, Vanguard will soon be freed of this limitation.

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- *Intel Flash—Still a Leader?*
- *Tough Times in Taiwan*
- *ProMOS Technologies Inc. Opens Chip Plant in Taiwan*
- *Dataquest Semiconductors Conference Memories Recap*
- *DRAM Corner*

Intel Flash—Still a Leader?

When Intel Corporation recently announced lower-than-expected third quarter 1997 results, much of the blame was pinned on the performance of its flash memory division. Subsequently, its deal with Digital Equipment Corporation has allowed Intel to push out development of its Texas logic fab and switch the planned output of the up-and-coming Israel fab from flash memory to logic. With unit shipments of flash memory exploding globally, even Intel admits that unit demand is high. So what's happening to Intel's flash memory business that justifies a scaling down of production capacity?

DQ Take

The prevailing conditions in the flash market at present are certainly not to Intel's liking. Dataquest believes that Intel has lost significant market share in 1997 as a result of very aggressive price competition, particularly from Intel's partner Sharp Electronics Corporation, but also from the Advanced Micro Devices Inc./Fujitsu Ltd. camp, and it has been suggested that this has led to a loss of business at some key accounts. For example, in Europe at one time, Intel was a sole supplier to a certain telecommunications company deep within the Arctic Circle. However, recent anecdotal evidence, confirmed by a Dataquest teardown analysis of a GSM handset, has established the presence of a competitor's flash product in a

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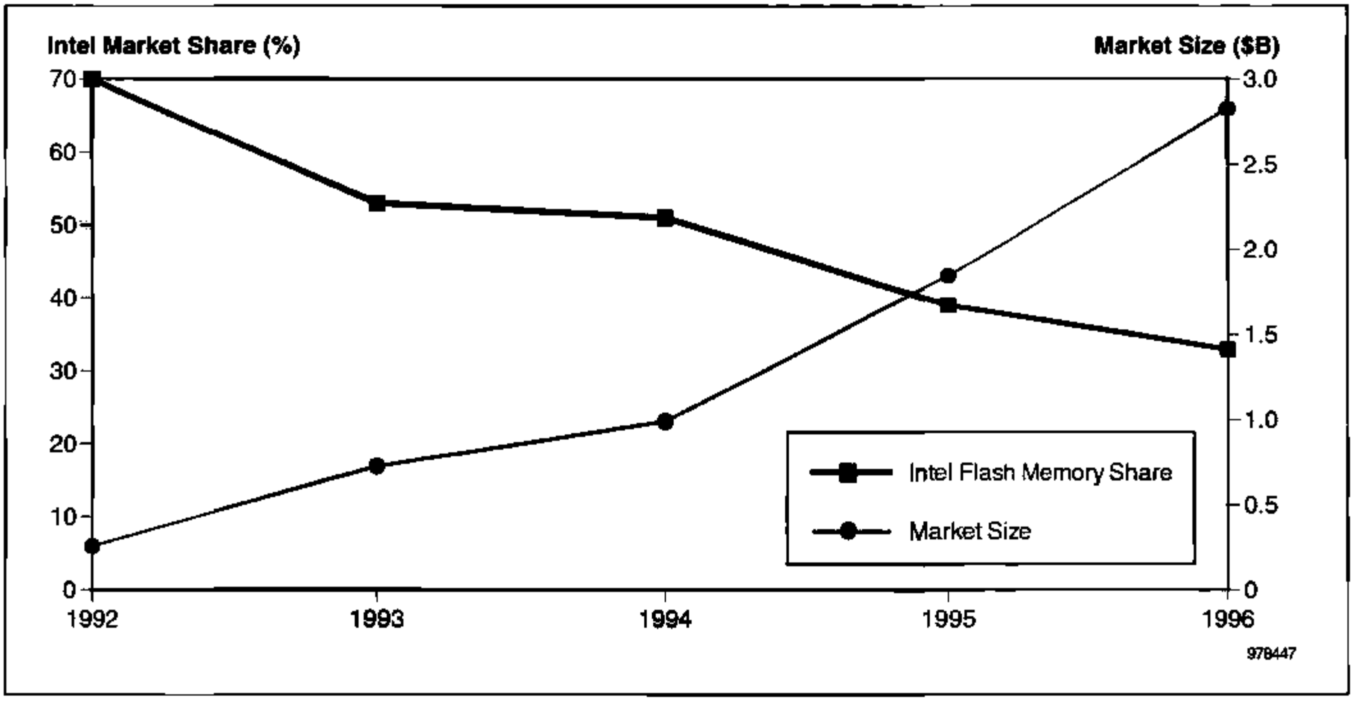
current-generation model. Intel's dependence on the GSM handset market in Europe leaves it vulnerable to a competitive challenge, and this is what appears to be happening now. Rumors from other regions tell a similar story.

Intel is not the sort of company to suffer fools gladly. Such is the level of its corporate ego that it quickly divests itself of any product line in which it loses a dominant position. Remember SRAM, DRAM, EPROM, and EEPROM? Intel was once at the forefront of all these memory technologies, but over the years, all have been discarded. And it's easy to see why. Through its microprocessor business, the company has gotten used to gross margins of 50 percent-plus. In the early 1990s, a similar magnitude of gross margin was also available in the flash memory business. Allocation was widespread, and the flash vendors could hold customers to ransom. But Intel's market share, as shown in Figure 1, has continued to drop over the years as the market has grown. For the record, Intel says that it is making its other flash fabs more efficient and that it will not now need the Israel fab. Dataquest remains skeptical.

Figure 1
Flash Memory Industry Revenue and Intel's Flash Memory Market Share, 1992 to 1996



Source: Dataquest (October 1997)

In the past, flash memory acquired a reputation as a quirky product that was difficult to manufacture. Also, tightly specified programming algorithms meant that implementation in systems required a high degree of technical support. These "teething problems" meant that flash was expensive and its undoubted flexibility could be afforded only by customers that had an absolute need. However, the leading flash vendors persevered with the technology, and for a couple of years, the business opportunity fitted well with the Intel model—that is, high demand, controlled supply, falling costs, and high average selling prices (ASPs).

However, times change, and the flash market is becoming a commodity business more akin to DRAM than to microprocessors. High unit volumes, increased competition, and sharply declining ASPs now characterize the market. Although not all segments operate in this manner, it is more and more the case.

Is it time for Intel to bail out of flash memory? Dataquest will release 1997 market share data next year, and the answer may well determine the future of flash at Intel. In other words, watch this space.

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Tough Times In Taiwan

A recent article in the Asian edition of the *Wall Street Journal* ("Taiwan Chip Makers Lose a Supply-Demand Gamble") reported on the difficult environment faced by Taiwanese semiconductor manufacturers.

DQ Take

Dataquest believes that the development of the Taiwan semiconductor industry will follow the same path as the PC industry in Taiwan. For many years, Taiwanese manufacturers have tried to develop their own brand-name PCs, with limited success. There are some small brand-name PC manufacturers in Taiwan, but only Acer has become a worldwide brand name. However, from a manufacturing point of view, many companies have built successful business models around production for major OEM clients.

Taiwan's semiconductor foundry industry puts the OEM manufacturing model into practice and continues to show promise. However, Taiwanese DRAM manufacturers face challenges as they fight to develop a presence in the DRAM industry. Today, Taiwan's DRAM companies are maneuvering for market share with competitively priced 16Mb DRAM. The biggest challenge is whether Taiwanese manufacturers should continue to develop their own independent manufacturing capability for next-generation DRAM or whether they should partner with others to manage the high cost of new fabs. A decision to partner would symbolize a move toward offering independent design services and away from company-owned manufacturing.

Taiwanese DRAM companies may not be able to make the decision to invest in company-owned fabs independently, but only in the context of larger vertically integrated information technology (IT) solution companies. Nan Ya Technology is a good example. Nan Ya is part of the Formosa Plastics Corporation. Few people are familiar with Formosa Plastics, but they may know some of the following companies: Nan Ya Technology, First International Computer Inc. (a PC and notebook manufacturer), VIA Technologies Inc. (a core logic design house), or Formosa Komatsu Silicon

Corporation (a 20,000-unit-per-month 8-inch silicon wafer plant, a joint venture with Komatsu Electronics). All these companies are part of the Formosa Plastics Group. FPG also has its own printed circuit board manufacturing capability. Combined, these companies represent a very vertically integrated IT company group.

The semiconductor industry depends on creative solutions, such as foundry. Taiwan's pioneering role in foundry services shows it has something to offer the semiconductor world. Taiwan also possesses resources such as qualified engineers, capital, and a growing demand for PCs, consumer electronics, and other electronic equipment. The *Wall Street Journal* article states correctly that Taiwan's semiconductor manufacturers do face many problems, but the dire outlook it presents may be a bit pessimistic.

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ProMOS Technologies Inc. Opens Chip Plant in Taiwan

ProMOS Technologies Inc., a joint venture of Mosel Vitelic Inc. and Siemens AG, celebrated the formal opening of its new wafer fab in Hsinchu, Taiwan. The 8-inch wafer facility enables both partners to begin high-volume 64Mb DRAM production.

The joint venture, formed only 11 months ago, represents a total capital investment of around $1.7 billion over three years. ProMOS employs 1,100 people and will be running at full capacity by the end of this year, beginning with 20,000 8-inch wafer starts per month of its initial product, the 64Mb DRAM chip on 0.35-micron technology. The 64Mb DRAMs are based on a technology that Siemens developed with IBM and Toshiba Corporation. Within the next three months, Mosel Vitelic and Siemens will expand their 64Mb portfolio with the release of configurations of 64Mb synchronous DRAMs (SDRAMs).

DQ Take

In September, Mosel Vitelic signed a contract under which Siemens will deliver to Mosel Vitelic 50 percent of the output of 16Mb DRAM and SDRAM from Siemens' new plant in North Tyneside, England. However, with the current unsteady price of 16Mb DRAM, this addition may not actually increase Mosel Vitelic's earnings. With the ProMOS joint venture, Mosel is preparing for 64Mb DRAM. Initially, the agreement calls for both Mosel Vitelic and Siemens to purchase ProMOS products for resale. Sixty-two percent of ProMOS's 64Mb DRAM will be labeled with Mosel Vitelic's brand name.

Mosel Vitelic has also licensed 256Mb manufacturing technology from Siemens and may participate in IBM, Toshiba, and Siemens' DRAM joint development project, but an agreement has not yet been reached. If its participation is granted, Mosel Vitelic is expected to become the first Taiwanese company to acquire 1Gb DRAM technology. The cooperation in both original technology and joint-venture manufacturing between Mosel Vitelic and Siemens is significant. Other partnerships involving Taiwanese companies include Texas Instruments Inc./TI-Acer, Toshiba/Winbond Electronics Corporation, and Mitsubishi Corporation/Powerchip Semiconductor Corporation.

Mosel Vitelic was the first Taiwanese company to license Japanese technology when it opened its 6-inch-capable wafer fab with transferred and licensed DRAM technology from Oki Electric Industries Company Ltd., in 1994. Today, Mosel Vitelic is the first Taiwanese semiconductor company to set up a joint-venture company with a European semiconductor company. The result is the first Taiwanese facility to produce 64Mb DRAM.

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Dataquest Semiconductor Conference Memories Recap

Sparks Fly in Flash Panel at Semiconductor Conference

At Dataquest's annual Semiconductor Conference last week, leaders of the flash memory industry participated in a panel discussion. The market leaders, Intel and AMD, were represented by their vice presidents and general managers, Bill Howe and Walid Maghribi, respectively. Dan Auclair of SanDisk Corporation and Dr. H.K. Lim of Samsung gave a mass storage perspective, with Bruno Beverina, vice president of SGS-Thomson, and Miin Wu, president of Macronix International Company Ltd., giving an international flavor to the event. Crisp opening statements were given by the participants, then questions were taken from the floor.

The theme of the panel was "will big or better win?" and various interpretations emerged from the discourse. Mr. Wu pointed out that when the market matures and existing applications dominate, large manufacturing concerns can bring learning-curve efficiencies to bear to increase market share. But this transition can be postponed by adding new applications to the market, delaying the switch to a commodity mode. He also disclosed a new flash array architecture, the Paired Array Contactless AND (PAC-AND) design, that can do multilevel cell (MLC) also. Another MLC surprise was supplied by Mr. Beverina when he disclosed that SGS-Thomson will present a paper early next year on 4-bit per cell storage, which the company has working in the lab now. He also gave an impassioned vision of flash memory adding value to global communications networks and adding more "intelligence" to electronic systems because of flash's nonvolatile rewritable capability. Mr. Auclair was another MLC cheerleader, with SanDisk's D^2 technology, which came to market first. He said digital cameras will be a "monster market" for flash cards, and SanDisk's CompactFlash small-form-factor card standard is clearly leading the design-win horse race in this market.

Mr. Howe presented Intel's new StrataFlash MLC vision, including its use in existing code storage applications. In contrast, Mr. Maghribi said MLC is only suitable for mass-storage applications, but he sees that market expanding to 20 percent of the total flash market, from the current 10 percent. He also said that AMD will introduce a mass storage-optimized technology that is *not* MLC and that AMD has made significant market share gains at the expense of Intel. Finally, weighing in on the "big" side of the equation, Samsung showed the commonality of DRAM and flash manufacturing and technology, which was hardly surprising, given that Samsung is the world's largest DRAM manufacturer.

Overall, the event showed the diversity and energy of the flash memory industry, from geographic, business, and technology positions. All participants said that pricing was very poor, with intense competition depressing all types but especially depressing 4Mb and 8Mb parts. But all agreed that the market is growing in terms of units and bits and that it will continue to grow for the foreseeable future.

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System-Level Integration

Three panelists presented their views in a Dataquest Semiconductor Conference session on the semiconductor market of tomorrow. Nathan Brookwood presented his microprocessor forecast, Bryan Lewis and Jordan Selburn presented their view of the way that intellectual property would be used to produce system-level integration (SLI), and Jim Handy presented a piece on the need for and the current offerings in embedded DRAM and other embedded memory categories. The following is a summary of the points of the paper on embedded DRAMs.

Embedded DRAM technology suffers from the availability of a phenomenal number of good solutions, ranging from embedded SRAM to external DRAM, and even further, to a complete restructuring of the design to remove the need for DRAM altogether!

Some good reasons for using embedded DRAM are:

- Lower power
- Lower chip count
- Greater bandwidth

Some good reasons for *not* using embedded DRAM are:

- Higher costs
- Difficulty in test
- Difficulty in processing
- Limited sourcing

One of the significant factors that can drive the costs of an embedded DRAM solution higher than that of other choices is the difference between a logic IC process and a DRAM process. Logic processes focus on achieving the highest speed through high transistor gain and low-resistance interconnect. DRAM processes compromise gain and interconnect resistance to produce physically small capacitors with high capacitance and low leakage. To combine these processes, the process complexity must be increased, increasing the cost of the die significantly.

There are indeed several great applications, however, for embedded DRAM. Many of these applications have a lot of characteristics in common:

- They use memories that are large in comparison with the largest SRAMs that can be efficiently integrated onto an application-specific IC (ASIC) die.
- The memory size does not change significantly over time, even though the density of the average DRAM increases at an annual rate of more than 60 percent.
- They are produced in high unit volumes.

This means that we can expect to see increasing use of embedded DRAM in applications like rigid disk drives, graphics accelerators, DVD players and recorders, digital set-top boxes, and some other applications of increasing importance in the longer term.

In the presentation, die photos were shown for a half-dozen currently available devices based on embedded DRAM technology. Embedded DRAM is here now! The only question is, where does it make the greatest economic sense?

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DRAM Corner

During the most recent DRAM shortage—which now seems a distant memory—a client said that the DRAM market is either "on" or "off." When it is on—usually meaning a shortage—it is something that everyone talks about all the time. When it is off—read "oversupply"—everyone avoids it like the plague. At Dataquest's recent Semiconductor Conference, our Direct Products sales team said attendees really enjoyed talking about wireless semiconductor applications, radio frequency ICs, global positioning systems, system-level integration, and other topics—but not DRAM.

Against this backdrop, Dataquest recently issued its *DRAM Supply and Demand Quarterly Statistics: Fourth Quarter 1997 Outlook.* We expect the current oversupply to last through most of 1998. What are DRAM companies to do, meanwhile?

As shown in the *Fourth Quarter Outlook,* most Japan-based and Korea-based suppliers see 64Mb SDRAM as the place to be. In the worst case, 64Mb SDRAM profit margins might prove quite narrow, but this appears more attractive to them than the brutal reality of the highly competitive 16Mb market. The emergence of Taiwanese suppliers into the 16Mb market means a 16Mb de-emphasis for Japanese and Korean suppliers.

So what are some of the numbers, based on Dataquest estimates? For fourth quarter 1997, NEC Corporation and Samsung will be the only companies with 64Mb SDRAM monthly shipment rates of 1 million (or higher). By the second quarter of 1998, they will be joined by Fujitsu, Hyundai Electronics Company Ltd., and Toshiba. For 1998, NEC and Samsung will each ship nearly 50 million units of 64Mb SDRAM. For 1999, Fujitsu, Hitachi, Hyundai, Mitsubishi, and Toshiba will exceed 50 million units—while NEC and

Samsung surpass 100 million units of 64Mb SDRAM. LG Semicon Co. Ltd. will also be making large quantities of 64Mb SDRAM, but some are likely to carry the Hitachi brand name.

What about 16Mb SDRAM? For the fourth quarter of 1997, Dataquest expects Micron Technology Inc. to ship more than 10 million units per month, with NEC and Texas Instruments not far behind. For 1998, Micron and Texas Instruments should each ship more than 150 million units of 16Mb SDRAM. NEC and Samsung will each likely exceed 100 million units, but, as indicated, their focus has already shifted to the 64Mb SDRAM density.

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Dataquest's Tactical Memories Newsletter
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Market Analysis

Dataquest's Tactical Memories Newsletter —Vol. II, No. 23

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DRAM Spot Market Slips Another Notch

Figure 1 shows statistics for the DRAM spot market since the most recent slide began in April. This was after some price increases stemming from the late-January announcements of Korean cutbacks. The two metrics are the American IC Exchange's lowest price per megabyte for 4Mb and 16Mb, any organization, extended data out (EDO) or fast page mode (FPM), and electronics retail chain Fry's Electronics' lowest price for a DRAM module.

DQ Take

Although the chart shows a relatively steady slide, the last week saw an unusual 16 percent drop in the Fry's price, which was reflected by the spot market prices we heard on the street. The AICE price dropped only 7.5 percent; however, this appears to be a late response to the market conditions.

How far can this go? Dataquest believes that contract prices are currently limited by antidumping concerns and are likely to stay at a cost-driven downward slope matching history's average price-per-bit decline of 28 percent per year. The spot market, however, is not entirely responsive to such measures and could very well drop further in the future. This depends

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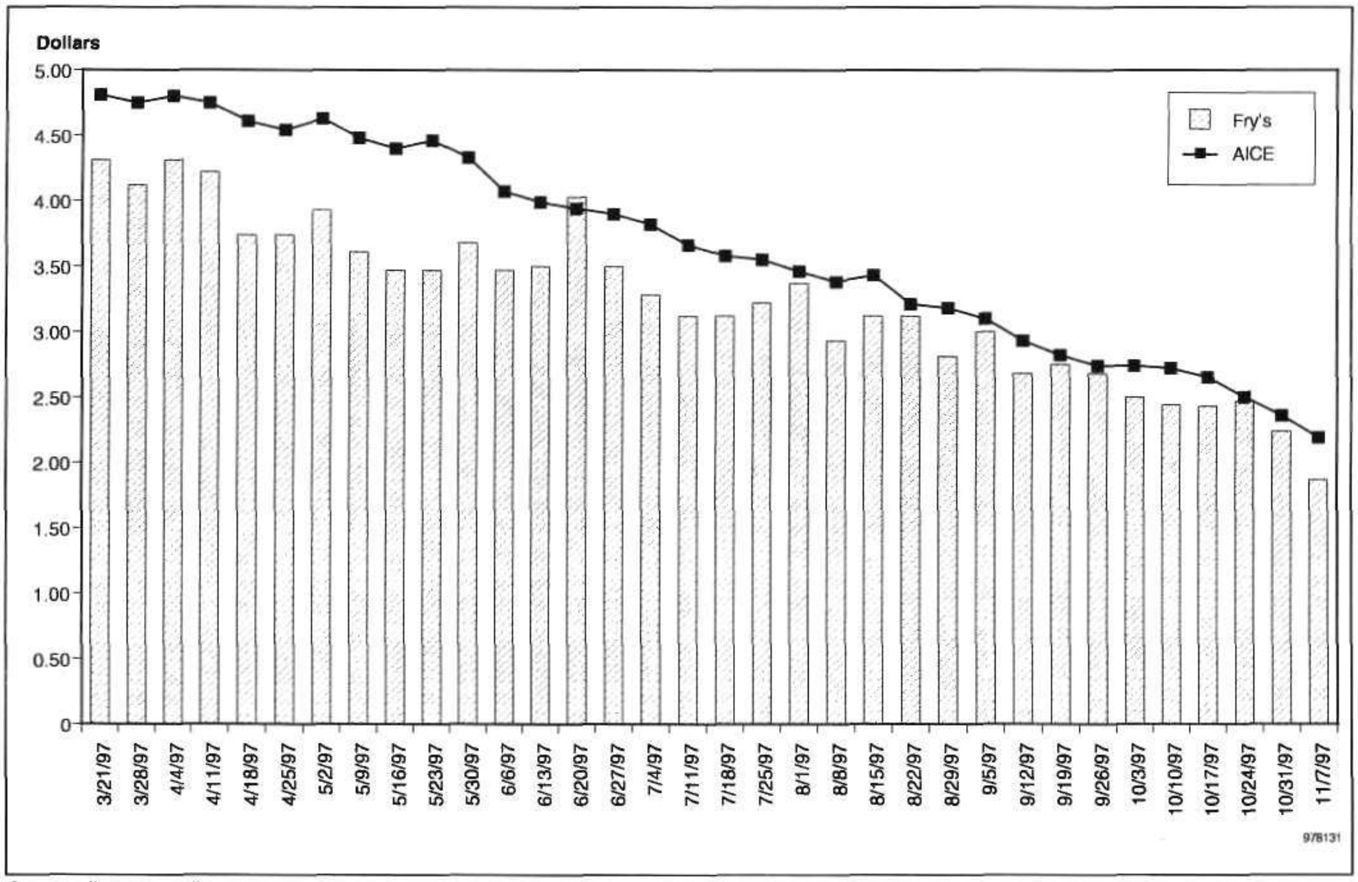
on the response of both buyers and sellers in the winter holiday market. Many DRAM manufacturers were looking to the 1997 holiday season as a time when prices would firm up, but most builds for that season happen in or before October. It appears that the hopes of the DRAM manufacturers may have outstripped the needs of OEMs and that there is now a greater surplus on the market than there would have been otherwise.

Figure 1
DRAM Spot Market Price per Megabyte, 1997



Source: Dataquest (November 1997)

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Dongbu Group to Produce 64Mb DRAM in 1999

The Dongbu Group, Korea's 22nd-largest conglomerate, announced on Wednesday it will enter the semiconductor industry through a technological team-up with IBM. Dongbu said it will invest a total of 2 trillion won (about $2 billion) to establish a plant to produce advanced DRAM chips, beginning in 1999. The plant, which will be part of Dongbu Electronics, will process a monthly output capacity of 30,000 8-inch wafers, processing them into 64Mb DRAMs and next-generation 128Mb and 256Mb DRAMs. Production capacity will grow to 36,000 wafers a month by 2001. Dongbu is expected to finish construction of the production facilities by the end of May 1999. The facility is located on 990 square kilometers in Eumsung-gun, North Chungchong Province.

DQ Take

This is similar to the deals that Texas Instruments Inc. struck with the Acer Group, Kobe Steel Ltd., and the government of Singapore. Dongbu will bear all investment costs for the project, and IBM will provide the technology needed to produce the next-generation DRAMs. To fund the project, Dongbu will spend 600 billion won of the group's own capital and borrow 700 billion won from domestic financial institutions, while attracting the remaining $1.1 billion in foreign capital. Dongbu has already secured $900 million in foreign capital and is negotiating with the state-run Korea Development Bank to mobilize additional loans through a syndicated loan formula, in which a number of domestic banks are participating.

The contract reached between Dongbu and IBM covers the transfer of DRAM-related design and manufacturing technology from IBM to Dongbu. IBM also agreed to purchase finished memory products and to participate in the joint development of next-generation semiconductor technology.

Dongbu will dispatch workers to IBM for training, and IBM technology experts will visit Dongbu as part of its technology-transfer program this year. In a related development, Dongbu Electronics will increase the number of its employees from 200 to 1,200 by the end of 1998. Dongbu, which is currently involved in the steel, chemical, and finance industries, will become the fourth Korean company to make DRAMs.

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Third-Party Module Manufacturers Continue to Expand Capacity

Simple Technology Inc. and SMART Modular Technologies Inc. both recently announced plans to expand their respective manufacturing capability. Simple Technology announced the expansion of its headquarters in Santa Ana, California, by 25,000 square feet, to 75,000 square feet. The additional space is to add four new manufacturing lines for PC memory and peripheral products. Simple also announced it will operate three shifts at its Santa Ana location and its Scotland facility to increase output.

SMART Modular Technologies announced that it has reached an agreement with the government of Puerto Rico to lease an 83,000-square-foot facility in Aguada, Puerto Rico. This new facility will replace SMART's 23,000-square-foot facility in Arecibo, Puerto Rico. The company plans to move to the new facility in late November. The announcement also indicated that SMART expects to add 400 new jobs in Puerto Rico over the next three years.

DQ Take

From a revenue and unit shipment perspective, 1997 appears to be following the same pattern as 1996 for third-party module manufacturers—strong unit growth, but industry revenue growth stifled by falling DRAM prices. Industry unit growth does seem to be slowing. When Dataquest surveyed third-party manufacturers last year, many indicated unit shipment growth rates ranging from 100 to 300 percent over 1995. Based on recent conversations, many of the same companies expect growth rates of about 100 percent this year.

SMART and Simple represent different variations of the third-party business model. SMART is dedicated to providing module design and manufacturing services for OEM customers. SMART's model has worked well the last two years; it is one of the few third-party module companies to grow revenue. Simple is more representative of third-party module companies because it primarily supplies the channel, distributors, resellers, and system integrators, while developing its OEM business.

Because both companies are adding capacity, it looks as though both OEM and channel customers continue to demand product from third-party sources. One must wonder, however, if all third-party companies will add capacity while experiencing slumping revenue. Adding to the problem is the current transition to synchronous DRAM (SDRAM), which adds difficulty to designing and testing modules. Depressed revenue and increasing test costs may force some third-party companies to slow their capital expenditure, which may result in a concentration of business among a handful of larger third-party companies capable of expanding in tough times.

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Korean Companies Intensify Efforts for Next-Generation DRAM

Searching for the right path for next-generation DRAM, Korean DRAM manufacturers are intensifying their efforts to develop high-speed DRAM that can improve PC performance. Samsung Electronics Company Ltd. announced that it has developed the world's first 64Mb double data rate (DDR) SDRAM, while LG Semicon Co. Ltd. announced it has begun mass production of the world's fastest 18Mb Rambus DRAM (RDRAM).

DQ Take

Samsung's DDR SDRAM, as its name indicates, has a data rate double that of synchronous DRAM (SDRAM), the current high-end DRAM for PCs. DDR was proposed by a group of DRAM companies, including Samsung, as an alternative to Direct RDRAM and was standardized by the Joint Electronic Device Engineering Council (JEDEC) this summer. Samsung played a leading role in the standardization process and is the first company to develop DDR SDRAM based on the standard.

While Samsung is focusing on DDR SDRAM, LG Semicon is putting more weight on Direct RDRAM. Direct RDRAM, although capable of offering higher data rates than DDR SDRAM, is expected to be more expensive to produce because of its larger die size and an associated licensing fee. According to some DRAM manufacturers, Direct RDRAM will be about 20 percent more expensive than SDRAM, a large cost penalty. This characteristic has made Samsung and other DRAM makers stop short of fully committing themselves to Direct Rambus, even though the technology has been endorsed by Intel Corporation.

The Direct RDRAM specification has only just been announced, and there has not been enough time since the start of development for manufacturers to produce working Direct Rambus parts. How then can LG Semicon demonstrate its commitment to the Rambus technology? LG Semicon has begun mass production of the predecessor to the Direct Rambus, the 18Mb RDRAM, which is already being used for graphics memory in PCs. LG Semicon expects RDRAM to rapidly take market share from synchronous graphics DRAM (SGDRAM) in the graphics memory market. Although LG Semicon is making a push for its RDRAM in the graphics market, the company's main concern lies in introducing Direct RDRAM to the main memory market as early as possible. RDRAM is the technology base that is being used by Rambus Inc. to develop Direct RDRAM.

Samsung and Hyundai Electronics Industries Co. Ltd. also support Direct RDRAM and are working to develop it, but LG Semicon appears to be much more strongly committed to this technology. Direct RDRAM is generally expected to debut in 1999, but LG Semicon is determined to develop it in the first half of 1998 and establish leadership in the development and production of the new chip. One of the first companies to license RDRAM technology from Rambus, LG Semicon hopes its long development experience with RDRAM will help it attain this goal.

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SRAM Roundup

There have been four interesting SRAM announcements in the last two weeks. Cypress Semiconductor Corporation, Integrated Silicon Solution Inc., and Paradigm Technology Inc. each introduced 64Kx16 fast SRAMs designed to be used with digital signal processor (DSP) chips. Intel announced that it will be producing a cost-reduced version of the Pentium II that does not contain an L2 cache.

DQ Take

SRAM manufacturers that have not been picked by Intel as vendors for the L2 cache chip for the Pentium II have been busily working on strategies that will allow them to stay in business. One approach has been to focus on telecommunications. It appears that the three 64Kx16 devices (which, at a cursory glance, appear to be incompatible with each other) are a move in this direction. We have seen no indication that any of these three companies has been qualified as a source to Intel for the Pentium II L2 cache SRAM IC. On the other hand, now that there is to be a Pentium II without an integrated L2 cache, there is a glimmer of hope that some of the 20-odd suppliers of the 32Kx32 will have a chance to supply cache SRAMs to maverick PC companies that design their own systems with external caches, perhaps on a module. This should be fun to watch.

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DRAM Corner

Reuters picked up the LG Semicon announcement mentioned earlier with some confusion. It reported that "the Rambus DRAMs would be used as graphics memory units in computer workstations, servers, digital television sets, and automated teller machine switching systems from next year." We at Dataquest are not certain what benefit the Rambus channel brings to automatic teller machines. We were also amused that the article states that "the chips are expected to be used as central processing units." Watch out, Intel!

SLDRAM Test Chips

On a more serious note, there is some other work being done as an alternative to the RDRAM, and that is the SLDRAM (formerly known by the name "SyncLink"—until this name was found to be copyrighted by a modem manufacturer). SLDRAM is an open specification with no royalties attached, targeted to offer the same bandwidth as the Rambus interface. In an announcement released on October 31, Hyundai and Mitsubishi Corporation announced that they have delivered SLDRAM test chips for approval by the SLDRAM Consortium. This is a milestone in the effort to produce this alternative interface in time for it to be considered as an alternative to the Rambus architecture. Intel has stated that it reserves the option of backing down from its stated Rambus migration plan, and it appears that the SLDRAM Consortium is trying hard to make this happen.

New NEC Fab for 128Mb DRAM?

A report on the Japan Economic Newswire states that NEC Corporation plans to add a $1.2 billion wafer fab to its Roseville, California, site to produce 128Mb DRAMs (although NEC has not officially announced this and will not confirm this story). The article says that production is scheduled to start in 2000. We have heard that many Japanese companies are bullish on this density since it was first requested by Compaq Computer Corporation, and the new fab appears to be a ramification of NEC's faith in the part. Our main reservation about the chances of success for the 128Mb DRAM chip (among the many we have) is that the device has been conceived to solve certain granularity problems that will result from the fact that a 32-bit-wide version of the 256Mb DRAM will probably not be mass-produced. If Rambus DRAMs are widely used in PCs in 2001, or even in 1999, as Rambus Inc. appears to believe, the problem of needing a 32-bit bus for granularity disappears. This implies that the NEC fab will be unnecessary at about the time it is expected to ramp into production.

NEC Virtual Channel Memory

NEC announced, in a highly technical presentation, its Virtual Channel Memory, or VCM. The technical specifications of VCM were unveiled at the COMDEX show on November 17, 1997. VCM is a core technology that will enhance existing memory architectures, such as SDRAM.

NEC says that VCM technology is expected to reduce latency and improve throughput in practically any memory device, including SDRAM, EDO, FPM, DDR, and Rambus. The core architecture will be marketed by NEC as an open industry standard. NEC also plans to garner industry support from memory and chipset manufacturers and major OEMs.

Although the announcement leaves out a lot of details, this technology is an attempt to solve a problem that has been overlooked so far. Processors have been accelerated through higher clock rates, and cache memories have been added. DRAM input/output bandwidth is benefiting from an onslaught of new technologies, from EDO through SDRAM, DDR, Rambus, and SLDRAM. The only part left out of the equation so far has been the core speed of the DRAM itself. In essence, NEC is proposing that the DRAM core (or any other memory technology, for that matter) have a cache added, controlled by an external cache controller.

The technology has been used before by Mitsubishi, and the differences among the Mitsubishi CacheDRAM, the MoSys MDRAM, and the new NEC technology are very subtle. All have multiple internal SRAM copies of the row buffer that can be used to accelerate the apparent operation of the memory core. The major difference between the CacheDRAM, the MDRAM, and NEC's approach is that NEC wants to promote an open standard, while the two predecessors had limited sourcing. Limited sourcing causes limited acceptance. If NEC is able to get industrywide support, there is a good chance that this technology will be adopted.

NEC takes pains in its announcement to point out that the new technology is the result of a project that was initiated and conducted in the United States by design resources at NEC Electronics. NEC opened a U.S. R&D arm about two years ago, and this announcement helps show that good things can be developed away from company headquarters.

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Dataquest's Tactical Memories Newsletter
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- *Fall Forecast Telebriefing*
- *DRAM Corner*
    - *-The Dielectric Difference*

Fall Forecast Telebriefing

Memories Worldwide held a telebriefing on Friday, October, 17, 1997, to discuss Dataquest's fall memories forecast. A review of the material presented in the telebriefing follows.

Figure 1 shows Dataquest's MOS memory fall forecast. Worldwide MOS memory revenue should total $32.8 billion for 1997, a decrease of almost 13 percent from 1996 revenue of $37.6 billion. This is an extension of the 1996 cyclical decline in DRAM. By the second half of 1998, Dataquest expects to see a successful return to a normal market. Although much of the profit has evaporated in SRAM and flash memory, Dataquest still expects that 1997 will be a profitable year in these markets. However, we expect 1997 to be the least profitable year in DRAM since 1992, if not before.

Dataquest sees long-term growth in most segments, including DRAM, SRAM, flash, and EEPROM, but flat performance in the EPROM and ROM markets. Memory revenue should grow at a compound annual growth rate (CAGR) of 27.3 percent between 1997 and 2001, with worldwide revenue reaching over $87 billion in 2000 before retreating slightly to just over $86 billion in 2001.

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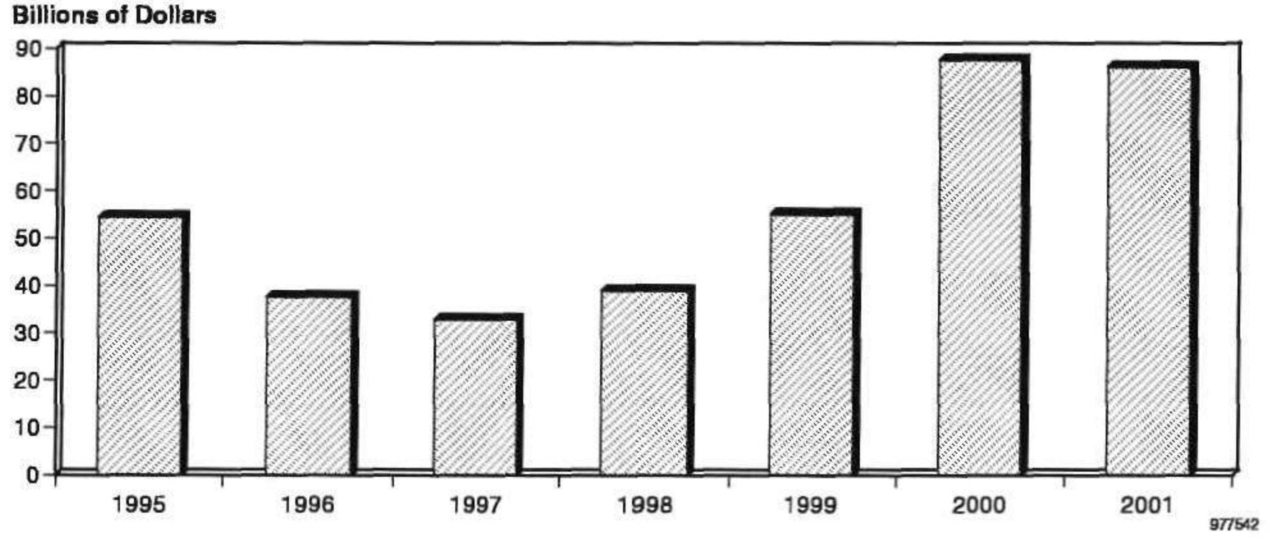
Figure 1
MOS Memory Revenue, 1995 to 2001



Source: Dataquest (October 1997)

DRAM

Worldwide 1997 DRAM revenue should decline to $22.0 billion, from $25.8 billion in 1996, a decrease of 14.6 percent. Worldwide DRAM revenue should total nearly $63 billion by 2001 and will peak in 2000 at over $68 billion.

Dataquest expects very strong PC demand throughout the forecast horizon, with worldwide unit shipments of PCs to more than double during the 1997-to-2001 period; PC shipments should expand from fewer than 71 million units in 1996 to nearly 152 million units in 2001. The amount of DRAM in each PC is likely to more than quadruple during this period. The amount of factory-installed DRAM had tripled from 8MB in 1995 to 24MB by the end of 1996. By 2001, most PCs are expected to have main memory sizes approaching 128MB, the current memory size of many workstations and network file servers.

Late this year, the conversion of the PC market from extended data out (EDO) to synchronous DRAM (SDRAM) will pose great difficulties for many DRAM manufacturers. Intel Corporation has recently shown Pentium II systems that don't support anything except SDRAM. Suppliers already strong in SDRAM will see their average selling prices (ASPs) rise slightly and will see their share of the market increase, while SDRAM laggards will lose market share and suffer from mushrooming EDO inventories. This will result in SDRAM shortages and a worsening oversupply of EDO, which should be expected to last for four months.

SRAM

Dataquest has adjusted the SRAM forecast downward for 1997, and we now expect 1997 worldwide SRAM revenue to total just under $4 billion, a 16 percent decrease from a disappointing 1996 total of $4.7 billion. This change is brought about by the continuing price slides that began with 1996's 32Kx32 crash. Nonetheless, Dataquest expects a strong rate of SRAM revenue growth in the long term. SRAM revenue will expand at a 30 percent annual rate from 1997 to 2001. Total SRAM unit shipments will hover at about 1 billion units through the term of this forecast, but ASPs should rise above their current extremely low levels.

The PC cache market is oversupplied in 1997 and in 1998 will be sourced through Intel Corporation, which will purchase these parts at aggressive prices. For this reason, the high-speed 1Mb market continues to suffer from low prices. Dataquest no longer believes that Intel's bundling of the 32Kx32 will cause prices for cache SRAMs to increase substantially.

Telecommunications continues to increase its importance in the SRAM market, consuming growing quantities of all densities of SRAMs at all speed ranges. Dataquest sees continuing demand, especially in telecom, for 256K parts in speed ranges from 10ns through 44ns. This is in spite of this part's discontinuance in PC caches because of the widespread availability of inexpensive 32Kx32s.

Nonvolatile Memory

The four nonvolatile memory technologies reflect differing market characteristics, although at times they compete head-on for applications. Flash memory—the emerging nonvolatile technology—is enjoying rapid bit and unit growth in 1997. However, prices have come down faster than this growth, creating a flat revenue trend, compared to last year. A wide range of applications use EEPROMs, including industrial, telecommunications, and consumer systems. Diversified applications mean a bright long-term outlook for the EEPROM market. In contrast, the mask ROM market has depended heavily on video game demand. ROM suppliers, however, are shifting their focus to other applications, such as laser printers. EPROMs are losing designs to flash memory, with unit shipments and revenue expected to be down from 1996.

Dataquest expects each to perform differently in the forecast window. Flash should continue to expand and benefit over the forecast horizon from the continued emergence of low-voltage handheld systems for telecom and computing applications. The outlook for EPROM shows a relatively flat market, despite the advent of more flash capacity coming on line. This is because EPROM manufacturing costs should remain below those of flash memory, and the product will simply move into a niche as long as it is supplied, which suppliers guarantee Dataquest will be a very long time. EEPROM market revenue quietly surged during 1996, and we expect impressive growth for the next several years. EEPROM market revenue will exceed both ROM and EPROM revenue in 1997, a reversal of history. The mask ROM market should be down but should bounce back through the forecast period.

Worldwide flash memory revenue should approach $3 billion for 1997, for a diminutive 6 percent growth rate over 1996—especially in light of its five-year CAGR of 21 percent. Dataquest sees the flash market trisecting into three distinct segments: low-voltage code store, mass data storage, and a generic "vanilla" type for the broad range of smaller applications.

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DRAM Corner

Hitachi Ltd. has announced that it will ship its 256Mb DRAM in a 400-mil package, skipping over the 500-mil package that most of its competitors will initially produce. The company says that it will do this using a new process, including a change in dielectric type.

The Dielectric Difference

Dataquest asked around and found that Hitachi will be using tantalum pentoxide (Ta_2O_5) as the storage dielectric. We are hearing that some of the technical integration issues that have held the technology back are now being solved.

Tantalum pentoxide will be used for the storage dielectric because it has a higher dielectric constant than today's predominant DRAM dielectric, S_3N_4. The higher the dielectric constant, the more charge the capacitor can hold and the denser the DRAM can be made. To put it another way, the higher dielectric constant is necessary to achieve a higher capacitance within a smaller capacitor area. NEC Corporation used BST—$(BaSr)TiO_3$—for its experimental sample of 4Gb DRAM. The dielectric constant of tantalum pentoxide is higher than S_3N_4 and lower than BST.

The current problem with higher-dielectric-constant materials is that these materials are difficult to use in conjunction with today's silicon processes. These difficulties are slowly being overcome.

Some dielectric constants are:

- Silicon dioxide: 4
- Silicon nitride: 6
- Tantalum oxide: 25
- PZT: 400 to 600
- BST: 700 to 800

Tantalum oxide will be implemented first, because it is compatible with polysilicon structures. After that, some companies will use PZT, and others will use BST.

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Dataquest's Tactical Memories Newsletter
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Dataquest's Tactical Memories Newsletter —Vol. II, No. 20

- *Micron Technology Reports Quarterly Earnings*
- *Antidumping Charges in the SRAM Market*
- *FRAM Technology Update*
- *SIMMs, DIMMS, and Now RIMMs*
- *Moore's Law Intact Despite Multilevel Flash*
- *DRAM Corner*
  - *- Texas Instruments DRAM Rumor*
  - *- Samsung Says There Is No Premium for Synchronous over EDO*

Micron Technology Reports Quarterly Earnings

Micron Technology Inc. reported earnings for the fiscal fourth quarter of 1997 and fiscal year 1997 on September 22. This article focuses on the quarterly results announced, especially for the semiconductor and DRAM business.

For the fourth quarter of fiscal year 1997, Micron Technology's net sales were $946 million and net income was $72 million, or $0.33 per fully diluted share, compared to net sales of $965 million and net income of $97 million ($0.44 per fully diluted share) for the third quarter of 1997.

DQ Take

The recent quarter was quite challenging, and the company is glad that quarter is now behind it. Key results included the following:

- Average selling prices (ASPs) for the company's semiconductor memory products declined 13 percent in the fourth quarter of 1997, compared to the third quarter.

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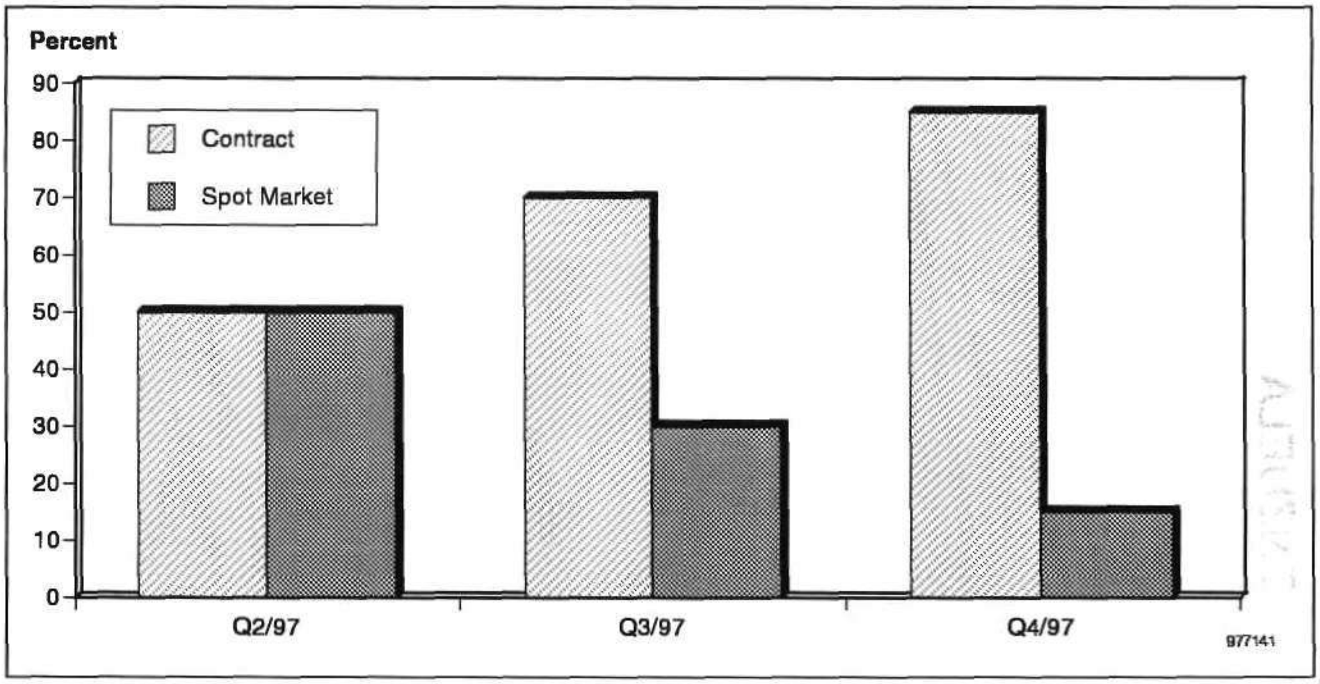
- Gross margins on the company's semiconductor memory products declined from 49 percent in the third quarter to 44 percent in the fourth quarter of 1997.
- DRAM and other semiconductor ASP declines exceeded Micron's ability to reduce costs for these products.

The analyst conference call with Micron as usual provided lots of insight into today's DRAM environment. Highlights include:

- An assembly and test bottleneck prevented Micron from shipping as many DRAMs as possible; factors such as the migration to synchronous DRAM (SDRAM) in part explain the bottleneck.
- Micron does about 85 percent of its DRAM business via contracts and sells the other 15 percent on the spot market—a dramatic reversal from six to 12 months ago and in line with the company's goal of focusing on the more stable contract business. This transition away from the spot market is shown in Figure 1.

Figure 1
Micron's Transition away from Spot Market Sales



Source: Dataquest (October 1997)

Micron reported the following 16Mb DRAM pricing trends as of mid-September 1997:

- Spot pricing ranged from $5.20 to $5.30.
- Contract pricing was 5 percent to 10 percent higher (a likely range of $5.45 to $5.85).

As Dataquest has noted before, Micron is likely to be the market's lowest-cost 16Mb DRAM producer, so the company can remain profitable at these prices. Micron had indicated last quarter, however, that it really desired a contract price of $7 or more. A price under $5 for 16Mb DRAM would mean more challenge for Micron—and a lot of heartburn for other DRAM suppliers.

In response to a question from Dataquest, Micron said it will migrate to 0.25-micron technology in early or mid-calendar year 1998. By the end of 1997, the 0.3-micron process will represent 100 percent of Micron's manufacturing technology. In response to another analyst's question, Micron said it will be able to perform 0.25-micron processing without the need for deep-UV stepper technology.

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Antidumping Charges in the SRAM Market

Alliance Semiconductor Corp. responded to a preliminary determination by the U.S. Department of Commerce that Alliance should pay a duty of 59.06 percent on the importation of Taiwan-fabricated SRAMs. The preliminary decision was issued in response to a petition filed in February 1997 by Micron Technology claiming that a number of companies, including Alliance, sold SRAMs in the United States in 1996 below "fair value." The Commerce Department also announced that antidumping duties of up to 113.85 percent should be imposed on other companies that manufacture SRAMs in Taiwan or Korea and import these products into the United States.

Alliance's president said that the company believes this decision is unjustified and that it will vigorously contest the Commerce Department's preliminary determination.

DQ Take

Our eyes popped when we first saw the 113 percent number! Thinking that this was based on the damages done, Dataquest called the International Trade Commission, and a representative explained that the duty was retribution for those companies that ignored the department's orders to supply data for the investigation. These companies were TI-Acer, which doesn't even *make* SRAMs (and probably thought the order was a mistake), Advanced Microelectronics, and Best Integrated Technology Inc., companies that do not deal in the United States and probably do not see a need to comply with a law in a country in which they conduct no business.

The ITC also explained how U.S.-based companies could be penalized if they produced products overseas and sold them at a price below cost that was injurious to their competition. This point is a little difficult to grasp.

The companies named in the original suit were Winbond Electronics Corporation, Alliance, Integrated Silicon Solution Inc., United Microelectronics Corporation, Mosel Vitelic Inc., Vanguard International Semiconductor Corp., Hualon Microelectronics Corporation, Lien Hsing

Integrated Circuits, Chia Hsin Livestock Corporation, Etron Technology Inc., G-Link, Utron, Kes Rood Technology Taiwan Ltd., Taiwan Memory Technology Inc., Best Integrated Technology, Asian Specific Technology Limited, Samsung Electronics Company Ltd., Hyundai Electronics Company Ltd., and LG Semicon Co. Ltd. Because we have not yet seen the text of the finding, we do not know of the status of any companies but those named in an *Electronic Buyers' News* article that ran last week. Rumors indicate that the Taiwanese company names (many of which are so obscure that they even avoid Dataquest's eye) and the names of U.S. companies that manufacture in Taiwan were taken from Taiwanese newspapers. Dataquest's understanding is that TI-Acer wasn't even named in the original complaint!

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FRAM Technology Update

Matsushita Electric Industrial Company Ltd. announced that it has acquired more than 10 patents for ferroelectric (FRAM) technology in the United States and that it has about 200 FRAM technology patents pending. Matsushita has applied for the FRAM patents in both the United States and Japan.

DQ Take

The 10 Matsushita patents are for memory cell and circuit construction and are based on the Y-1 method of Symetrix Corporation. Matsushita believes that other FRAM designs may infringe on Matsushita's patents. Currently, FRAM development is categorized as either Ramtron-type or Symetrix-type technology.

Ramtron International Corp.'s FRAM licensees are Fujitsu Ltd., Toshiba, Hitachi, Samsung, Rohm Company Ltd., and SGS-Thomson Microelectronics B.V.; Symetrix's licensees are Matsushita, NEC Corporation, and Siemens AG. The following quote from Ramtron's form 10Q dated August 14, 1997, gives an indication of how important these licenses are for Ramtron:

"The Company is continuing its efforts to improve existing internal manufacturing capabilities and obtain commercial production of its FRAM products through its alliance partners, which the Company believes is essential to its future profitability."

There is already a significant level of effort devoted to the mass production of Ramtron-based FRAM technology. The Matsushita patents should help push the mass-production capability for the Symetrix process. The Symetrix technology is believed to be superior to Ramtron's in access speed and number of write operations.

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SIMMs, DIMMs, and Now RIMMs

Eighteen companies, including DRAM, memory module, connector, clock chip, and test equipment manufacturers, announced support for Rambus Inc.'s Direct Rambus DRAM (RDRAM). In related announcements, both Kingston Technology Corp. and SMART Modular Technologies Inc., two of the 18, made joint statements with Rambus that they will manufacture and distribute memory modules that support the Direct Rambus high-speed memory interface. The announcements coincide with Rambus' disclosure of the Direct Rambus main memory system packaging at the inaugural Intel Developer Forum in Burlingame, California. The Direct RDRAM modules for use in PC main memory will be known as Direct Rambus RIMM modules.

DQ Take

There are two important points in these announcements. One is that technology advances in DRAM may change the landscape of the third-party memory module industry. And the second is that Rambus is actively preparing the infrastructure needed to manage the transition to this new interface.

Third-party memory module manufacturers pride themselves on being service-oriented companies and not necessarily technology leaders. The current transition to SDRAM, and then the following transition to next-generation memories like Rambus, will challenge their business model. The design, manufacture, and test of SDRAM and Rambus modules will prove to be much more daunting than the board stuffing of the past, which may trigger an industry consolidation. Kingston and SMART, both well-positioned, are stating with their announcements that they are committed to succeeding in this changing market. Dataquest expects that many of the other top module companies will follow with similar announcements.

The infrastructure issue is critical for Rambus. Intel's memory road map designates 1999 as the starting point for the transition to Direct Rambus in PC main memory. For this to have any chance of occurring, not only will Direct RDRAM chips and an associated chipset have to be available, but the memory system infrastructure (testers, modules, connectors, and so on) will also have to be ready.

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Moore's Law Intact Despite Multilevel Flash

In the last issue of this newsletter, we covered Intel's multilevel flash announcement, which even Intel said "goes beyond Moore's law." Moore's law, as most will remember, states that the number of transistors on a chip seems to increase at a relatively predictable rate, based on three factors: shrinking line geometries, increasing die sizes, and an extra "something" Dr. Moore called "cleverness."

Dataquest believed that the use of individual memory cells to store two bits instead of one did not go beyond Moore's law but instead fell within the often-overlooked cleverness category.

Dataquest spoke with Dr. Moore this week, and he refuted even this. He pointed out that the findings of his papers, so often called Moore's law, projected the number of transistors on a chip and had nothing to do with how they were used. We were wrong. But, then, so was Intel!

Interestingly, Dr. Moore himself says that his findings are often misrepresented. He started his 1995 paper by saying: "The definition of 'Moore's law' has come to refer to almost anything related to the semiconductor industry that when plotted on semilog paper approximates a straight line. I hesitate to review its origins and by doing so restrict its definition."

Anyone wishing to receive a bad photocopy of Moore's two papers from 1975 and 1995 is welcome to contact Carole Phillips at the phone number or e-mail address shown at the end of this newsletter.

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DRAM Corner

Texas Instruments DRAM Rumor

Oddly enough, Dataquest was asked this week to confirm or deny a rumor that Texas Instruments is leaving the DRAM market. Dataquest has heard nothing like this. TI's top-level public comments are that it expects that DRAM revenue in the long term will continue to be about 15 percent to 25 percent of total revenue. Digital signal processing (DSP) will be one key driver and DRAM will be the other to its process technology, product portfolio, and intellectual property portfolio. TI wants to keep DRAM capital risk low (which will be executed through the joint venture and funding route with competitors such as Hitachi, governments, and major customers), but no signals point toward a TI DRAM market exit.

There is no good reason for TI to get out of DRAMs. TI gets everybody else to do the capital investing for it and exchanges this for the rights to its technology. This is pretty profitable for TI, when its royalties are added to its DRAM profits. Why would a company even think of getting out of such a business?

Earlier this year, Motorola Incorporated announced that it planned to leave the DRAM market. Maybe the rumor got these two companies confused with each other.

Samsung Says There Is No Premium for Synchronous over EDO

From a PaineWebber Incorporated report on an analyst tour to Korea, Dataquest extracted the following information:

"Samsung is the largest 64Mb DRAM producer, with 20 to 25 percent of 64Mb output presently synchronous, expected to grow to 40 percent by December; however, there is no price premium for SDRAM over EDO."

Although this appears to be news, Samsung and NEC have been saying that SDRAM carried no price premium for about one and a half years.

Why? Well, when companies can pick which EDO business to take, they can avoid taking EDO orders for prices lower than those for SDRAM. The same holds true for the 4Mb-to-16Mb crossover and the 16Mb-to-64Mb crossover, which Samsung expects to happen late this year, although this might be effected by raising the 16Mb price rather than by lowering the 64Mb price.

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Dataquest's Tactical Memories Newsletter
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Dataquest's Tactical Memories Newsletter —Vol. II, No. 19

- *Intel Announces Multilevel Cell Flash with Great Fanfare*
- *IDT, Micron, and Motorola ZBT SRAMs*
- *NEC and Toshiba Announce Production of 16Mb SGRAMs*
- *DRAM Corner*
    - *- SLDRAM Standard Responds to Rambus Heat*
    - *- Several Capacity Expansion Projects Announced*

Intel Announces Multilevel Cell Flash with Great Fanfare

Intel Corporation announced a 64Mb flash memory dubbed "StrataFlash" that uses a multilevel cell (MLC) technique that dramatically increases capacity per chip, and reduces the cost per bit. The device, 28F640J5, has only 32 million cells to store 64 million bits using a two-bits-per-cell MLC method. Intel positioned the technology as "moving beyond Moore's law," and states that it "allows Intel to be one chip generation ahead of the industry." It said the chip is now available for samples, and production will start in the first quarter of 1998 at a price of $29.90 in quantities of 10,000.

DQ Take

This story was widely covered by the popular daily press, including a front page article in the *New York Times*, as a breakthrough event that will have a broad effect. Later stories were more subdued than the original *Times* article, which tried to link MLC to processing speed—which is *not* the case. Not only is this applicable only to memories, flash memory alone can use it to advantage. So why is it significant?

The breakthrough is in storing more than a bit per cell. This gives a density improvement that is akin to building a high rise on a plot of land that previously had a single-story structure. More people will fit on a given lot,

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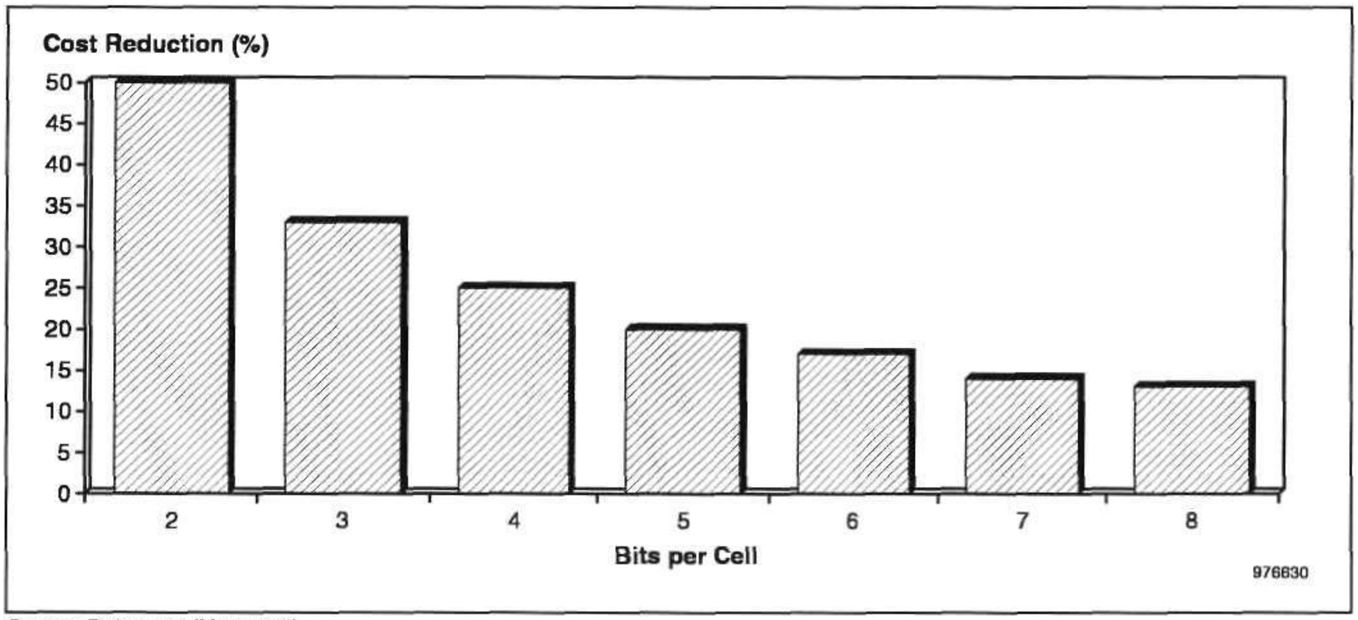
but at some extra cost. The same is true for MLC flash, with the overhead cost associated being around 10 percent. Ignoring this overhead cost, Figure 1 shows the ideal cost benefits of adding more bits per cell. It shows diminishing returns of implementing more levels per cell. So this technique does not break Moore's law (double density/speed every 18 months), it merely gives a temporary boost that will allow flash to get closer to the lithography leader of the semiconductor industry, DRAM.

Figure 1
Incremental Cost Reduction for Multiple-Bits-per-Cell Storage



Source: Dataquest (May 1997)

Other companies have been shipping MLC flash already, but not as a separate standalone memory chip like Intel's. SanDisk Corporation has been shipping high-density solid-state disk memory cards using 64Mb MLC chips since last quarter, and Integrated Storage Devices has been selling single-chip voice recorders using MLC in EEPROM since 1992. Samsung Semiconductor Inc. is already selling a 64Mb NAND flash memory (single bit per cell) for about the same price as Intel, $30; one could see Intel's move as a catch-up tactic. The importance of this announcement is as a signal that flash can use MLC in high volume and that flash will become a true mass-storage medium, as hard disk drives are in personal computers, but at a much higher cost per megabyte. It will *not* replace disk drives!

What it will be used for is solid-state mass storage in applications that can benefit from cheaper nonvolatile memory, such as digital cameras and handheld computers/organizers, perhaps using Windows CE. For instance, this could be enabling to high-quality digital photography because it lowers the user cost of storing the coming megapixel images to less than a dollar, which is acceptable because the flash memory cards are reusable after the pictures are downloaded to a PC. Further, Dataquest believes this will allow mass-storage flash memory to drop to $1/megabyte within three years, promoting its widespread use to support the "digitalization" of consumer electronics.

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IDT, Micron, and Motorola ZBT SRAMs

Integrated Device Technology Inc., Micron Technology Inc., and Motorola Incorporated have announced a cooperative agreement to market SRAMs based on the Zero Bus Turnaround (ZBT) architecture. The three companies have agreed to manufacture and market proprietary products based on the same architecture and product pinouts.

ZBT SRAMs are ideal for high-end networking products requiring high bandwidth, such as switches and routers. The ZBT architecture, as opposed to other forms of synchronous SRAMs, provides users with 100 percent bus utilization by eliminating idle bus turnaround cycles.

IDT, Micron, and Motorola have established a common pinout for 3.3V 4Mb-density ZBT SRAMs allowing for a future upgrade path to 8Mb and 16Mb densities. All three vendors will be offering 3.3V 4Mb ZBT SRAMs in 128Kx36 and 256Kx18 configurations. The 4Mb SRAMs are packaged in 100-pin thin quad flat packages (TQFPs) with initial speed grades of 133 MHz for the pipelined version and 66 MHz for the flow-through version. Initial 3.3V 4Mb samples are expected early in calendar year 1998.

DQ Take

Just when you thought you had seen your last confusing acronym, along comes another. ZBT, despite what you may think, is a very logical means of providing slightly more bandwidth in the highest-speed synchronous systems. What it means to these three companies, all of which are weary of the difficult pricing brought about by a massively oversupplied PC cache market, is an opportunity to keep a corner of the market operating in a higher-profit-margin area.

The device appeals to the telecommunications market, one that has been good to Motorola and IDT. It is a little surprising to see Micron on the team, since it has been downplaying its role in the SRAM market for the past two years, and it both is and is not a surprise to see that Cypress Semiconductor Corporation's name is not on the list. Cypress and IDT have always been rivals, to the point that it is not surprising to see a lack of cooperation on this specification, yet Cypress has aligned itself more and more with the needs of the telecom market and therefore should be interested in a device that is interesting to its own customers. It appears that Cypress has decided to follow its own direction with a similar device, the NoBL, which stands for "no bus latency." This part is supposed to be pin-compatible with the ZBT device, further adding to the list of acronyms.

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NEC and Toshiba Announce Production of 16Mb SGRAMs

NEC Corporation and Toshiba Corporation have both announced 16Mb-density synchronous graphics RAMS (SGRAMs). NEC sampled the device as early as last March. Operating at up to 143 MHz, both companies' 16Mb SGRAMs have a bandwidth of 572 MB/sec. Both vendors' devices conform to the Joint Electron Devices Engineering Council (JEDEC) SGRAM standard.

SGRAM features include wide I/O bus width (32 bits), increased effective bandwidth, and write-per-bit (WPB) and block-write features. The 16Mb devices are organized as 256K words x 32 bits x 2 banks. This organization is oriented toward the resolution and color needs of a high-performance 1280 x 1024 display.

Toshiba's chip currently runs at 100 MHz and is based on a 0.45-micron CMOS DRAM process. The NEC part is manufactured on a 0.35-micron process and runs at the full 143-MHz speed.

Customer samples of the Toshiba device are available now priced at $15 in quantities of 1,000. Full production is scheduled for fourth quarter 1997. NEC's 16Mb SGRAM is available for about $11 in quantities of 10,000.

Toshiba also announced that it is developing next-generation SGRAM devices, which include a die shrink to 0.25 micron and additional features such as single data rate (SDR) and double data rate (DDR) with 100-MHz and 125-MHz performance levels.

DQ Take

Just as the 8Mb SGRAM is reaching mass acceptance, the 16Mb part is making its debut. Interestingly enough, the 8Mb market is one in which Toshiba did not participate. The company says that it felt that it had the graphics market covered with Rambus and extended data out (EDO).

These parts are already supported by several graphics controllers, including Matrox Graphics Inc.'s engines and S3 Inc.'s ViRGE/GX. This should help it rapidly gain acceptance in systems needing higher performance than that which could be easily achieved using the 8Mb device.

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DRAM Corner

SLDRAM Standard Responds to Rambus Heat

The SLDRAM Consortium released specifications for its first reference devices. These specifications, released on September 15, were not due until early 1998 and so were significantly ahead of schedule. The specification is for a 400-Mbps/pin 64Mb SLDRAM (formerly called SyncLink DRAM). The consortium plans subsequent generations with increasing density and bandwidth, to 1Gb, 800 Mbps/pin and beyond. The SLDRAM specification is available now through the consortium's Web site: www.sldram.com.

The development of a 64Mb SLDRAM meeting the new specification is in advanced stages at MOSAID Technologies Inc. of Canada, with the participation of other consortium members' engineers. The device, using Siemens' 0.25-micron process, will be a reference device for all consortium members to ensure compatibility with the SLDRAM specifications. Samples are expected to ship in the second quarter of this year. Test chips incorporating SLDRAM drivers, receivers, and timing adjustment circuits have been fabricated by both Hyundai Electronics Company Ltd. and Mitsubishi Corporation.

Standardization of SLDRAM is proceeding with the presentation of packages, pinout, command format, and interface specifications at JEDEC and the final IEEE specification, P1596.7.

Micron announced to *Electronic Buyers' News* that the company plans to sample its own implementation of the SLDRAM in the first half of 1998. The company said it will be first to demonstrate both working SLDRAM silicon and a functional chipset next year in an attempt to persuade Intel to drop its Rambus PC design.

The plan to sample the Micron SLDRAM in the first half of 1998 should put the company well ahead of any Direct RDRAM chip samples, allowing Micron to get a significant advantage with computer OEM designers, based on the fact that the final Direct RDRAM specification has not yet been delivered to licensees.

Meanwhile, JEDEC, in its first-ever overseas meeting, held in Taipei, approved specifications for DDR synchronous DRAMs, although certain issues still need to be resolved. DDR uses both the rising and falling edge of the clock cycle for data manipulation. The 125-MHz clock speed DDR specification supports data rates of 250 MB/sec on an 8-bit-wide device and twice that on a 16-bit-wide device.

Rambus Inc., on the other hand, is succeeding in rounding up the stragglers, now with Intel on its side. The latest company to announce a Direct RDRAM license is IBM.

DQ Take

As Rambus gains a following, the alternatives to Rambus technology seem to be working harder and harder to get to the point at which they can make a difference to what appears inevitable. Intel has been known to change direction at the last minute, and there is a slim chance that the SLDRAM consortium or another technology could displace Rambus entirely; however, Dataquest thinks that this is against the odds.

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Several Capacity Expansion Projects Announced

NEC and Siemens Investments in Singapore and Malaysia

NEC plans to build a new assembly and test facility in Singapore by December 1998 and to invest an additional $200 million in its Singapore operations by the year 2000. NEC has so far invested about $350 million in its Singapore operations since the unit's founding as a semiconductor manufacturing base in 1976. As a result of the expansion, NEC expects to hire 600 more employees and raise the facility's production volume to more than 2.5 times its current level. The new factory will assemble and test 64Mb and 256Mb DRAMs, application-specific ICs (ASICs), and other components.

Meanwhile, Siemens AG will invest another $83 million to modernize a similar plant in Malacca, Malaysia. Over the past decade, Siemens has invested about $3 billion in its two semiconductor factories in Malaysia, which produce memory chips and electronic components.

Toshiba IBM Dominion Fab Coming on Line

Toshiba and IBM began operations on September 15 of their 50-50 joint venture 64Mb DRAM wafer fab in Manassas, Virginia.

The venture, called Dominion Semiconductor, will become the first plant in the United States to mass-produce next-generation 64Mb DRAM chips, according to the leading Japanese and U.S. computer makers. The plant will initially make 64Mb DRAMs using 0.35-micron lithography. From the second half of the fiscal year ending in March 1999, it will shift to more sophisticated 0.25-micron products, moving to the 256Mb DRAM in the future.

When it reaches full operation, the $1.7 billion plant's capacity will exceed 27,000 wafers per month. The number of employees is expected to rise to 1,200 in 1999 from 470 at present.

Fujitsu Expands Gresham, Oregon, SDRAM Fab

Fujitsu Microelectronics Inc. opened an expanded 545,000-square-foot facility in Gresham, Oregon, more than doubling its U.S. manufacturing capacity. The enlarged facility, which will cost more than $1 billion, will produce 64Mb synchronous DRAMs (SDRAMs). Mass production will begin in October. The 8-inch, 0.32-micron facility is expected to employ about 600 technicians and professionals when it reaches full production.

Fujitsu Ltd., FMI's parent company, has been shipping 64Mb SDRAM chips manufactured in Japan for more than a year.

DQ Take

It is nice to continue to see announcements of increasing capacity in the face of the current difficult DRAM market. In prior times, capacity expansion has suffered severely from the effects of an oversupply. Is the industry maturing in its response to the ebb and flow of DRAM market tides?

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Dataquest welcomes DRAM tactical reports from readers. Please send them by e-mail to ron.bohn@dataquest.com.

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Dataquest's Tactical Memories Newsletter
251 River Oaks Parkway, San Jose, California 95134

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Perspective

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Market Analysis

Dataquest's Tactical Memories Newsletter —Vol. II, No. 18

- *PC-100 SDRAMs and Intel's 440LX Chipset*
- *Market Rebound?*
- *European Expansion, Part II*
- *DRAM Corner*
    - *- 64Mb DRAM: A $30 Price This Month?*
    - *- Micron Shrinks 16Mb Die below 30 Square Millimeters*

PC-100 SDRAMs and Intel's 440LX Chipset

Last week was pretty stirring, with the introduction on Monday of Intel Corporation's 440LX chipset and Micron Technology Inc.'s announcement the very next day of a 125-MHz 16Mb synchronous DRAM (SDRAM). Intel's 440LX chipset is expected to be used in PCs with SDRAM main memories, and Micron's 2Mx8 SDRAM is aimed squarely at the PC-100 specification for PCs with a 100-MHz system bus speed. The week before, SMART Modular Technologies Inc. introduced a line of 100-MHz modules "in compliance with new component and module specifications." We should explain that the PC-100 specification had not been formally announced by Intel at the time. Figure 1 shows the 440LX chipset shipment forecast.

DQ Take

There is a lot of talk about the technical issues causing the switch from EDO to SDRAM. Many believe that the increase SDRAM produces in computing horsepower alone does not warrant the transition, although the adoption of AGP might bring about a change in that thinking. Some here at Dataquest believe that competitive marketing will cause PC OEMs to differentiate their products based on main memory type, whether or not the performance difference is significant.

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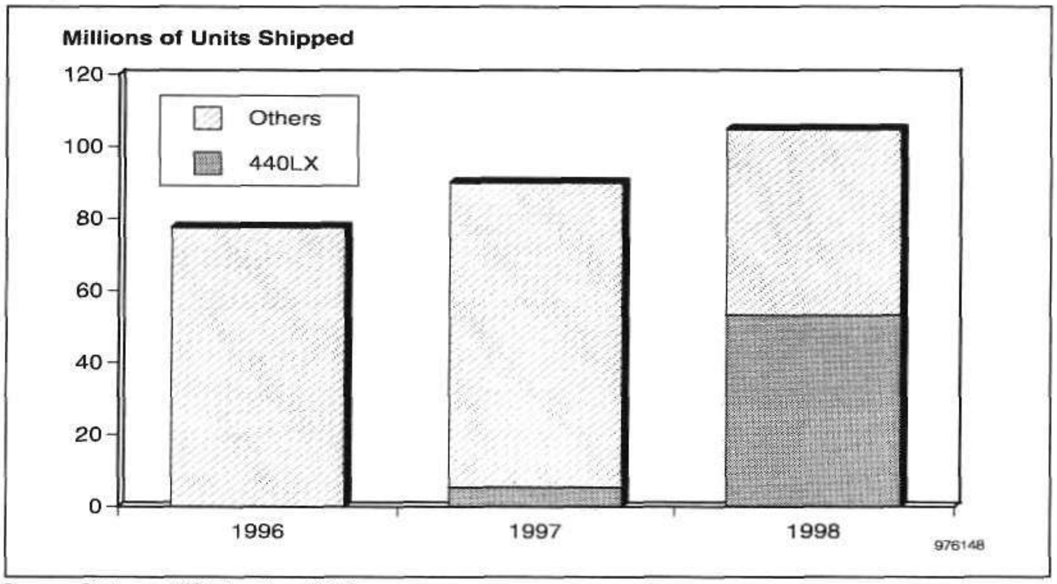
Figure 1
Recently Introduced 440LX Chipset Will Dominate System Shipments in 1998



Source: Dataquest (September 1997)

We have recently heard that some PC OEMs plan to simplify their inventory management by producing only PCs using SDRAM. On the other hand, some Japanese DRAM manufacturers are reducing their SDRAM production, based on the poor benchmark improvements SDRAM brings to 440LX-based systems in comparison with extended data out (EDO), and are hoping that the 440BX will produce a better opportunity for SDRAM success next year.

The 400LX is putting DRAM manufacturers in a difficult position, because the technology most needed to meet the PC-100 specification is something smaller than 0.35 micron, and most have lined themselves up to produce 0.25 micron as their next process. The 0.25-micron process is targeted at the 64Mb density and is less efficient at producing 16Mb devices than it is at producing the 64Mb DRAM. Should Intel drive the market from 66 MHz to 100 MHz too soon (which is expected to start late in the first half of next year), it might cause granularity problems. DRAM manufacturers will support PC-100 with 64Mb SDRAMs, while PC OEMs will want to purchase PC-100 16Mb SDRAMs.

The 100-MHz target is tough for other reasons, too. Modules need to be optimized significantly in order not to ruin the tricky timing required in PC-100 systems. For this reason, module manufacturers that can design, manufacture, and test 100-MHz PC-100-compliant modules deserve a pat on the back.

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Market Rebound?

Robertson Stephens and Company LLC, an investment banking firm, said on Thursday that it expects a strong rebound in the PC industry such that Intel's third quarter revenue will be up 5 percent. It believes that Intel had a much better July and August than first expected. Intel initially gave guidance of flat third quarter revenue. It also expected Intel to have a better-than-expected fourth quarter because PC demand continues strong.

Robertson Stephens said that PC demand is strong, with several PC companies indicating strong year-over-year growth. Dell Computer Corporation reported unit growth up 60 percent in their July quarter, Compaq Computer Corporation's unit growth was up 84 percent in July and more than 60 percent in August. Regionally, North America is doing better than expected, Europe is also doing better than expected, Japan is on plan, and Asia/Pacific seems to be slightly below plan.

DQ Take

Dataquest has been hearing of bad bookings in both July and August from DRAM companies, which are hoping that this quarter will be heavily loaded at the back end. Meanwhile, prices are about as soft as they can be.

Although we do not doubt it for a minute, we find it strangely ironic that the same PC market that is driving Intel's success and in which unit volumes are increasing for most regions of the world is a painful market for DRAM manufacturers. This all boils down to the nature of an oversupply and should not be expected to end until the demand/capacity balance that Dataquest's Supply and Demand Quarterly Statistics Worldwide program has been forecasting for the past two years.

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European Expansion, Part II

Kingston Technology Corp. announced that plans have been approved for a 50,000-square foot European manufacturing facility in Dublin, Ireland. Kingston will invest about $10 million over the next five years, with the support of Ireland's Industrial Development Agency, or IDA Ireland. The facility is expected to begin operation in early 1998.

DQ Take

In the previous *Tactical Memories Newsletter*, Dataquest addressed the importance of global coverage for third-party module companies that want to manufacture for DRAM companies and OEMs. With this announcement, Kingston is adding its name to the list of U.S. manufacturers that operate or have announced plans for European manufacturing facilities.

Kingston has expanded quickly from a company that relied on contract manufacturing to a company that now has opened or announced in-house manufacturing capability in the United States, Ireland, and Taiwan. It is no coincidence that this expansion follows closely after Kingston's dedication to providing manufacturing services to OEMs. With these facilities, Kingston will be manufacturing in the three regions that Dataquest believes constitute a minimum for global coverage (the United States, Europe, and Asia/Pacific).

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DRAM Corner

Dataquest welcomes DRAM tactical reports from readers. Please send them by e-mail to ron.bohn@dataquest.com. The recent comments and questions are appreciated.

64Mb DRAM: A $30 Price This Month?

Recent reports have indicated that some first-tier DRAM buyers would win a $30 price for 64Mb during calendar fourth quarter 1997. Much to suppliers' consternation, perhaps buyers will win it this quarter. Reports from Asia show that several suppliers now offer 64Mb at $30. At least one major supplier was offering the x16 device for a price of about $29. Expect more reports on the incredibly shrinking 64Mb price.

Micron Shrinks 16Mb Die below 30 Square Millimeters

Speaking of shrinks, reports continue circulating of 16Mb die shrinks. For example, Samsung Semiconductor Inc. reportedly has shrunk its 16Mb die to a size of 35 square millimeters.

The King of Shrinks

Micron, however, ranks as the "king of DRAM shrinks." Dataquest wrote a consulting report in 1996 on Micron's die shrink strategy. It stated that, based on historical data, "it would seem reasonable to expect a 16Mb (DRAM) die from Micron having a size of 28 square millimeters..." after 1996.

Table 1 highlights some of the history behind this die size projection.

Table 1
Estimated DRAM Die Size History for Micron Technology (as of September 1997)

DRAM Density	Initial Die Size (Sq. mm)	Total Number of Shrinks to Date	Time for Total Number of Shrinks	Latest Die Shrink Size (% of Initial Die Size)
64K	15	2	3 years	60
256K	50	3	4 years	38
1Mb	101	6	7 years	18
4Mb	100	6	6 years	17
16Mb	141	5	6 years to date	20
64Mb	208	Not available	3 years to date	≤ 50

Source: Dataquest (September 1997)

We should note that Micron's most recently developed shrink likely will not enter volume production until 1998. The number of 16Mb dice per 8-inch wafer (from the 28-square millimeter die) could total 900. By contrast, the current die—with a size of just over 40 square millimeters—generates more than 600 16Mb dice per 8-inch wafer.

64Mb Die Shrink Expectation

The information in the table indicates that, if historical trends prevail, Micron will shrink its 64Mb die to a size of about 40 square millimeters within several years.

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Market Analysis

Dataquest's Tactical Memories Newsletter—Vol. II, No. 17

- *WSTS Analysis Indicates DRAM Recovery*
- *Is There a 128Mb DRAM Market?*
- *SanDisk Inks Risky Cross-License Agreement*
- *Third-Party Expansion Continues in Europe*
- *DRAM Corner*
  -64Mb DRAM: $30 Price by the End of 1997?

WSTS Analysis Indicates DRAM Recovery

Figure 1 shows two rates of growth of the DRAM market plotted over each other: the 3/12 moving average (solid line), and the 12/12 moving average (dashed line). These curves are based on World Semiconductor Trade Statistics (WSTS) total DRAM market from January 1990 to June 1997.

Dataquest Europe regularly watches similar statistics for the overall semiconductor market in Europe. The crossover points for these two curves are indicators of a change in the market. The chart in Figure 1 shows total semiconductors worldwide rather than total semiconductors in Europe.

The crossover points are in April 1995 and March 1997 (marked with vertical lines), two apparently inauspicious dates from a DRAM market standpoint. Conspicuous in their absence are June 1992 (when prices first started to flatten) and December 1995 (when the collapse began).

The formulas used to construct the curves are:

- 3/12: For December 1996, (October + November + December 1996)/(October + November + December 1995) -1
- 12/12: For December 1996, (Sum [January - December] 1996)/(Sum [January - December] 1995) -1

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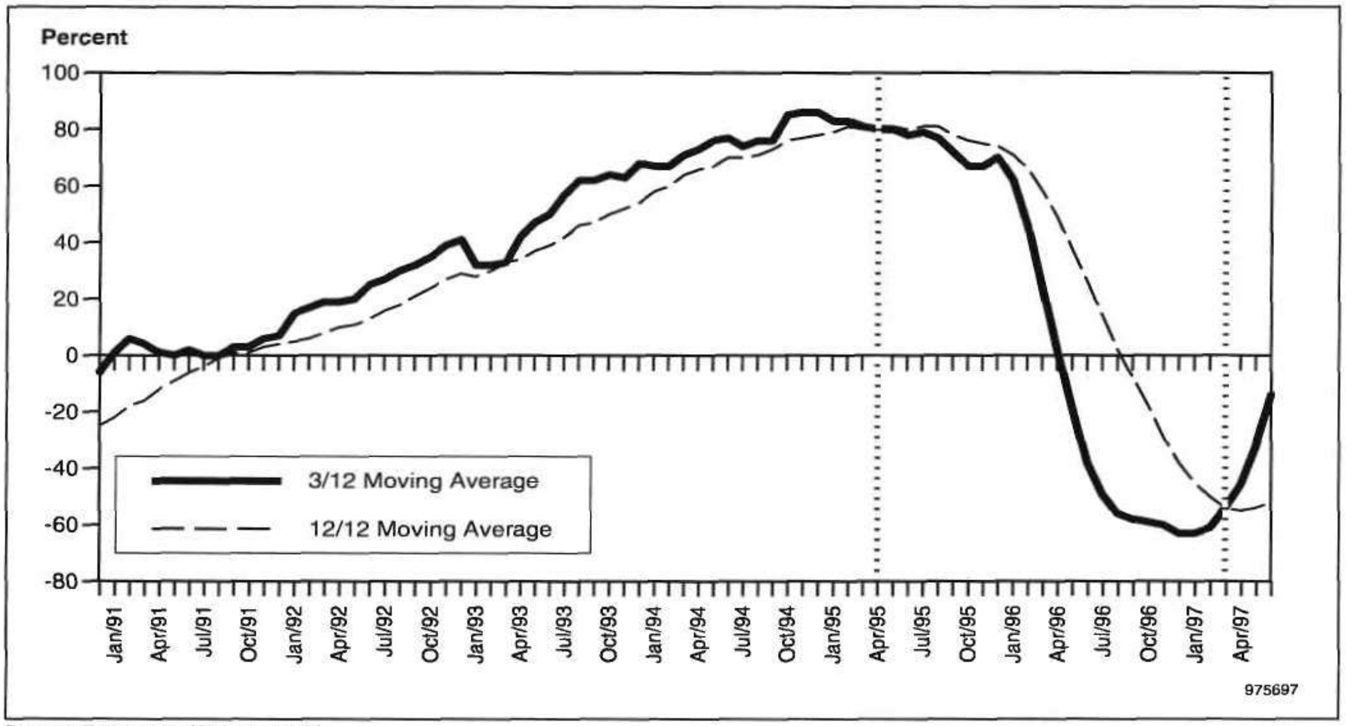
Figure 1
3/12 and 12/12 DRAM Growth Rates, December 1990 to June 1997



Source: Dataquest (August 1997)

DQ Take

It's always interesting to look at these curves with hindsight and try to explain what happened!

Aside from the rate of change of the 12/12, which is important in itself (and which dramatically follows the steep drop throughout 1996), the crucial points are the crossovers between the 3/12 and the 12/12. When the 3/12 crosses the 12/12, it tells us that the 12/12 curve is about to go through a turning point (usually about a quarter ahead). The crossover in April 1995 was a precursor of the DRAM crash in late 1995 and early 1996. There is some lag because even when the 12/12 is falling, it is still exhibiting growth until it falls below the x axis.

The crossover in March 1997 is a good sign because it predicted that the 12/12 would go through a minimum turning point—as it did a couple of months later. This should give us some confidence that a DRAM recovery is under way, although it may take several months for this to become apparent.

December 1995 on the graph shows the DRAM industry right on the edge of a cliff. As each subsequent month went by, the rolling annual growth dropped like a stone as more of the lower-revenue months were included in the averages.

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Is There a 128Mb DRAM Market?

Recently, 128Mb DRAM has been a frequent subject of discussion. A leading PC OEM asked selected DRAM companies to make 128Mb DRAM to support the OEM's granularity requirements. Now, breaking the traditional quadrupling pattern for DRAM capacity growth, major DRAM manufacturers are inclined to nominate 128Mb as the next generation after the 64Mb device.

DQ Take

The OEM considers a 128Mb part to be the most efficient way to configure a 64MB main memory for PCs. For a microprocessor with a 64-bit bus width, four 8Mbx16 versions of the 128Mb DRAM provide an easy means of building a 64MB main memory. Although the same memory could be built with only two 256Mb DRAMs, these parts would have to be made using an 8Mbx32 configuration. This high number of I/O pins is expected to present a problem to DRAM manufacturers. Products with wide outputs require additional interconnections and increasing die size, and they suffer from high levels of ground noise, limiting the maximum speed of the device and otherwise reducing yield.

Some DRAM makers are working vigorously and plan to ship monolithic 128Mb samples using a 256Mb process in the first half of 1998. Others plan to introduce a two-chip implementation sooner by using stacking technology.

Dataquest does not publish 128Mb DRAM statistics in the current version of the *DRAM Supply/Demand Quarterly Statistics* report. But we expect this device to influence demand and the balance status of 64Mb in 1998.

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SanDisk Inks Risky Cross-License Agreement

Samsung Electronics Company Ltd. and SanDisk Corporation announced that they have signed a cross-licensing agreement for flash memory-related patents. Under the agreement, Samsung and SanDisk have licensed each other's patents covering design and manufacture of flash memory products, giving both companies worldwide rights to use those patents. Also, this agreement resolves all the disputes between the companies before both the International Trade Commission and the U.S. District Court of Northern California. Specific terms of the agreement are confidential.

DQ Take

Dataquest predicted in the last issue of the *Tactical Memories Newsletter* that the flash memory cross-license agreement between Toshiba Corporation and SanDisk would pressure Samsung to settle also, because they are a team promoting NAND-style flash. Bingo—this happened fast! Samsung obviously felt it needed to maintain participation in the largest market for flash, North America, from which the ITC action removed it. Dataquest assumes this deal is similar to the Toshiba agreement, which seems to be a per-unit royalty instead of a lump-sum payment such as the one that the company received from Sharp, because no financial disclosures have been made. U.S. laws require publicly traded companies to disclose significant transactions quickly.

The really interesting twist on this is that the small-form-factor card that SanDisk is promoting, CompactFlash (CF), is also the reason for Samsung's growing success with its flash chips. CompactFlash is an open standard based on the rigid disk drive ATA electrical interface standard, which effectively masks the type of flash chip used in a card. SanDisk has been using this feature with its proprietary flash devices, based on NOR flash technology.

The clever thing some OEMs, such as Simple Technology Inc., are doing is designing CF cards with NAND chips. Doing this increases the credibility and support for the CF standard, aiding SanDisk. But NAND chips have much better write performance than NOR chips, almost 10 times better, so there is potential for Samsung to dominate the CF market that SanDisk started! Also, Samsung is the world's largest memory manufacturer and has the capability to drive the flash chip cost low enough to hurt SanDisk overall. But for right now, SanDisk has done something smart by being able to participate in a competitor's success via royalty payments and getting a potential CF supporter back on track.

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Third-Party Expansion Continues in Europe

Memory Card Technology, a Denmark-based third-party module manufacturer, is building a new 55,000-square-foot corporate, design, and manufacturing facility in Aarhus, Denmark. The manufacturing facility is scheduled to open in May 1998 and will be set up to include 10 manufacturing lines to produce memory module and PC card products.

DQ Take

Dataquest wonders how important regional positioning is to succeeding in the third-party memory module world. Considering that memory modules are small and easily shipped in volume throughout the world, one can argue that module-rich California can feed the world's appetite for third-party modules. However, anyone with product stuck on a shipping dock or in a United Parcel Service warehouse knows how delicate a balance overnight shipping can be.

MCT's growth over the last five years supports the argument that regional location does matter. With revenue approaching $100 million, MCT has capitalized on the opportunity that Europe offers. MCT has about doubled revenue every year since its inception in 1992, with sales almost exclusively to Europe. MCT benefits from the preference of many OEMs and resellers for using regionally close manufacturers.

Traditionally, third-party companies concentrate on aftermarket sales opportunities, but faced with declining industry revenue in 1996 and a continuing soft 1997, they are scrambling to establish revenue-enhancing relationships with OEMs and DRAM manufacturers to provide module manufacturing services. This musical chairs-like scramble impacts the importance of regional location. OEMs and DRAM manufactures will choose to work with companies that not only provide high quality and service but that are also strategically located. This implies that it is important to have manufacturing capability in the United States, Europe, and Asia/Pacific, at a minimum.

OEM and DRAM companies can approach outsourced manufacturing in two ways—through relationships with many manufacturers that are regionally dispersed or with a single manufacturer that has global capability. Dataquest suspects that both approaches will be implemented, but with a nod to global players. Any third-party company that is serious about contract manufacturing should look closely at the business models of large electronic equipment contract manufacturers such as Solectron, Jabil, SCI, and Celestica. Not only are these companies competitive threats, they have worldwide capacity already in place.

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DRAM Corner

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64Mb DRAM: $30 Price by the End of 1997?

Current reports indicate that the 64Mb price has fallen to the $35 level on some transactions. As noted in the prior report, several top-tier suppliers target a $30 price for the 64Mb part for major customers by or before the end of 1997. Current trends indicate that some first-tier DRAM buyers will win a $30 price for 64Mb during calendar fourth quarter 1997. Assuming that they will, the question shifts to whether they will get this price in early fourth quarter or much later in the year.

Dog Days of August

In American baseball, the season has hit the hot, humid, and tiring "dog days of August." Some teams know now that they no longer have any championship potential—but they must keep playing for another one and one-half months. The first-place team wishes that the season ended today—with it as champion—but it must play another six weeks and even more, if it is "lucky" in the postseason.

This sounds a lot like the DRAM market. Many suppliers are experiencing slower business. DRAM has moderated somewhat on a seasonal business, and pricing has really weakened. Meanwhile, conflicting PC market reports, centering on hard-to-confirm reports of a channel inventory buildup, concern DRAM suppliers.

Hope Springs Eternal ...

For baseball teams, hope springs eternal from February through March—the so-called springtime "preseason"—because every team, no matter how hopeless, could optimistically imagine having an opportunity to emerge as the ultimate champion.

For DRAM suppliers, hope springs eternal during the dog days of August that fourth quarter business will boom and they will meet or exceed the year's revenue and profit goals. For this year, Dataquest expects robust fourth quarter DRAM demand, but current pricing trends dampen the revenue and profit outlook.

Most suppliers will not be able to profitably sell a 64Mb DRAM for $30 by the end of 1997. They would love to sell 16Mb parts for $7.50 or more but instead confront sub-$6 price expectations from major customers. For DRAM suppliers, all of the 1997 cheering might already be over.

Looking forward, 16Mb pricing could be especially aggressive and ugly for them during the first half of 1998. By second quarter 1998, a growing number of suppliers will likely be ramping 64Mb supply. Major buyers will likely have secured low pricing on 16Mb parts late in 1997 and early in 1998. This could set the stage for a second quarter 1998 4:1 crossover to 64Mb DRAM at a price level that would have been almost unfathomable to DRAM suppliers just several months ago.

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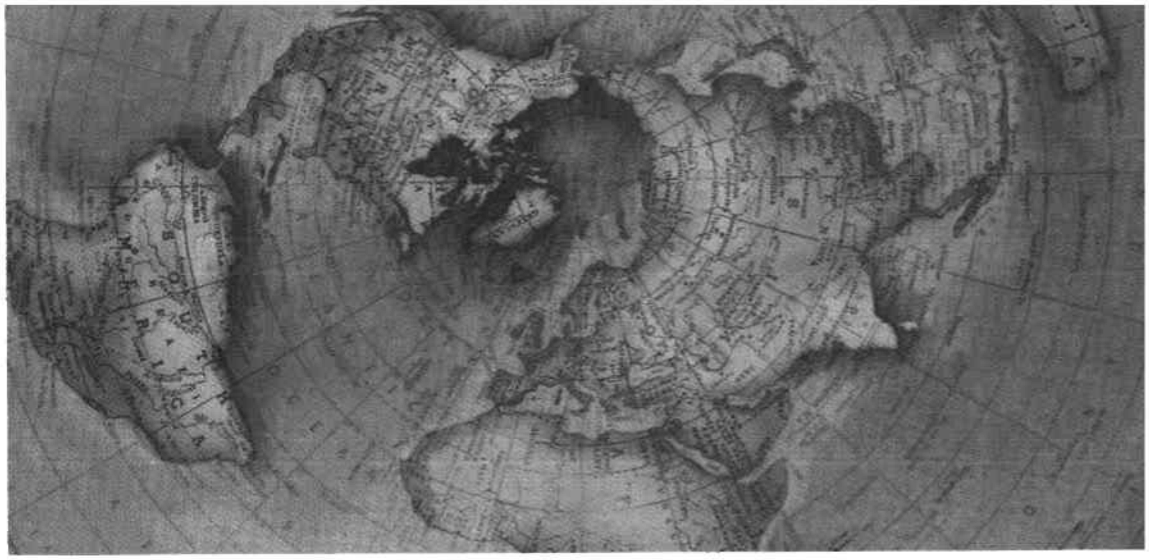

Memories Worldwide

Market Analysis

Dataquest's Tactical Memories Newsletter —Vol. II, No. 16

- *Intel Pushes Specification for PC Cameras without Its Flash Cards*
- *The 300mm Team-Up?*
- *SanDisk Signs Up Toshiba with Flash Patent Cross-Licensing Agreement*
- *Robertson Stephens Semiconductor Conference Review*
- *DRAM Corner*
  - *- Near-Term 64Mb DRAM Profit Outlook*

Intel Pushes Specification for PC Cameras without Its Flash Cards

Intel Corporation has released a design guideline that will enable the development of what it says will be low-cost, easy-to-use PC cameras for use with Intel-based computers. The Portable PC Camera '98 design guideline, which outlines how PC cameras can be used to capture, enhance, store, and share images and connect easily to the PC, is supported by 25 companies, including Hewlett-Packard Company, Eastman Kodak Company, and Microsoft Corporation. As shown in Figure 1, Dataquest believes the digital still camera market will grow to almost 6 million units by the year 2000, and the small form-factor cards for them will expand to nearly 18 million units.

DQ Take

The interesting part of this announcement, from a memory perspective, is not what is here, but what is not. First, this is mostly a PC specification, not really a camera spec. The file format in question, FlashPix, is not one meant for digital film or even for transferring data from the camera to the PC by a cable, but rather for PC-to-PC movement. The call for an MMX-class processor is somewhat redundant because the market is moving that way quickly. The strong suggestion to use Universal Serial Bus (USB) as the connection from the camera to the PC is the most significant, but still very obvious, part of the communique. All this is meant to give a clear set of PC

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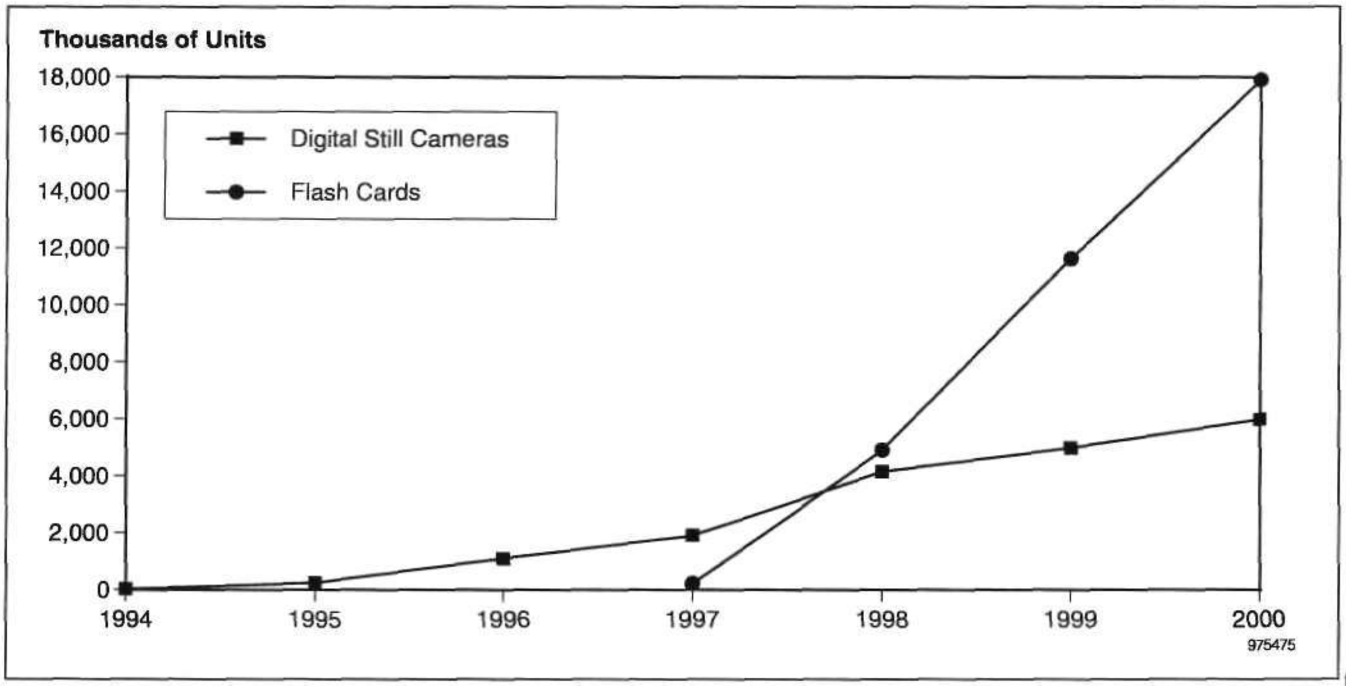
features for OEMs to have for a "school and holiday season 1998" push campaign that will have digital cameras bundled with specially configured PCs.

Figure 1
Unit Shipments of Digital Still Cameras and Small Form-Factor Flash Memory Cards



Source: Dataquest (August 1997)

But what came out after the paper announcement was released was that, while Intel would of course like to see everyone use its Miniature Card standard for removable storage, the company was not pushing hard for it compared to the FlashPix (which has nothing to do with flash memory). Worse yet, in this application, the Miniature Card is in direct competition with USB to get digital images back to the PC. If you have one, you do not need the other. When it came down to telling PC OEMs what to put into a system—USB or a Miniature Card slot—the answer was USB. Flash cards are to be used to expand the storage capacity of the camera, not for data interchange.

This reference design came out of Intel's Digital Peripherals Division, not the Memory Components Division that actually promotes flash cards. But it indicates that behemoth Intel is not 100 percent behind Miniature Card. Since it is in a fierce battle with SanDisk's CompactFlash products and Toshiba and Samsung's Solid-State Floppy Disk Card (SSFDC) products for camera design-wins, this does not bode well. CompactFlash already has a sizable lead in the market, and Dataquest sees the battle for the digital film standard being fought more and more between CompactFlash and SSFDC in the future, with the Miniature Card getting few invitations to design parties from now on.

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The 300mm Team-Up?

The Nihon Keizai Shimbun reported that Toshiba Corporation and NEC Corporation plan to partner with IBM and Samsung Electronics Company Ltd., respectively, in designing 300mm-capable fabrication facilities for 256Mb DRAM. The fabs are expected to begin production in 1999. The Nikkei also reported that Hitachi will spend ¥150 billion to construct a 300mm fab at its Naka site to come on line in 1999.

DQ Take

Dataquest believes the correct way to look at this is that Toshiba will work with IBM and NEC will work with Samsung to develop production equipment for 300mm wafers, not that the partnerships will run joint fabs. The possibility of these companies running joint 256Mb DRAM fabs exists, but it is not a certainty at this time.

NEC has denied reports of an agreement on joint construction of a 300mm fab. Dataquest believes that NEC will start 300mm operation in 1999, but NEC has not made an official announcement yet.

Dataquest believes that this additional Toshiba and IBM fab could come on line only after 2000. At that time, a 300mm-capable fab will not be a special choice any more. Toshiba and IBM have not made a solid decision yet, but the fact that they did not deny the story when Dataquest asked them about it, as NEC did, is significant.

The Hitachi investment in a new fab is already under way. The new facility's finished shell is located next to the current N1 fab (4Mb DRAM, microcontroller, and ASIC) and N2 fab (16/64Mb DRAM). The Naka plant is currently going through a transition; N2 will be used for microcontrollers as well as DRAM, as opposed to the original plan for 16/64Mb DRAM. N2 is the first Hitachi fab to use 0.30-micron technology in mass production.

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SanDisk Signs Up Toshiba with Flash Patent Cross-Licensing Agreement

Toshiba Corporation and SanDisk Corporation announced that they have signed a cross-licensing agreement for flash memory-related patents. Under the agreement, Toshiba and SanDisk have licensed each other's patents covering design and manufacture of flash memory products, giving both companies worldwide rights to use those patents. Specific terms of the agreement are confidential.

DQ Take

This is really a coup for SanDisk. Toshiba invented flash memory and therefore has a very powerful intellectual property portfolio. If the company wanted to, it could have made life very difficult for SanDisk. The press release said that the terms were confidential, but under U.S. securities rules, any significant transaction must be disclosed, and since none was, one can assume that not a lot of money changed hands. By contrast, when SanDisk signed a deal with Sharp in December and received a significant licensing fee that boosted its financial results, it shouted it from the rooftops. Inasmuch as the company is staying very much on the ground floor, this agreement appears to be more a nonaggression pact than a cash generator.

But the real significance of this deal is the pressure it applies to Samsung. Samsung is a licensee of the NAND-type flash that Toshiba developed. NAND is optimized for mass storage, which is the same market SanDisk is after, and Samsung has been much better at producing and marketing it than Toshiba has been. In short, Samsung is a much bigger threat to SanDisk than is Toshiba. If SanDisk can make Samsung pay it every time it sells a NAND chip, any damage can be minimized or perhaps turned into an opportunity, if the royalties are high enough.

SanDisk was recently successful in petitioning the U.S. International Trade Commission to bar Samsung NAND flash devices from the United States for patent infringement. Samsung thought it could tough it out by redesigning its parts, but Toshiba's taking SanDisk's side in the fight has to make the company question its position. It's time now to watch Samsung and see if it is going to blink.

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Robertson Stephens Semiconductor Conference Review

Robertson, Stephens & Company LLC, a stock brokerage, recently held its 11th Annual Semiconductor Conference, at which top executives from various semiconductor-related companies presented the highlights of their financial and technological performance to financial and industry analysts. The companies represented all parts of the semiconductor industry, including wafer manufacturing, front- and back-end equipment manufacturing, semiconductor manufacturing, and technology development.

DQ Take

The memory companies that presented at Robertson Stephens stuck to the four P's: products, processes, partnerships, and prices. New products and improved processes are keys to financial strength, and partnerships, whether with foundries, technology partners, or customers, enable the high cost of technology development to be managed. But ultimately, the success of these companies comes down to supply and demand and the prices that result.

SRAM

SRAM manufacturers were well represented at the conference. Alliance Semiconductor Corp., Cypress Semiconductor Corporation, Integrated Device Technology Inc., and Integrated Silicon Solution Inc. all presented. Each company expressed a reserved optimism, stating that SRAM demand continues to show strength and that average selling prices (ASPs) are stabilizing. Another common message was that these companies are not just SRAM companies anymore. With Intel Corporation changing the PC cache game, product diversification is a must for these companies to succeed.

Founded originally as a DRAM manufacturer, Alliance switched to SRAM. In the last year, Alliance has changed its focus again to a broad memory base of DRAM, SRAM, graphics memory, and flash. Alliance targets DRAM to contribute 40 to 45 percent of company revenue, SRAM follows at about 40 percent, graphics memory at 10 to 15 percent, and flash at about 1 percent. At a $6 16Mb DRAM price, Alliance said that its DRAM business is profitable, and over 90 percent of its DRAM business is with module makers. Alliance also said that any excess capacity is used to manufacture DRAM.

Cypress Semiconductor's president bounced from presenting the company's health to a critique of the way stock analysts determine the value of a stock, then to the strategy the company now uses. Cypress is bent on increasing manufacturing efficiencies, even on products at the end of their life cycles. The company will also try to keep the share of revenue from memory products in the current low range of 40 percent. The main message was that there is a lot of money to be made in products on the trailing edge of technology and that Cypress does a good job of gaining market share for SRAMs that other companies have chosen not to produce. Another way of putting it is that Cypress is determined to take a larger and larger share of shrinking markets, until it achieves total market share for a market that has diminished to nothing. Do not get us wrong. There is profitability in selling 64-bit SRAMs at gross margins higher than 90 percent.

IDT's message is "enabling a connect world." Specialized memories for communications accounted for about 40 percent of company revenue. SRAM is the next largest at about 30 percent, with logic at 20 percent and microprocessors at 10 percent. IDT hopes to continue to decrease the SRAM portion while increasing the microprocessor contribution. One area that IDT wants to improve is capacity utilization, which is keeping its fixed-cost allocation high.

ISSI presented its trademarked Fab-Lite business model, a hybrid of fab and fabless. Although ISSI works with foundries for its production (the fabless part of its model), the "Fab-Lite" idea comes from joint-venture and partnership capital investments that ISSI has entered into with its foundries. From a product perspective, ISSI is a broad-based memory company, offering SRAM, DRAM, flash, EPROM, EEPROM, and embedded memory products. SRAM dominates ISSI's company revenue today, accounting for 80 percent of revenue, but the one-year goal is for SRAM to decrease to 50 percent, DRAM to account for 20 to 30 percent, nonvolatile for 20 percent, and embedded for 5 percent.

DRAM

As most of the companies that presented were U.S. based, only two large DRAM manufacturers were present, Micron Technology Inc. and Texas Instruments Inc. Although many people still think of Texas Instruments as only a DRAM company, its internal and external focus is set on digital signal processing (DSP), not DRAM. TI's dependence on DRAM is relatively small, as only 15 to 20 percent of company revenue is from DRAM. Micron's presentation, however, was dedicated to DRAM.

Micron may be changing its image as a technology trailer, but it is clear that Micron is not changing its dedication to process improvements and shrinks for the current dominant density. Micron is working on optimizing its 64Mb DRAM capability, but it openly questions the business sense of moving quickly to 64Mb, as DRAM leaders NEC and Samsung are.

Micron continues to focus on improving 16Mb production, and it mentioned that two shrinks are in the works, with the goal of 900 dice per wafer by the end of the year. The switch to synchronous DRAM (SDRAM) is not expected to be a major difficulty; Micron said that its SDRAM process is outyielding extended data out (EDO). SDRAM accounts for 15 percent of Micron's output today, and it is expected to account for 25 to 30 percent by the end of the year. Overall bit growth is expected to be about 20 percent.

Capital spending for fiscal year 1997 is expected to be $575 million and for fiscal year 1998 somewhere between $600 million and $950 million. These capital expenditures are to maintain capability, not to add capacity. There are no new plans for Lehi at this time, but once the decision is made, it is expected that between 14 and 18 months will be needed to get the front end running well.

Addressing price and inventory, Micron said that spot market activity ranged from a low of $5.80 to the mid-$6 range. Micron's contract price is about $0.50 more than spot pricing for similar DRAM configurations. Micron also said that with a $6.10 ASP, margins would not improve and that its inventory level was three weeks and two days.

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DRAM Corner

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Near-Term 64Mb DRAM Profit Outlook

Several top-tier suppliers target a $30 price for the 64Mb part for major customers by or before year-end 1997. Their expectation is that few competitors will be able to profitably match the $30 price. If so, this means challenging market conditions for suppliers that have started or are about to start their 64Mb ramp.

Implications

With suppliers striving to maintain a 16Mb contract price of $6 for the rest of this year, the most obvious implication of a year-end $30 price for 64Mb devices is no 4:1 crossover this year, except for very select major customers. If 16Mb contract pricing slips below $6 during fourth quarter 1997, the timing of the 4:1 crossover to 64Mb could delayed well into 1998—especially bad news for suppliers that are ramping now with expectations of an early 1998 4:1 crossover.

The top-tier suppliers that target a profitable $30 64Mb by later this year also expect a $7 price for 16Mb parts. This is close enough to a 4:1 crossover that major customers can choose to migrate aggressively to the 64Mb device during late 1997 or early 1998. If 16Mb contract pricing dips to the $6 level later this year, the major customers of top-tier suppliers will still be at the 5:1 level—meaning that they can comfortably move to the 64Mb part during early 1998.

The scenario becomes more complicated, however, for suppliers that will be unable to profitably make and sell the 64Mb part for $30 later this year. If 16Mb pricing falls below the $6 level during fourth quarter 1997, then major customers will see a 6:1 differential (or higher) between 64Mb and 16Mb parts. There will be no clear "5:1 signal" for customers of such suppliers—nothing to set the stage for the 4:1 price crossover to 64Mb devices in the next quarter or so. The ugly reality could become persistently strong 16Mb DRAM through much of 1998, which is bad news for suppliers now heavily shifting to 64Mb devices.

Micron Will Do Well

As noted before, Micron Technology could and should do very well under such a scenario. The company has demonstrated 64Mb capability but has publicly stated its strong emphasis on 16Mb devices well into 1998. With a sub-$5 cost of manufacture for 16Mb devices—now likely approaching the $4 level for SDRAM versions—the company will quite likely do well the rest of this year, and especially well if the 64Mb price crossover stalls next year.

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Dataquest's Tactical Memories Newsletter
251 River Oaks Parkway, San Jose, California 95134

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Perspective

Memories Worldwide
Market Analysis

Dataquest's Tactical Memories Newsletter —Vol. II, No. 15

- *Shift to 64Mb DRAM Not as Sudden as It Sounds*
- *Next-Generation Memory Update*
- *Submicron Looks for Help*
- *IDT FIFO News*
- *DRAM Corner*
  - *-Korea Fights Back in U.S. Dumping Case*

Shift to 64Mb DRAM Not as Sudden as It Sounds

Given all the talk about accelerated movement toward the 64Mb DRAM, one would expect that an unprecedented change was taking place. This, of course, would be indicated by a change in the growth of the average density of all DRAMs combined. This has not been happening, according to Dataquest's analysis of World Semiconductor Trade Statistics (WSTS) data through last May.

The data in Figure 1 shows the average density of all DRAM chips shipped each month from the beginning of 1991 through May 1997, the most recent data available from WSTS. If there is any change in density increases, it appears that the trend may actually be tapering off slightly.

If the stories Dataquest has been hearing are true, that 16Mb DRAM production is being reduced significantly in order for the major producers to shift their focus to the 64Mb density, then we would expect the curve in Figure 1 to show a more upward trend than the historical line. This would account for a more dramatic shift to the new density. This is obviously not the case.

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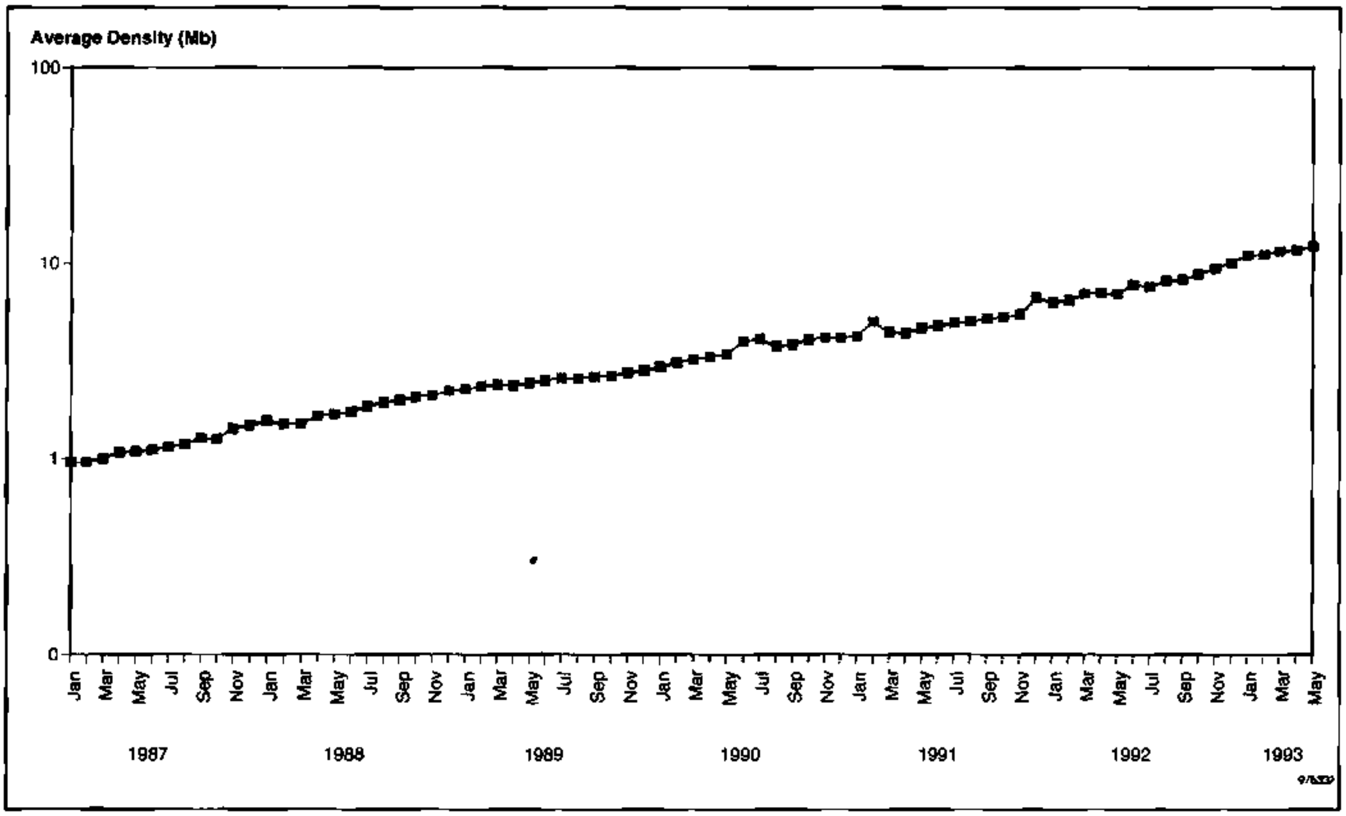
Figure 1
Average DRAM Density, January 1991 to May 1997



Source: Dataquest (July 1997)

Dataquest does not attribute much to the minor inflections in the curve of Figure 1 but believes that these are simple erratic variations in the market. It appears that the shift to the 64Mb density is occurring at a rate consistent with historical shifts in DRAM densities. Surprisingly enough, although the curve encompasses the difficult transition from the 4Mb density to the 16Mb density, when the x16 version of the 16Mb DRAM held back acceptance of that density, we see no leveling off of the density transition at that point, either. It looks as if this again may have been a point at which there was much talk of a break with past trends but little proof that it actually happened.

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Next-Generation Memory Update

Texas Instruments Inc. and Rambus Inc. announced that TI has taken a broad license for Rambus's high-bandwidth memory-interface technology. TI will incorporate the technology into several next-generation products, including digital signal processors (DSPs), communications application-specific ICs (ASICs), and DRAMs.

Fujitsu also recently licensed Rambus technology for incorporation into its DRAM products. In addition to Fujitsu's licensing of Rambus technology, word is that Fujitsu will begin shipping samples of its double-data rate (DDR) type of DRAM late this year.

DQ Take

While synchronous DRAM (SDRAM) is still waiting in the wings to become the dominant DRAM technology, the next-generation contenders seem to get all the attention. Rambus leads the way in the next-generation arena, and, with TI's licensing of Rambus' technology, all of the top 10 DRAM vendors are now accounted for. The DDR DRAM and SLDRAM camps have considerable ground to make up, but both continue to hold out hope that they can catch up by presenting working silicon.

The TI announcement is significant in that TI is the first company to announce a Rambus license for DSP ICs and communications ASICs. Initial DSP and ASIC products implementing Rambus technology are scheduled to sample early in 1998. TI's Rambus-based DRAM products will come at a later date, and TI plans to use the Direct Rambus interface in its 64Mb and higher-density DRAM devices.

Fujitsu's initial DDR DRAM will be a 64Mb device targeted for use in PCs, with follow-up plans to expand the DDR product to other applications, such as workstations. Fujitsu, already strongly positioned in SDRAM, is positioning its DDR, Rambus DRAM, and SLDRAM products in order to maintain the profitability of its memory operations.

The listed lineup of Fujitsu's future memory products exemplifies how confusing next-generation DRAM product positioning is. SDRAM is the obvious first step, but, as mentioned earlier, DRAM manufacturers are still waiting for PC companies to make the across-the-board transition to SDRAM. The first step is the only easy step, and the longer it takes, the more unlikely a 1999 transition to any next-generation memory is. DDR and SLDRAM look as though they will be made, but will Intel support them in its chipset designs? Rambus has a proven track record and Intel's mind share, but it is still looked at as the higher-cost solution.

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Submicron Looks for Help

Submicron Technology, a Bangkok-based IC wafer foundry start-up and a subsidiary of the Alphatec Group, is struggling. A recent *Electronics Buyers' News* article (July 14, 1997) stated that employees have not been paid in the last two months and that they are threatening to resign if they are not paid by the end of this month.

DQ Take

The sources Dataquest spoke with indicate that Submicron is in survival mode and that it would take a lot to pull the company out now. To survive the current dire situation, Submicron needs an investor with deep pockets, technology expertise, and a strong reputation.

Because of its mounting problems, especially financial, Submicron needs to attract an investor within three to six months. The Thai government is a possible investor, but it cannot offer the needed technology expertise.

Addressing the dissatisfied employee issue, some reports circulating say that Chartered Semiconductor Manufacturing Ltd. Singapore has taken out recruiting ads in Bangkok newspapers. If so, CSM is grabbing the opportunity to benefit from Submicron's problems.

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IDT FIFO News

Integrated Device Technology Inc. announced a new member of its synchronous first-in first-out (FIFO) buffer memories. The new device is a bidirectional bus-matching device with a single 36-bit-wide bidirectional port on one side and two unidirectional ports (one incoming, one outgoing) that match the intended application of fiber-optic networks. One advantage of the approach is that it can be cascaded at high speeds to allow for considerable depth increases.

DQ Take

With this announcement, IDT is reiterating its intent to continue the company's dominance of the FIFO market. Dataquest estimates that this market is around $200 million worldwide. The company owns as much as two-thirds of the market, and although it has been thwarted at times by up to 28 potential competitors, it has continued to keep the bulk of this market to itself.

Procter & Gamble, a U.S. consumer products company, has shown that the dominant player in the market can be extremely difficult to displace. This implies that IDT is in a very good position to keep this market, as well as a couple of other markets—multiport memories and SRAM modules—to itself. All of these are businesses in which Dataquest expects the company to continue to thrive.

IDT finds that the bulk of its FIFOs and multiport memories are used in telecommunications applications (certainly a growing market) and is aligning the company to better serve the telecommunications market.

This certainly looks like an approach that could help the company to grow and keep continued strength while the SRAM market, which has been both good and bad to IDT in the past, continues to suffer the uncertainties that have caused IDT its recent losses.

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DRAM Corner

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Korea Fights Back in U.S. Dumping Case

According to a Dow Jones International News Service report, South Korea will file a suit with the World Trade Organization accusing the United States of keeping improper antidumping duties on its computer memory chips. The announcement from Korea's trade ministry came after the U.S. Department of Commerce decided on the July 17 to preserve antidumping sanctions, imposed since 1993, against imports of South Korean 16Mb DRAMs, saying the penalties must be kept because of the possibility of future South Korean dumping. According to the Korean Foreign Ministry, this extension is a violation of WTO rules.

South Korean companies first demanded the removal of the sanctions, saying they were no longer valid, in May 1996. DRAMs are one of South Korea's key exports, accounting for as much as 10 percent of the country's exports in 1995.

The two countries must begin negotiations within 10 days of the filing or face a WTO panel ruling on the dispute.

DQ Take

Although semiconductor companies traditionally are run by relatively apolitical souls, this appears to be far from the truth in Korea. The Korean manufacturers are fighting back, using the political process to right a wrong. From the United States, this looks very different from what we have seen in earlier antidumping cases against Japanese companies, where an agreement was reached through negotiation rather than through a showdown.

Although it is difficult to anticipate how this suit will be resolved, Dataquest suspects that a positive outcome for Korean companies would have a dramatic influence on one of the strategies that Micron Technology has pursued for several years. Micron is often the first to ask the U.S. DOC to investigate allegations of dumping.

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Dataquest's Tactical Memories Newsletter —Vol. II, No. 16

- *Intel Pushes Specification for PC Cameras without Its Flash Cards*
- *The 300mm Team-Up?*
- *SanDisk Signs Up Toshiba with Flash Patent Cross-Licensing Agreement*
- *Robertson Stephens Semiconductor Conference Review*
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Intel Pushes Specification for PC Cameras without Its Flash Cards

Intel Corporation has released a design guideline that will enable the development of what it says will be low-cost, easy-to-use PC cameras for use with Intel-based computers. The Portable PC Camera '98 design guideline, which outlines how PC cameras can be used to capture, enhance, store, and share images and connect easily to the PC, is supported by 25 companies, including Hewlett-Packard Company, Eastman Kodak Company, and Microsoft Corporation. As shown in Figure 1, Dataquest believes the digital still camera market will grow to almost 6 million units by the year 2000, and the small form-factor cards for them will expand to nearly 18 million units.

DQ Take

The interesting part of this announcement, from a memory perspective, is not what is here, but what is not. First, this is mostly a PC specification, not really a camera spec. The file format in question, FlashPix, is not one meant for digital film or even for transferring data from the camera to the PC by a cable, but rather for PC-to-PC movement. The call for an MMX-class processor is somewhat redundant because the market is moving that way quickly. The strong suggestion to use Universal Serial Bus (USB) as the connection from the camera to the PC is the most significant, but still very obvious, part of the communique. All this is meant to give a clear set of PC

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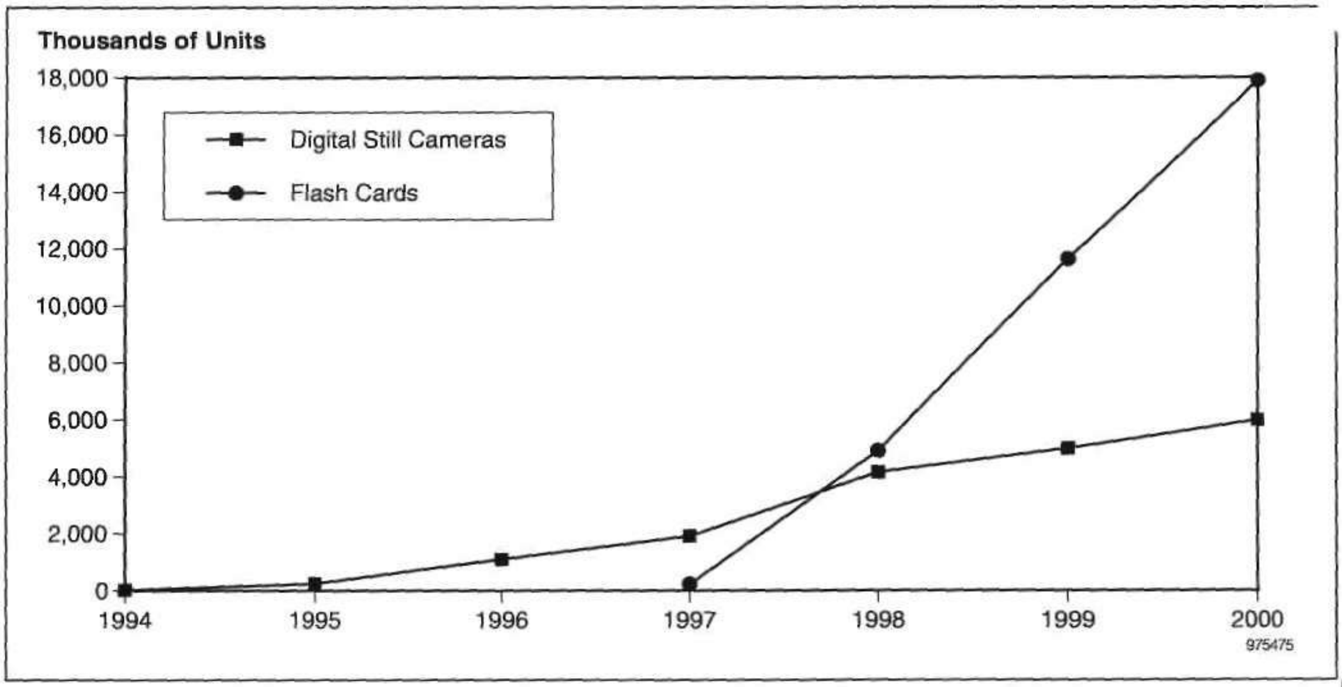
features for OEMs to have for a "school and holiday season 1998" p
campaign that will have digital cameras bundled with specially cont.
PCs.

Figure 1
Unit Shipments of Digital Still Cameras and Small Form-Factor Flash Memory Cards



Source: Dataquest (August 1997)

But what came out after the paper announcement was released was that, while Intel would of course like to see everyone use its Miniature Card standard for removable storage, the company was not pushing hard for it compared to the FlashPix (which has nothing to do with flash memory). Worse yet, in this application, the Miniature Card is in direct competition with USB to get digital images back to the PC. If you have one, you do not need the other. When it came down to telling PC OEMs what to put into a system—USB or a Miniature Card slot—the answer was USB. Flash cards are to be used to expand the storage capacity of the camera, not for data interchange.

This reference design came out of Intel's Digital Peripherals Division, not the Memory Components Division that actually promotes flash cards. But it indicates that behemoth Intel is not 100 percent behind Miniature Card. Since it is in a fierce battle with SanDisk's CompactFlash products and Toshiba and Samsung's Solid-State Floppy Disk Card (SSFDC) products for camera design-wins, this does not bode well. CompactFlash already has a sizable lead in the market, and Dataquest sees the battle for the digital film standard being fought more and more between CompactFlash and SSFDC in the future, with the Miniature Card getting few invitations to design parties from now on.

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The 300mm Team-Up?

The Nihon Keizai Shimbun reported that Toshiba Corporation and NEC Corporation plan to partner with IBM and Samsung Electronics Company Ltd., respectively, in designing 300mm-capable fabrication facilities for 256Mb DRAM. The fabs are expected to begin production in 1999. The Nikkei also reported that Hitachi will spend ¥150 billion to construct a 300mm fab at its Naka site to come on line in 1999.

DQ Take

Dataquest believes the correct way to look at this is that Toshiba will work with IBM and NEC will work with Samsung to develop production equipment for 300mm wafers, not that the partnerships will run joint fabs. The possibility of these companies running joint 256Mb DRAM fabs exists, but it is not a certainty at this time.

NEC has denied reports of an agreement on joint construction of a 300mm fab. Dataquest believes that NEC will start 300mm operation in 1999, but NEC has not made an official announcement yet.

Dataquest believes that this additional Toshiba and IBM fab could come on line only after 2000. At that time, a 300mm-capable fab will not be a special choice any more. Toshiba and IBM have not made a solid decision yet, but the fact that they did not deny the story when Dataquest asked them about it, as NEC did, is significant.

The Hitachi investment in a new fab is already under way. The new facility's finished shell is located next to the current N1 fab (4Mb DRAM, microcontroller, and ASIC) and N2 fab (16/64Mb DRAM). The Naka plant is currently going through a transition; N2 will be used for microcontrollers as well as DRAM, as opposed to the original plan for 16/64Mb DRAM. N2 is the first Hitachi fab to use 0.30-micron technology in mass production.

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SanDisk Signs Up Toshiba with Flash Patent Cross-Licensing Agreement

Toshiba Corporation and SanDisk Corporation announced that they have signed a cross-licensing agreement for flash memory-related patents. Under the agreement, Toshiba and SanDisk have licensed each other's patents covering design and manufacture of flash memory products, giving both companies worldwide rights to use those patents. Specific terms of the agreement are confidential.

DQ Take

This is really a coup for SanDisk. Toshiba invented flash memory and therefore has a very powerful intellectual property portfolio. If the company wanted to, it could have made life very difficult for SanDisk. The press release said that the terms were confidential, but under U.S. securities rules, any significant transaction must be disclosed, and since none was, one can assume that not a lot of money changed hands. By contrast, when SanDisk signed a deal with Sharp in December and received a significant licensing fee that boosted its financial results, it shouted it from the rooftops. Inasmuch as the company is staying very much on the ground floor, this agreement appears to be more a nonaggression pact than a cash generator.

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As most of the companies that presented were U.S. based, only two large DRAM manufacturers were present, Micron Technology Inc. and Texas Instruments Inc. Although many people still think of Texas Instruments as only a DRAM company, its internal and external focus is set on digital signal processing (DSP), not DRAM. TI's dependence on DRAM is relatively small, as only 15 to 20 percent of company revenue is from DRAM. Micron's presentation, however, was dedicated to DRAM.

Micron may be changing its image as a technology trailer, but it is clear that Micron is not changing its dedication to process improvements and shrinks for the current dominant density. Micron is working on optimizing its 64Mb DRAM capability, but it openly questions the business sense of moving quickly to 64Mb, as DRAM leaders NEC and Samsung are.

Micron continues to focus on improving 16Mb production, and it mentioned that two shrinks are in the works, with the goal of 900 dice per wafer by the end of the year. The switch to synchronous DRAM (SDRAM) is not expected to be a major difficulty; Micron said that its SDRAM process is outyielding extended data out (EDO). SDRAM accounts for 15 percent of Micron's output today, and it is expected to account for 25 to 30 percent by the end of the year. Overall bit growth is expected to be about 20 percent.

Capital spending for fiscal year 1997 is expected to be $575 million and for fiscal year 1998 somewhere between $600 million and $950 million. These capital expenditures are to maintain capability, not to add capacity. There are no new plans for Lehi at this time, but once the decision is made, it is expected that between 14 and 18 months will be needed to get the front end running well.

Addressing price and inventory, Micron said that spot market activity ranged from a low of $5.80 to the mid-$6 range. Micron's contract price is about $0.50 more than spot pricing for similar DRAM configurations. Micron also said that with a $6.10 ASP, margins would not improve and that its inventory level was three weeks and two days.

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DRAM Corner

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Near-Term 64Mb DRAM Profit Outlook

Several top-tier suppliers target a $30 price for the 64Mb part for major customers by or before year-end 1997. Their expectation is that few competitors will be able to profitably match the $30 price. If so, this means challenging market conditions for suppliers that have started or are about to start their 64Mb ramp.

Implications

With suppliers striving to maintain a 16Mb contract price of $6 for the rest of this year, the most obvious implication of a year-end $30 price for 64Mb devices is no 4:1 crossover this year, except for very select major customers. If 16Mb contract pricing slips below $6 during fourth quarter 1997, the timing of the 4:1 crossover to 64Mb could delayed well into 1998—especially bad news for suppliers that are ramping now with expectations of an early 1998 4:1 crossover.

The top-tier suppliers that target a profitable $30 64Mb by later this year also expect a $7 price for 16Mb parts. This is close enough to a 4:1 crossover that major customers can choose to migrate aggressively to the 64Mb device during late 1997 or early 1998. If 16Mb contract pricing dips to the $6 level later this year, the major customers of top-tier suppliers will still be at the 5:1 level—meaning that they can comfortably move to the 64Mb part during early 1998.

The scenario becomes more complicated, however, for suppliers that will be unable to profitably make and sell the 64Mb part for $30 later this year. If 16Mb pricing falls below the $6 level during fourth quarter 1997, then major customers will see a 6:1 differential (or higher) between 64Mb and 16Mb parts. There will be no clear "5:1 signal" for customers of such suppliers—nothing to set the stage for the 4:1 price crossover to 64Mb devices in the next quarter or so. The ugly reality could become persistently strong 16Mb DRAM through much of 1998, which is bad news for suppliers now heavily shifting to 64Mb devices.

Micron Will Do Well

As noted before, Micron Technology could and should do very well under such a scenario. The company has demonstrated 64Mb capability but has publicly stated its strong emphasis on 16Mb devices well into 1998. With a sub-$5 cost of manufacture for 16Mb devices—now likely approaching the $4 level for SDRAM versions—the company will quite likely do well the rest of this year, and especially well if the 64Mb price crossover stalls next year.

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Dataquest's Tactical Memories Newsletter
251 River Oaks Parkway, San Jose, California 95134

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Memories Worldwide
Market Analysis

Dataquest's Tactical Memories Newsletter —Vol. II, No. 14

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- *Brighter Times for SRAM Companies?*
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    - *-"Who's on First" in DRAMs?*

Micron Dominates the DRAM Business: Fact or Fiction?

The July 7 edition of *Electronics Buyers' News* published an article stating that Micron Technology Inc. had superseded Samsung Electronics Company Ltd. in DRAM market share and now held 20 percent of the DRAM market. The finding was attributed to an unnamed analyst at Merrill Lynch, a U.S. stock brokerage.

Although things are moving in a positive direction at Micron, Dataquest still believes that the company is lower than Samsung in overall DRAM sales and that some miscalculations may have been made in this recent analysis. Micron does appear to have ramped its 16Mb DRAM shipments to the highest level in the industry, but the company's shipments of the 64Mb density—the device to which the historical market leaders are turning their attention—are still extremely small. Thus, Micron's overall DRAM revenue by Dataquest's estimates is less than both Samsung's and NEC Corporation's.

The analysis referred to in the EBN article appears to have made two key assumptions: first, that the gross dice-per-wafer (DPW) number Micron gave out in a recent analysts' teleconference (detailed in a Dataquest Alert sent to

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Memories Worldwide clients on June 18) was the yielded DPW; and second, that all 15,000 wafers per month that Micron started were used to build 16Mb DRAMs. Using these assumptions, we arrive at the 30 million 16Mb DRAMs per month that propel Micron to these heights. If we assume a more typical yield in the 80 percent to 85 percent range, and we assume that around 85 percent of Micron's wafer starts go to the 16Mb DRAM, we arrive at a more realistic figure of about 20 million 16Mb DRAMs per month. That still puts Micron in the lead at this density, ahead of the 18 million units per month shipped by Samsung and the 13 million to 15 million units shipped monthly by NEC, Hitachi Ltd., and Texas Instruments Inc. This number would place Micron third in DRAM revenue, after Samsung and NEC, still far ahead of the eighth-place position Micron held in Dataquest's 1996 DRAM market share rankings.

Figure 1 shows Micron's DRAM unit shipments by density compared to those of the market as a whole. The vertical axis on the right and the thin lines represent the entire market. The right-hand vertical axis and the thick lines represent Micron's shipments, including Dataquest estimates for the third quarter of this year. This chart shows that since the 4Mb density, Micron appears to have decided to aggressively increase its share of the market (from the 15 percent level it pursued in prior generations). It looks as though Micron is taking a new direction, something the company mentioned in a recent conference call.

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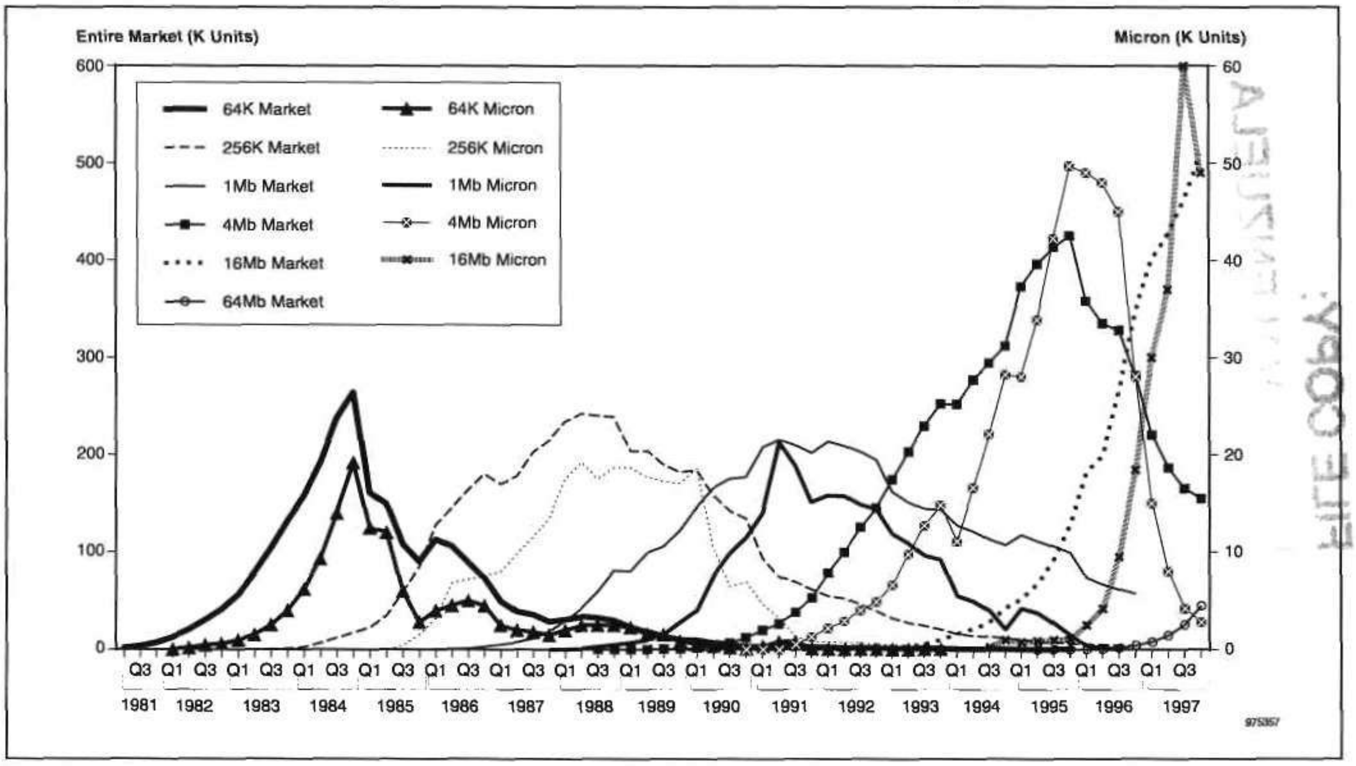
Figure 1
Micron's DRAM Unit Shipments Relative to the DRAM Industry



Source: Dataquest (July 1997)

Taiwanese Companies Set Their Sights on 12-Inch Fabs

Texas Instruments-Acer announced the planned investment of NT$100 billion in two stages to expand its DRAM production capability before the year 2000. TI-Acer, Taiwan's largest producer of DRAM chips, is also planning three more fabs to produce DRAM after the year 2000.

DQ Take

In the past few weeks, many Taiwanese semiconductor companies, including TSMC, UMC, Winbond, Mosel Vitelic, Powerchip, VIS, Nan Ya, and TI-Acer, announced new 12-inch wafer fab investments. It makes one wonder why these announcements came in such close proximity, since some companies didn't reveal much detail on their new projects.

The one thing that looks certain is that these Taiwanese semiconductor companies will continue new fab investments, but it is hard to predict what will happen after the year 2000. In the short term, the DRAM market is still facing overcapacity. This overcapacity, coupled with the high cost of building a 12-inch wafer fab, suggests that joint ventures and alliances are the best approach for investment by these companies.

Turning to the TI-Acer announcement, the company will continue to invest in the future, but market conditions are moderating this to some degree. One example is TI's withdrawal from its proposed new fab in Thailand. This puts increased importance on TI-Acer's Taiwanese investment. The expansion of TI-Acer to 12-inch is inevitable but will require a revised agreement between TI and Acer.

By the way, it is expected that TI-Acer will go public by the end of this year. The company recently received approval from the Taiwanese Stock Foundation.

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Intel and Sharp Introduce 32Mb Flash Memory with CFI

Intel Corporation and Sharp Electronics Corporation introduced this week a new line of symmetrically blocked 16Mb and 32Mb flash memories for both 2.7V and 5V operation. The chip includes a new feature from the "NOR 4" (Intel, Fujitsu, Sharp, and Advanced Micro Devices Inc.) named the Common Flash Interface (CFI) that allows descriptive information to be obtained from the chip that may be used by systems such as digital cameras and programmers to categorize the chip. It will be available in micro-BGA packaging and standard packages, and it can be programmed as fast as 2 µsec/byte at 5V or 6 µsec/byte at 2.7V. The 16Mb version is sampling now, with production planned for September, and the 32Mb is expected to sample in fourth quarter 1997 and be available for volume delivery in first quarter 1998.

DQ Take

The significant aspects of this announcement are the density and the CFI interface. With respect to density, Samsung and Toshiba have been shipping a 32Mb NAND flash memory for some time, and Intel is finally catching up. This presumably is a precursor to the 64Mb multilevel cell (MLC) product Intel has been promising, which it is now saying will be released this fall. Meanwhile, in the real world, a NAND 64Mb part is already being sampled and a 128Mb MLC version is being worked on. High density lowers price per bit, and Toshiba is saying that an 8MB (64Mb) Solid-State Floppy Disk Card (SSFDC) will have a sample price of $30, or about $4 per megabyte, which is in the same ballpark as DRAM.

Flash chips have used JEDEC identifiers to allow programming machines to determine the manufacturer and density of a memory. CFI improves upon this with a "minidata sheet" stored in the control logic of the device that gives memory size, byte/word configuration, block configuration, necessary voltages, and timing information. This is desirable because the designs of new flash chips have been evolving quickly as higher densities are released, making higher densities incompatible with lower ones. For applications that have fixed functionality, such as digital cameras, that cannot have their software drivers updated periodically for the latest in-vogue flash chip, iron-clad backward compatibility is a necessity, not an option.

The CFI interface is envisioned for Miniature Card applications. The competition here is the ATA-based CompactFlash cards from SanDisk, which have the advantage of being "device independent," meaning the system has no visibility of the specific vagaries of a particular manufacturer's flash memory chip specifications. CFI can give a similar freedom *if* an OEM design engineer takes advantage of the feature. The problem with CFI is not its function, but its birthday. ATA has been available for many years with rigid disk drives (RDDs), and CompactFlash seems to be winning the war for small form-factor flash cards, in part because of the lack of a viable alternative. CFI's coming on the scene at this late date probably will not be enough to affect CompactFlash.

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Update on Europe's Review on DRAM Dumping

The Dataquest Alert sent to Memories Worldwide and Semiconductors Europe clients two weeks ago expressed expectations that the European Union would announce the lifting of its antidumping legislation on June 25. But it appears that the DRAM antidumping item was dropped from the June 25 committee meeting. This delay was taken to wait for related events to unfold in the United States.

DQ Take

Dataquest has heard that the U.S. antidumping case brought by Micron is supposed to be heard July 16 and that the EU wants to wait for the outcome. The assumption is that no evidence of dumping is going to be found in the

U.S. case, and this is expected to "persuade" the European Electronic Components Association (EECA) to drop its complaint in Europe. The Korean and Japanese vendors are then expected to agree to monitor prices to prevent dumping in the future.

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Brighter Times for SRAM Companies?

Both Paradigm Technology and Integrated Silicon Solution Inc. made more positive announcements than they have had in the past.

Calling the current business climate challenging, Paradigm announced that it has seen an increase in orders for some of its high-speed SRAMs and that market demand appears to be improving in the growing telecommunications and networking markets. The company says that it has booked more orders this quarter than in any other quarter in the past year.

ISSI announced that the outlook for its revenue for the quarter just ended will be slightly higher than the $25.8 million for the previous quarter but lower than the company's earlier target. Citing push-outs from specific customers in the disk drive and communications areas, which have delayed shipments into the next quarter, the company expects to see a loss for the quarter ended June 30.

ISSI said that it sees some stability in average selling prices (ASPs) and believes that the industry trends are improving, despite the recent push-outs.

DQ Take

It is interesting to note that the two companies cite the communications industry as one that has caused change—for a positive impact on one company and a negative impact on the other.

The SRAM market continues to be a tough one to deal with. Dataquest will continue to watch the many players and report on their health as SRAM vendors transform their business away from the once-open PC cache market.

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DRAM Corner

Dataquest welcomes DRAM tactical reports from readers. Please send them via e-mail to ron.bohn@dataquest.com. Thanks for recent comments.

Will NEC Ship 128Mb SDRAM in Early 1998?

NEC reportedly is proceeding aggressively on the development project for its 128Mb synchronous DRAM (SDRAM). NEC plans to provide samples of 100-MHz 128Mb SDRAM in first quarter 1998 and move to mass production during second quarter 1998. This schedule marks acceleration of NEC's original release schedule.

NEC plans to set the price of 128Mb SDRAM around 2.3 times higher than the 64Mb DRAM price. The company plans to use a 0.22-micron process for the one-chip solution. Product configurations will include the 32Mbx4, 16Mbx8, and 8Mbx16 geared for workstation, PC server, and high-performance computers. NEC also plans to release a 4Mbx32 device targeted for PCs during third quarter 1998.

Some of the product specifications are: memory array: four-bank type; Vdd, 3.3V; access time, 6.5ns; interface, LVTTL or SSTL; package, 54-pin TSOP.

Dataquest has also heard that Samsung may accelerate the release of its 128Mb SDRAM. A 128Mb SDRAM is a part Dataquest would expect to see in about 1999, and NEC's timetable is a full year ahead of that. A major influencing factor is the availability of Intel's 440LX chipset, which Dataquest expects to be in the fourth quarter of 1997. The 440LX chipset allows the use of SDRAM and the Advanced Graphics Port (AGP).

"Who's on First" in DRAMs?

Reports that Micron now has the world's highest monthly 16Mb DRAM production rate have caused consternation for some Asian-based DRAM suppliers.

16Mb DRAM

Samsung publicly expressed little concern because its strategic and emotional focus will be on 64Mb and higher densities. For some Asian-based DRAM suppliers, however, the news from Boise, Idaho (Micron's headquarters), is disturbing because it means Micron will gain—or has already gained—considerable 16Mb market share at their direct expense. While many Korean- and Japan-based suppliers throttled down or diverted 16Mb capacity for the past year—and shifted DRAM marketing efforts to the 64Mb density—Micron relentlessly focused on the 16Mb device. The result: Micron generates a 50 percent margin on 16Mb DRAMs and will likely remain quite profitable while many competitors struggle through the 1997 PC/DRAM summer doldrums.

256Mb DRAM

Meanwhile, Micron shocked some competitors when it announced during late June 1997 that the company had provided 256Mb samples to Dell. This shatters the public's image of Micron as a DRAM technology laggard that inherits the mature markets, such as 16Mb DRAMs in 1997. Some competitors were convinced that Micron had a "secret" alliance partner that gave the 256Mb technology to Micron. The rumors went something like, "No way could Micron—alone—develop this leading-edge technology so soon." From what Dataquest has learned, Micron did it alone. Rumors about secret DRAM alliances involving Micron will likely swirl for some time. Regardless, it seems Micron has moved, on its own, to the top tier of DRAM technology companies.

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Perspective

Memories Worldwide

Technology Analysis

Flash Solid-State Disk—The Idea That Keeps Coming Around

Abstract: *This document explores the use of flash memory for mass storage applications, specifically as a solid-state disk (SSD). The value of a flash SSD and business and technical issues are identified and discussed.*

By Bruce Bonner

Introduction

The concept of making a solid-state replacement for mechanical rotating storage has almost a magical quality for those in the semiconductor memory business and has been pursued ever since rigid disk drives (RDDs) were introduced for mainframe computers. The undeniable technical advantages always attract those driven to develop superior products, but a higher cost per bit usually brings the dreamers back to earth quickly.

Specifically, MOS memory, such as DRAM, SRAM, or flash, has been used to replace mechanical RDDs for many years. Usually it is done for technical reasons, but occasionally it will provide a lower cost, too. This Perspective explores the choices and issues associated specifically with flash memory mass storage used as a disk drive replacement. A related topic, removable storage as memory cards, is not directly addressed but is discussed in other Dataquest documents, such as the Dataquest Perspective "Flash Memory Digital Film Standards Battle Heats Up," (MMRY-WW-DP-9713, June 2, 1997).

For the purposes of this Perspective, a solid-state disk (SSD) is defined as a system-level product containing semiconductor memory that usually has a standard disk drive hardware interface. Another variation is a system that has a memory interface but uses system software to emulate RDD operation.

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Advantages of Flash SSD

Technical Advantages

Semiconductor memory in general, and flash specifically, is technically superior to mechanical disk drives. Period. It is fast, rugged, low power, and small compared to an RDD. Because flash is also nonvolatile, it is an attractive substitute for a disk drive. The one issue, of course, is that flash is more expensive per megabyte—more on this later.

Any semiconductor memory is faster than a mechanical device because electricity will always outrun something physical. Memories are specified in nanoseconds, disk drives are specified in milliseconds; the difference is a million-to-one ratio! For many years, DRAM SSDs have been used in file servers and transaction-based systems to give instantaneous performance increases over RDD. These systems are expensive and mission-critical, so cost is not an issue. Flash's single performance issue is write speed, with the best available chip being about 1MB/sec in effective recording speed (erase plus program). Even inexpensive desktop disk drives outperform this by five to 10 times. But is this a critical specification? In many cases, no, either because the system is using flash for another technical reason or because flash devices can easily be used in parallel to improve write speed dramatically. DRAM can also be used for "plug in the wall" applications because nonvolatility is not a big issue where a uninterruptable power supply (UPS) can be used.

For portable systems, the advantage of semiconductor memory is a ruggedness that disk drives can only fantasize about. Flash cards usually have a 1,000g shock specification, operating or nonoperating; RDD specifications are 10 times lower than this. A drop to a concrete floor is not an issue for the memory chip, only for the packaging that surrounds it. Connectors are a weak point for operational conditions because of electrical noise creation. At the device level, a memory chip is no more susceptible to shock than any other chip, so the weakness is at the system level.

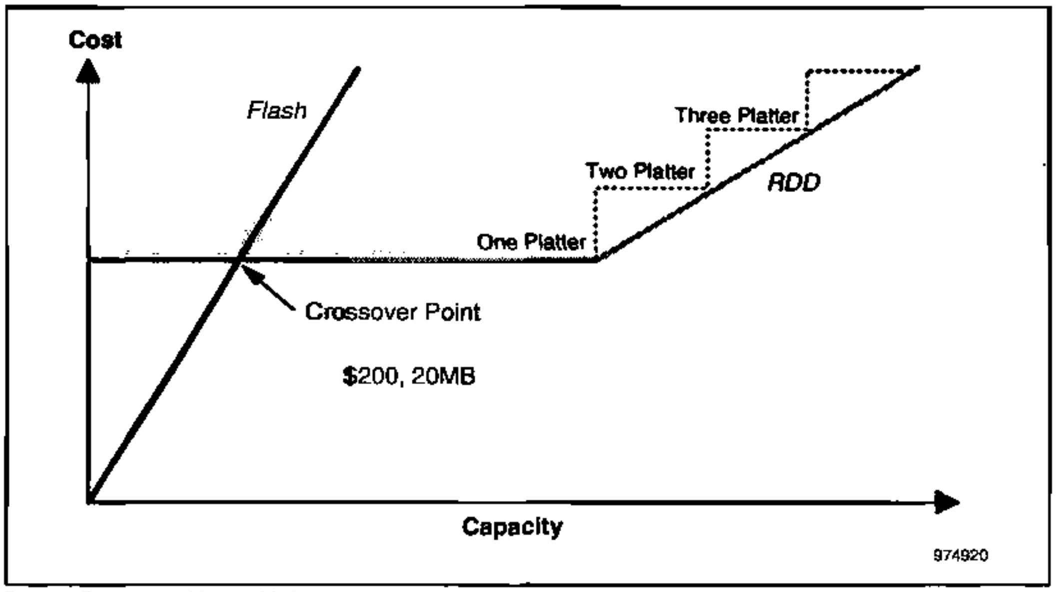
Another physical attribute of semiconductor memory is its small size. Although the areal density (bits/mm^2) of flash is about the same as that of an RDD, its footprint will be much smaller than that of a disk drive for a small amount of storage, such as one chip's worth. For larger capacities, three-dimensional packaging techniques can create dense, rugged storage; hence, flash is used in aerospace applications in this manner. The real limiting factor is cost per megabyte, not physical packing density.

Finally, flash memory consumes very little power compared to the instantaneous power dissipation of RDDs. Again, this is the advantage of a solid-state medium over a mechanical one. But flash also conserves energy because it goes on instantly and therefore can be powered down without the resulting "power up" delay that forces RDDs to remain on for longer than they should be. Low-voltage operation—3.3V now, going to 1.8V in the future—is another key solid-state value.

Financial Advantages

Flash memory and rigid disk drives have fundamentally different cost curves. Flash offers a constant price per megabyte; the first byte costs the same as the last one, and there is little overhead in using flash memory chips in a computer system. RDD, on the other hand, has a "floor" price of about $200 for a single-platter drive. Electronic components, casting, motors, platter, and read/write heads give a high fixed cost for an RDD assembly. However, adding platters and read/write heads to an existing drive design for extra capacity is relatively cheap; the first byte of an RDD is *very* expensive and the last one is free (almost). This is shown in Figure 1. The key value in the figure is the intersection of the two curves, which is the point at which flash is cheaper for smaller capacities and RDD is cheaper for larger ones. This is called the crossover point.

Figure 1
Flash versus RDD Cost Curves



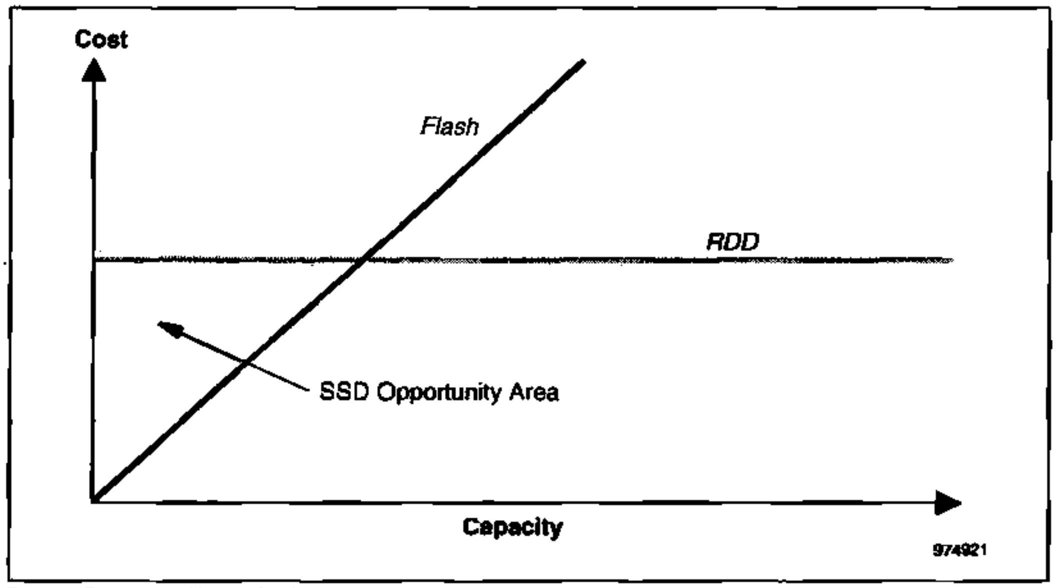
Source: Dataquest (June 1997)

RDD is *much* less expensive than flash for capacities over the crossover point because of the steep slope of the flash cost curve. Unless there are strong technical reasons to use flash, the extra cost usually motivates designers to use creative shock-mounting solutions to baby the RDD and make it viable in the application. As shown in Figure 2, all of this points to a flash SSD "sweet spot" of less than $200.

Flash Technology Alternatives

Flash memory is relatively new as a memory technology and is evolving in three directions: low voltage optimized, mass storage optimized, and generic for many applications. Even in the mass storage category alone, there is a technology battle developing among major memory vendors.

Figure 2
Flash Solid-State Disk Opportunity Area



Source: Dataquest (June 1997)

NOR

NOR technology flash memory is derived from EPROM technology, with the ultraviolet erase mechanism replaced by an electrical erase feature. It has very fast read times, as low as about 50ns, but much slower write times. The fast read time is necessary to allow for direct code (program) execution with an attached microprocessor or microcontroller. Currently, the largest NOR flash device density in production is 16Mb. The sponsors of NOR in the marketplace are market leaders Intel Corporation and Advanced Micro Devices Inc., which gives it a cost advantage with economy of scale. But NOR's inherent price per bit is somewhat higher than that of other alternatives. For code store use, data reliability is very important, with a typical specification of 10 years. The long-term mass storage strategy for NOR is to use multilevel cell techniques to effectively decrease the cell size.

Multilevel Cell NOR

Multilevel cell (MLC) storage is a technique to increase the bits per mm^2 in memory devices. Although theoretically possible with almost any type of memory, it is being pursued with the most enthusiasm with flash memory. Because the floating gate used in flash can easily store a variable quantity of charge, it is possible to define more than the traditional binary ("high" or "low") states. The number of states required for *n* bits is 2^n; thus, 2 bits needs four states, 3 bits needs eight, and 4 bits needs 16. The variable stored charge causes the turn-on threshold voltage, V_T, of the flash cell to change, allowing sensing of charge level. For example, for a 2-bit multilevel cell, a V_T from zero to 1.0V could equate to a binary value of "00," 1.0V to 2.0V would be "01," 2.0V to 3.0V would be "10," and 3.0V to 4.0V would be "11."

NAND

NAND flash was invented by Toshiba Corporation in Japan, which also invented flash memory. It has licensed it to Samsung in Korea, the world's largest memory and DRAM manufacturer. This technology has been aimed at mass storage from the beginning, so it has many features convenient for SSD design: fast write/erase, small block size, extra bit storage for error correction code (ECC) check bits, and a serial interface to reduce pin count. In addition, the flash cell design is minimized by not having separate electrical connections to every bit, with four cells connected in series. In contrast to NOR's perfect data reliability, NAND is assumed to have some "hard" defects and "soft" errors when reading stored information. Write speed has been enhanced by using tunneling instead of the channel hot electron (CHE) mechanism used in NOR devices.

Others

SanDisk Corporation

It should be noted that there are other mass storage-optimized flash memory technologies available. The most successful to date is from SanDisk, which focuses on system-level SSD products, mostly memory cards. SanDisk has developed proprietary "split gate" flash devices, built in outside foundries, that minimize on-board control circuitry in favor of placing it in a central controller. This reduces duplicate functionality in each chip in multidevice cards. They are NOR-type devices, which have a slower write speed using a CHE technique but include a separate erase element that shortens the erase delay. Although SanDisk does *not* sell discrete flash chips to others, controller-memory chipsets are available for OEMs.

Silicon Storage Technology Inc.

SST has developed what it calls SuperFlash technology aimed at mass storage applications. It uses a tunneling write mechanism to increase performance. The company has a full explanation of this on its World Wide Web pages (http://www.ssti.com). This was originally the corporate focus, but the company expanded into code store products to maintain profitability when the flash mass storage market was slow to develop.

Hitachi Ltd. and Mitsubishi Corporation

Hitachi and Mitsubishi have developed what they call AND flash, which is somewhat similar to NAND but is (surprise!) optimized for mass storage. Hitachi is now starting to ship with a 32Mb density.

System Issues

Error Correction

The primary difference between nonvolatile semiconductor memory aimed at code store applications and those focused on data storage applications is a tolerance for errors. Code store use, such as being connected to a microcontroller in an appliance, requires data to be perfect always. Otherwise the microcode, and the appliance, will malfunction, which is not allowed. Data storage is different in that the information retrieval time can include a delay for error correction, allowing the signal-to-noise ratio of the memory to decrease, which in turn allows the density to be pushed to the upper limits.

Thus, error detection and correction (EDAC) is a key issue in flash SSD system design. Perhaps the most important aspect of this function is *detecting* errors to prevent propagation of corrupted data files by unknowing users. This is especially true with removable media, such as memory cards. Once an error is detected, it must be corrected, with either a hardware or software approach possible. The system cost of a software approach is lower, but the correction time is longer, so this is used in cases where errors are infrequent. However, frequent errors would benefit from a hardware design, which can do "on the fly" error correction to maximize system throughput.

Controller Location and System Interface

A controversial subject in the flash industry is the best location for the controller required to manage flash mass storage media. Some argue that a dedicated microcontroller should be used for the "care and feeding" of the flash media. This approach lends itself to having a disk drive interface, such as the AT Attachment (ATA) interface used in most PCs, for the system connection. Another option is to use the system processor, a Pentium or K6, for instance, to perform the function under the direction of software drivers. This approach lends itself to the SSD having a address-data bus memory interface.

The advantages of a dedicated controller are:

- ATA interface
    - Transparent RDD emulation
    - Compatibility—built-in system "drivers"
    - Isolation from device specifications and idiosyncrasies
- Optimized algorithms for lowest cost per bit

The advantages of a software-driven architecture are:

- Minimum hardware cost
- Minimum system hardware complexity

None of these benefits is perceivable by the end user if the operating system has native support for both styles, so debates over which is best are decided on a system-by-system basis.

Device Issues

Architecture

The overall design strategy of a flash device aimed at mass storage applications is different from one destined for code store use. The practical requirement for some level of RDD emulation steers an architecture toward mimicking the operational characteristics of rotating magnetic storage. The disk organization of sectors, tracks/cylinders, and surfaces must somehow be respected, and the erase block size of the flash devices is the key specification on this quest.

Blocking

Flash memories have separate write and erase functions, with a byte/word granularity for writes and a block granularity for erases. Early flash chips imitated the EPROMs from which they were developed and therefore had only one erase block. This was appropriate for code store applications, but for data storage, smaller blocks are needed to allow for efficient rewriting of existing data blocks. If the block is too large, extra time and effort must be expended because an entire block may need to be erased if even a small portion of it needs to be changed. Also, most flash SSD designs choose to use one or two extra blocks as temporary storage, so a large block size carries a larger penalty for this than a small block size. Specifically, the size of RDD blocks is 512 bytes, NOR flash typically has 64KB blocks, NAND devices are between 4KB and 8KB, and split-gate memories have the "magic" size of 512 bytes.

Array Efficiency and Cost per Bit

The purpose of a memory is to store information—that is, bits. The part of a memory chip that does this is the cell array; all other circuitry is overhead and does not add value (bit storage) to the device. The ratio of the square millimeters used by the array divided by the total chip area is called "array efficiency" and is a key metric in tracking the cost per bit. NOR chips have a better array efficiency than NAND chips, but the NAND flash cell is smaller, usually giving it a total die size advantage. Also, NAND use focuses on mass storage, following in DRAM's footsteps by maximizing density, which NOR does not do because code storage does not require it. NAND vendors are now shipping 32Mb products and sampling 64Mb products. NOR vendors are just beginning to sample 64Mb MLC chips, with production shipment expected in 1998.

Speed

Code storage flash parts are usually used in a "read mostly" manner where read speed is paramount and write speed is inconsequential because the chip is rarely reprogrammed. Data storage applications reverse this situation, with the write operation occurring frequently and therefore being more important. The complication with flash is that two operations, erase and write, must be performed for a complete overwrite operation. Designers using NOR flash, with its larger block sizes, usually try to have erases done in the background, minimizing the impact of one-second erase times. NAND, with a smaller block size, has erase times on the same order of magnitude as writes, with effective write speeds of about 1MB/sec, compared with one-tenth that for NOR-based chips.

Packaging

Packaging is a key issue in the flash memory industry, especially when flash is incorporated in cellular telephones. The drive for miniaturization has given birth to chip scale packaging (CSP), in which the printed circuit board footprint approximates the memory die size. The package size is not critical for data storage flash except when it is used in a small-form factor memory card such as CompactFlash, Miniature Card, or Solid-State Floppy Disk Card (SSFDC). Then it increases packing density and card storage capacity. Another technique to minimize packing cost is to minimize package pin count, which can be done by making I/O serial instead of parallel. This offers some help, but because the chips are high density and not pad limited, reducing pins only minimizes package cost, not chip cost.

Dataquest Perspective

Flash is technically superior to mechanical mass storage in all respects except one: cost. It is fast, rugged, low power, and small compared to RDDs. When the required capacity is low, the cost issue is not relevant, so flash is the medium of choice. The type of flash, NOR or NAND, for instance, that is best for mass storage is being debated now, and no standards exist, but Dataquest expects them to emerge in the coming years. When this occurs, the flash memory market will increase its growth because of increased demand.

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Perspective

Memories Worldwide

Event Summary

A Bright Spring for Some

Abstract: *Dataquest's memories forecast shows promise for some and questions for others. The DRAM market is still in oversupply, but a turnaround is expected. The flash market continues to expand, while many SRAM manufacturers face an unattainable PC cache market. This Perspective transcribes the material covered in Dataquest's spring forecast telebriefing.*
By George Iwanyc and Jim Handy

Introduction

This Perspective is a transcription of Dataquest's spring memories forecast telebriefing. Telebriefing participants were:

- Jim Handy, George Iwanyc, and Bruce Bonner of Dataquest's Memories Worldwide program
- Mark Giudici and Evelyn Cronin of Dataquest's Semiconductor Supply and Pricing Worldwide program
- Clark Fuhs of Dataquest's Semiconductor Equipment, Manufacturing, and Materials Worldwide program
- Ron Bohn of Dataquest's Research Operations group

Forecast Highlights

- Dataquest has put together a new forecast for the memory market. This forecast shows the DRAM market continuing to dominate the overall memory market, followed by nonvolatile memories and then by SRAMs.

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- Dataquest forecasts the MOS memory market to hit $111 billion in the year 2000, then to suffer a downturn in 2001, dropping to $99 billion.
- DRAMs in 2001 will be a $67 billion market, down from $82 billion in 2000.
- SRAMs, after their 1996 decline, are back on a 25 percent compound annual growth rate (CAGR) path that will move the market to $14 billion in 2001.
- Of the nonvolatile technologies, flash memory is already nearly twice as large as the next larger market, EPROMs, and will grow at a CAGR of 30 percent to reach $9.5 billion in 2001.
- Dataquest is forecasting moderate growth for mask ROM after a period of stagnation and a flat EPROM business.
- EEPROMs will grow to $3.5 billion in 2001, fueled mainly by worldwide use in the smart card technology so prevalent today in Europe.

Underlying Assumptions

The memory business has been undergoing substantial changes over the past year, and it has been more difficult to tell where the market is going now than it has been in the past. Certain factors that influence this are:

- A significant DRAM overcapacity is still in play, although manufacturers are moderating capacity utilization.
- The transition from the 4Mb to 16Mb DRAM density is nearly complete; however, there will be challenging conversions later this year from extended data out (EDO) to synchronous DRAM (SDRAM), from 5V to 3V, from single in-line memory modules (SIMMs) to dual in-line memory modules (DIMMs), and so on, all of which confuses the art of forecasting.
- Certain DRAM vendors are trying to accelerate their changeover from the 16Mb density to the 64Mb density.
- Intel has announced two new PC-targeted processor modules that incorporate cache SRAMs.
- Flash is displacing EPROM in new system designs.
- There is oversupply in certain segments of the flash memory market as it continues to develop. This market is beginning to see an increasing number of competitors.
- Video games, recently the major market for mask ROMs, are now shifting to the use of CD-ROMs and cheap DRAMs.

Forecast Methodology

Dataquest's forecast methodology includes the following:

- A review of consumption trends using Dataquest's wide range of forecasts for the markets for computing, telecommunications, and other equipment that uses semiconductors
- Consideration of the effects of wafer fabrication capacity and the effects of overcapacity or shortages on the market
- Surveys of manufacturers, not only to review their shipment history but also to determine their production plans and pricing expectations
- Estimates of the impact of technology changes on the market and of suppliers' ability to follow, and users' willingness to accept, those changes
- Review of significant statistical trends in the market

Analysis by Technology

DRAM

It is interesting to compare the year 1997 against the year 1996. Despite a 12 percent increase in unit production and a transition from the 4Mb to the higher-priced 16Mb density that did not happen until the middle of 1996, 1997 revenue is expected to be 2 percent lower than 1996 revenue, at $25 billion this year versus 1996's $26.5 billion. Because profitability in early 1996 was still quite high, 1997 is the year in which Dataquest expects to see the lowest profits in the DRAM market of the past five years. Although manufacturers have been moderating capacity utilization to reduce availability and to increase prices, depreciation of their excess capacity still counts against the bottom line.

Although Dataquest expects to see continuing addition of moderate amounts of capital equipment during 1997, expenditure will be gated by profitability, and major expansion projects that were to be funded out of this year's profits have been put on hold. This will become a problem in the fourth quarter of 1999, when Dataquest forecasts an undersupply, not of the magnitude of the one from 1992 to 1995, but enough to drive up prices and to cause an industry cycle. This undersupply will last only until early 2000, then Dataquest expects a surge of capacity to be put on line, reducing DRAM prices nearer to costs. Through the market's peaks and valleys, Dataquest forecasts a CAGR of 19 percent for DRAMs from 1996 to 2000, where the market will be moving to about the $100 billion level.

In the short term, Dataquest expects to see difficulties stemming from a too-rapid conversion from EDO to SDRAM in PCs in the second half of this year. Suppliers already strong in SDRAM will see their average selling prices (ASPs) rise slightly and will see their share of the market increase, while SDRAM laggards will lose market share and will suffer from growing EDO inventories.

There are two possible scenarios for 1997, one indicating a price fall and the other a price rise. On one hand, the current higher pricing for DRAMs is a tenuous situation that could fall apart at any time. Should any DRAM manufacturer determine that prices are good enough to warrant an increase in unit production, the spot market would again plummet and 16Mb DRAM prices would drop to cost-based levels of as low as $6. On the other hand, manufacturers in Korea, buoyed by the results produced to date by their production cutbacks, believe that they will be able to raise the 16Mb DRAM's price to $12 contract and $15 spot this quarter. Dataquest's forecast assumes the midpoint between these scenarios, with a 16Mb DRAM price of $9.00.

Still, Dataquest's PC group has noted that the first quarter of this year has seen near-record growth, with PC units up 21.3 percent over the first quarter of last year. If this heated market keeps up, there could be a healthy rise in DRAM consumption that would give a needed boost to the market. Although acceptance of DRAM in non-PC applications such as DVD, set-top boxes, and video games is rising significantly, these markets are still very small, and their impact is negligible.

SRAM

Until this year, the PC cache market was the biggest and most attainable target for budding SRAM manufacturers. A few savvy chip designers, with the help of some workstations and contract foundry and back-end manufacturing plants, could compete in this largest portion of the SRAM market. This has changed. Now Intel is bundling the cache with its Pentium II and notebook modules. As does any major purchaser, Intel has limited its qualification efforts, reducing the number of competitors to a rumored three or four players from a field of some 50 SRAM manufacturers. This would imply that the other 47 manufacturers will have to find other markets to target. Some are going after other SRAM markets, while others, such as Alliance, G-Link, and ISSI are moving to DRAMs. Although this is a difficult period for those on the outside, the net effect of this reduced competition will be a price increase in the PC cache SRAM market, causing Dataquest to forecast solid growth in the fast SRAM market from now until the end of the forecast period.

As in most years before, the 1997 slow SRAM market is larger than the fast SRAM market. This situation reversed itself for the first time during the SRAM undersupply of 1995 and returned to normal in 1996. Dataquest anticipates continuing growth of the use of slow SRAMs, and despite a recent lag in the rate of the migration from one density to the next, Dataquest still sees slow SRAMs as a strong market. Many successful SRAM manufacturers will stay with the slow SRAM market. Slow SRAMs are used in an extremely broad range of applications and in most cases are not challenged by any other technology.

Dataquest forecasts total SRAM sales of $5.4 billion this year, up 14 percent from 1996's $4.7 billion market. Growth from 1996 to 2000 will be 25 percent, producing revenue in 2001 of $14.3 billion.

Flash

The flash memory market continues to grow and prosper as the base of large applications grows, with four now breaking away from the pack, as measured by unit consumption. In the personal computer market, a flash BIOS has become standard with the dominance of Pentium-class machines.

The explosion of digital cellular telephone sales has likewise created a boom market for flash manufacturers able to provide high-density, low-voltage devices. High-end rigid disk drives and automotive power train applications persist as large flash users, but with moderate growth. Future large users of flash bits look to be digital still cameras, internetworking routers and hubs, and digital set-top boxes.

Dataquest expects the flash market to grow from a record $2.8 billion in 1996 to $3.4 billion in 1997 and $9.4 billion in 2001, with a five-year CAGR of 30 percent. Unit expansion will start from 1996's 376 million units to 513 million units in 1997, eventually becoming 964 million units in 2001. Average density will break through the 4Mb level in 1997, but Dataquest still expects the 1Mb density to edge out 4Mb devices as the highest unit volume density this year. By 2001 Dataquest expects average density to almost quadruple to 15Mb, driven by high-density applications such as digital photography. Dataquest expects the 128Mb density to be shipping in volume that year.

Other Nonvolatile Memories

Mask ROM has seen hard times with the conversion of video games from cartridges to CD-ROMs, a move that was helped significantly by 1996's DRAM price slide. Lower DRAM prices allowed game console manufacturers to lower the price of the console to a point at which mass consumption was spurred. Although this resulted in a slowing of the mask ROM market, all sectors outside of video games continue to use ROMs in growing numbers, and the market will resume growth after it hits bottom this year. Dataquest forecasts 1997 revenue of $1.4 billion, rising to $2.3 billion in 2001,a modest CAGR of 14 percent.

EPROM is a stronger market than Dataquest has forecast in the past. Despite the appeal of flash memory, EPROM revenue appear to be leveling off, with overall market ASPs rising as competition drops out and as unit volumes decrease very slowly. Dataquest forecasts flat revenue of around $1.3 billion for the EPROM market through the term of the forecast.

The EEPROM market grew a healthy 31 percent last year, fueled by an explosion of consumer electronics devices and increasing use in PCs. Dataquest forecasts a 27 percent CAGR through the term of this forecast, resulting in year 2001 revenue of $3.5 billion. Dataquest expects the EEPROM market to surpass mask ROM revenue this year and for this to continue to be the second-largest nonvolatile market through the term of the forecast.

Conclusion

Overall, the new Dataquest memories forecast is a combination of both optimism and pessimism. Dataquest believes in the overall health of the market and expects the DRAM oversupply to resolve itself and turn into a regular cycle during the term of this forecast. Dataquest expects to see continuing health in the SRAM market, despite some serious adjustments in the supplier base. The nonvolatile market will see growing dominance of flash memory, with EEPROM gaining a significant position. Mask ROM will grow at its pregame rate, and EPROM will continue to slog along.

Questions and Answers

Q: Will you comment on your forecast for the flash market in 1997, based upon the relatively flat first quarter growth in 1997 versus 1996?

Bruce Bonner (BB): We still expect that digital cellular telephones and the new applications coming on line will, in fact, make flash revenue grow faster. Revenue will also increase as the market switches over to higher-density parts that have higher ASPs. For example, the current density in cellular telephones is about 8Mb, but we expect a transition to 16Mb, which has a higher ASP.

Q: I think you mentioned that the average cost to manufacture 16Mb DRAM is about $6. Based on this and your perceptions, what is the average cost to manufacturing 64Mb devices right now, and which companies are able to manufacture 64Mb profitably today?

Jim Handy (JH): I would like clarify that the $6 figure is not a cost to manufacture, but that is what we view as a minimum cost-based price that will not trigger dumping charges. We believe cost is about 10 percent lower than the $6 price. Since 64Mb DRAM is not in mass production by most manufacturers, there is a very broad range of costs to manufacture 64Mb DRAM.

Clark Fuhs (CF): As Jim mentioned, the 64Mb DRAM cost is pretty much all over the map. I believe the average is about five times the 16Mb cost at this point, which would place it in the $25-to-$30 range.

Q: Does Dataquest have a specific embedded flash study, and if so, is there a sneak preview you can give us with the basic growth rates that apply to that market?

JH: We call it system-level integration, and we are actually looking at it through several programs at Dataquest. The ASICs Worldwide program has looked at it (ASIC-WW-DP-9609, ASIC-WW-DP-9705) and the Embedded Microcomponents Worldwide program is deciding whether or not to do something. There is a lot of what some would call embedded flash already in existence, and so we have to decide what to include and what to exclude in those markets. However, I expect that in the next two quarters, you will see a new Dataquest report come out that addresses this issue.

Q: You said that there is some discussion of a half-step DRAM generation, specifically 128Mb DRAM. Would you or any of the analysts present comment on what you think of that proposition?

JH: What's fueling that discussion most of all is the reluctance of DRAM manufacturers to convert to a 32-bit-wide organization, coupled with the granularity needs of PC manufacturers. It's kind of funny that processes are only generated through four times the prior density. Manufacturers do not generate new processes oriented around two times the prior density, probably because of the economics. We think that if 128Mb parts are produced using 256Mb technology it will be in a x16 width, because nobody wants to make a 32-bit-wide 256Mb part.

CF: The DRAM product cycle has been typically driven by economics. The design, the product migration issues, and the transition costs drive the industry to at least a three- to four-year cycle in order to make a certain generation minimally profitable.

When we look at it in terms of comparable growth rates of bits per unit, the industry usually runs about 45 to 50 percent from a technology driven perspective. The growth rate of megabytes per PC has historically been in the low thirties, so the number of DRAM chips per PC is actually coming down. About a year and a half ago, we proposed that the four times DRAM cycles would actually lengthen the five- to six-year time frame because of this difference in growth rates. If that were to lengthen to seven years, then you could envision a profitability cycle that would include a two-times jump in DRAM density.

Q: When do you think the crossover between a 16Mb and 64Mb DRAM will occur, and, with that, please specify which width?

Mark Giudici (MG): The inputs to our pricing survey are being compiled right now. Prior to that survey, we expected mid-1998 to be the potential crossover point using a 4.5-times multiple. With the firming of the DRAM market, that may change.

Evelyn Cronin (EC): One important point is that the 16Mb-to-64Mb price crossover will occur far in advance of the volume crossover. This is one of the things that makes this crossover different from other density crossovers.

Q: Could you give me the percentage of the DRAM market that you think will be synchronous DRAMs in 1997, 1998, and 1999?

JH: There are two ways that we look at this. One is from the production plans that we get from DRAM manufacturers and the other is what the demand appears to be. If you believe that SDRAM is going to be handled by the PC market the same way EDO was, then what you can expect is a pretty violent changeover toward the end of this year. This is what we have been warning all our clients about. Purchasers need to be aware that they need to line up sources of supply, and manufacturers need to be aware that if they are not manufacturing synchronous devices by the end of this year, they are going to be left with a lot of inventory of EDO DRAM.

The production plans that we get from manufacturers indicate that they think there is going to be a graceful transition. We believe that DRAM manufacturers are talking to their customers, so this has a measure of credibility. However, Intel came to us when it made its Rambus announcement late last year and told us that by the end of last year, all high-end and desktop systems were using SDRAM. We think that Intel's SDRAM projection was a little bit premature. We think that Intel is going to push to have SDRAM used in all PCs by the end of this year, and we believe this will occur unless there is too little supply of SDRAM. For the 16Mb density, the synchronous transition is going to be very dramatic late this year. For all densities, 1998 should be at least 90 percent SDRAM.

Q: Could you comment on the dumping charges that have been filed against Korean and Taiwanese SRAM manufacturers and the impact this might have on U.S. producers and SRAM pricing?

JH: The dumping charges are written in a very confusing way. We have a number of American companies being hit with dumping charges, and we do not know how that works. What we are reading into these charges is that there is no legitimate way for Micron to go after Samsung with DRAM, so it used SRAMs as a way to go into that. Micron has made a statement that it filed these charges on behalf of Japanese SRAM manufacturers, and we haven't spoken to Micron about that. The impact it is having is not really anything special.

Where we expect to see a big impact to PC cache manufacturers is in Intel's sourcing of the SRAMs for the Pentium II cartridge and the mobile PC module. If Intel decides to go with manufacturers A, B, and C, then everybody else in the business will be left out. This takes away a very large part of the PC cache SRAM market, which is where the dumping issue was, and makes it into a market that is "hands off" to every small company.

Q: What are your DRAM bit growth assumptions for 1997 and 1998?

JH: Our bit growth assumption is based largely on DRAM manufacturers' responses. They shared these figures with us for the *DRAM Supply/Demand Quarterly Statistics* report (DSDR-WW-MS-97Q2). Bit growth in 1997 is 73 percent, and in 1998, it comes down a little bit to 54 percent. Our overall compound growth rate of bits is 69 percent from 1996 to 2001.

Q: Semiconductor companies have been ordering some new equipment to eventually shrink their line widths from 0.35 micron to 0.25 micron for both 16Mb and 64Mb DRAM. Can you comment on the impact this will have on pricing, and when you expect this to happen?

CF: One-quarter-micron capable equipment is being shipped into the world today, and most companies we talk to will introduce some sort of 0.25-micron process by the end of the year or by early next year. The full impact of that 0.25-micron shrink will not likely be until toward the later part of 1998 into 1999. This is a normal course of this business. Shrinks increase the number of bits that can go on a wafer by about 25 percent a year, on average.

This is a normal course of events and will add to the capacity in the industry as it normally does. It really isn't anything extremely special except during lean times, such as now, when transitions can happen a little faster because manufacturers have time to do it. During tight times, it takes a little bit longer than normal because they do not have time, as they are normally worried about production yields and ramps.

Q: I just wanted to clarify the point of DRAM bit growth. If I recall correctly, that is slightly higher in terms of consumption than we have historically seen in the industry. Could you comment a little about that?

JH: If you look back at our numbers for 1993 to 1996 (shown in Table 1), 69 percent is not out of line with those numbers for the bit growth rate.

Table 1
DRAM Bit Growth Rate, 1993 to 1996

Year	Bit Growth Rate (%)
1993	64
1994	53
1995	83
1996	78

Source: Dataquest (July 1997)

Q: Intel preannounced the fact that it is seeing slow order growth for its new Pentiums. Could you comment on how that is going to affect your forecast for the bit growth rate, the pricing, and the market in general for memories?

CF: Intel's press release says that the leading-edge processors are experiencing stronger demand, so I think that is pretty much counter to your comment. There is no comment in Intel's release about the unit volume. The company made comments about its revenue expectations being down 5 to 10 percent sequentially from the first quarter.

There are a couple of factors that put this into perspective:

- Intel normally makes its price cuts during the second quarter.
- Intel is in a product transition phase.
- There are a couple of other microprocessor companies that are taking aim at Intel.

First quarter PC unit shipments came in slightly above expectations, and it wouldn't be totally unreasonable if PC growth in the second quarter came in a little bit under as a result, but that is probably a normal minor fluctuation in the market. When the final analysis is done by the end of the year, we still feel our PC unit forecast at 18 percent is on course.

Q: I was wondering if you could tell me when you see the fabs that were delayed or put on hold in 1996 and 1997 starting to make announcements again?

CF: Those fabs that were technology or strategically oriented started to reaccelerate last November and December. That was to be expected, and it is why there has been some sequential strength in the equipment market in the first half of this year. Recently, there has been a second wave of fab delays. We think that these will start accelerating again in the second half or so.

Q: If you see SDRAM dominating through 1998, does that mean you see a change over to Rambus in the first quarter of 1999?

JH: What we are looking at with Rambus is the same kind of phenomenon that we saw with SDRAM. SDRAM is a technology that probably could have been manufactured over a year ago. Designers and management organizations have taken a long time to embrace SDRAM, for a number of reasons. They expected it to be more expensive, and it was a different technology. There is also incredible resistance to new design technologies when the old technology is seen as a satisfactory solution.

The same reasons make us anticipate a little later adoption of Rambus than the 1999 date that Intel has told us. We anticipate that there will be minor changes made to the SDRAM architecture, similar to the changes made by EDO to the fast page mode architecture. EDO slipped SDRAM adoption, and we think that with minor changes to the SDRAM architecture it will allow the adoption of Rambus to slip, too. Rambus looks like the technology of the future, but we are skeptical about the 1999 adoption, and we think that 2001 is a more realistic year for the adoption of Rambus technology.

Q: Following up on the synchronous question, if I hear you correctly, you are saying that there is potential for a real SDRAM shortage at the 16Mb density level. How long do you think that shortage might last in light of today's capacity?

JH: Capacity is not the issue. Our position is based on our understanding of the technology differences of SDRAM versus EDO DRAM and what we saw during the fast page-to-EDO conversion. I always tell people that Intel woke up one morning and said that it was going to change all the PCs over to EDO that day. When that happened, it took DRAM manufacturers about two months to get their run rates in line with demand for EDO. During that time, there was an oversupply of fast page mode and a shortage of EDO.

We expect to see the same phenomenon from a run rate management standpoint for SDRAM. However, EDO was usually done with a laser option or bonding option, so it took only about one week from the time somebody decided to adjust the run rate until run rates out of the factory door reflected those adjustments. With SDRAM, every vendor that we know of uses a completely new mask set from EDO, and that takes about two months to process through a fab. Add the two months to process through the DRAM fab to the two months it takes for manufacturers to get production in line with the market's needs, and the result is a four-month crisis when there will be a shortage. That's what we are telling people to brace themselves for, especially on the purchasing side.

Q: What percentage of total DRAM worldwide output is shipped as modules, and what is the growth rate through the year 2000?

George Iwanyc (GI): We believe that the amount of DRAMs shipped in modules to be around 70 to 75 percent. As for a forecast, we will not have those numbers until September or October.

JH: George Iwanyc has just done a report on the module market in which he examines the business of all the third-party DRAM module manufacturers worldwide (*Third-Party DRAM Module Manufacturer Study,* DPGR-WW-FR-

9702, April 21, 1997). That report is available outside the Memories Worldwide program, and if you are interested in the module market, you might want to contact a Dataquest salesperson to get a copy of that.

Q: Who do you see as the biggest beneficiary of Intel's purchase of cache SRAM?

JH: What we know is that the module that Intel gave us to demonstrate its mobile computer module had an NEC SRAM on it. We also know that the Pentium II that it passed around for us to look at had Mitsubishi SRAMs, which is surprising because we didn't know that it was one of the candidates. Now, given that Hitachi and Samsung are the No. 1 and No. 2 SRAM manufacturers and that we know that Samsung took a very strong position in the 32Kx32, then we would expect those two companies to be in on it. We would expect Sony, which also took a very strong position on the 32Kx32, to be in on it, and I would guess that Motorola is a contender on that. There isn't any other company that really comes to mind, so I have named five companies. The limit is expected to be three or four, so who gets left out of that party, I do not know.

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Perspective

Memories Worldwide

Market Analysis

Dataquest's Tactical Memories Newsletter —Vol. II, No. 13

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The End of an Era: Fry's Ads Drop DRAMs

Although it is not a part of the regular analysis that the Dataquest Memories Worldwide program provides to its users, we have amused ourselves by comparing the lowest weekly spot market prices reported by the American IC Exchange (AICE) against the lowest DRAM single in-line memory module (SIMM) prices given in the advertising supplement that the Silicon Valley store Fry's Electronics inserts into every Friday's issue of the *San Jose Mercury News* (Silicon Valley's leading newspaper). The results, missing a few dates, are shown in Figure 1.

For those who are unfamiliar with Fry's, the company runs a number of electronics "superstores" in California that sell computers, stereos, electronic components, snack foods, magazines, and toiletries, all under the same roof. The company aggressively advertises its electronics products and uses several loss leaders (products sold to the consumer at prices below the store's cost) to get the customers into the shop.

The chart seems to back up the notion that DRAM SIMMs were being sold at a loss, because the advertised prices were lower than the spot prices quoted by AICE. However, the AICE price is usually the starting point for spot market price negotiations. These prices are open to downward price

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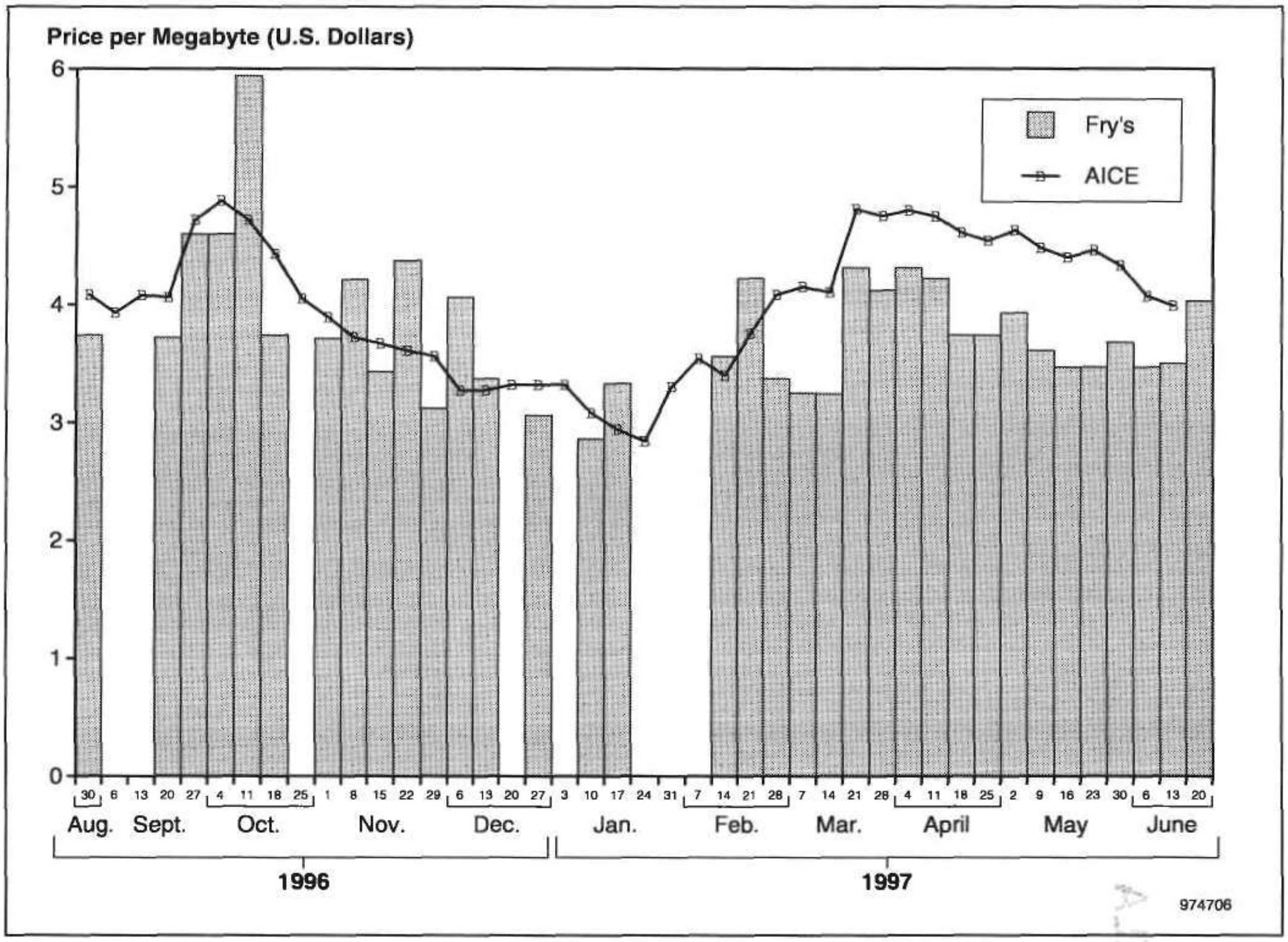
movement if the purchaser is buying in large volumes. Fry's has bought in volume and is passing the savings on to customers, but we suspect that Fry's is losing some money in the process.

Figure 1
Lowest Price per Megabyte: Fry's SIMMs versus AICE DRAM ICs



Source: Dataquest (June 1997)

On a greater scale, ever since the big price fall of 1996 rippled through to the end user, Fry's has advertised its SIMMs on the front page of its Friday advertising supplement. Last week was the first week that Fry's did not feature SIMMs in its advertisement. We suspect that this is because of the fact that DRAM pricing over the past few months has not suffered the alarming drops experienced in 1996 and is therefore much less of an attention grabber in Fry's advertisements. This would naturally remove the incentive to advertise SIMMs on the front page.

Dataquest does not take this to mean that spot market pricing is stabilizing. Excess product in both the contract and spot market channels, coupled with the continued above-demand output by manufacturers, has created a situation where current spot market trading of DRAM is almost zero despite excellent pricing and availability. This trend is set to continue until demand catches up with manufacturing capacity, which Dataquest does not expect until late 1998 (see Dataquest's *DRAM Supply/Demand Quarterly Statistics* reports). While the trend continues, any persons or companies buying in reasonable volume through this channel can negotiate to their heart's content! Brokers will fight tooth and nail to get the much prized but rare order. If dropping the price will get them the business, that's what will be done.

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TI and Vanguard Sign Cross-License Agreement

Texas Instruments Inc. and Vanguard International Semiconductor Corporation announced they have reached a 10-year worldwide semiconductor cross-license patent agreement. This is the first semiconductor patent agreement between TI and a Taiwanese company other than TI's joint venture with Acer Group. The new license will run until 2007, and TI will receive royalty payments throughout the life of the agreement. Under the agreement, VIS and TI will have the use of each other's patents involved in making semiconductor products.

DQ Take

Up to this time, VIS has been shipping DRAM into the United States using a "memorandum of understanding" between the two companies stating that a contract is being negotiated. Under the new agreement, TI will receive royalty payments from 1996 through 2007. The company started to ship DRAM to the United States in September 1996, and the United States now accounts for 30 percent of the company's sales.

Unlike other Taiwanese DRAM vendors, VIS was the only DRAM company without a technology alliance with a foreign company. The company came into being as a result of a government-sponsored project, originally with the limitation that 80 percent of the company's products had to be memory. Despite the DRAM downturn market, the company's long-term development in the memory field is unchanged. As a start-up company, VIS has sold its DRAM in the spot market for years; however, the company is starting to provide chips to Kingston Technology, which announced a total $100 million investment in Far East Kingston Technology to manufacture DRAM modules.

Jerry Yeh, Semiconductors Asia/Pacific, Taiwan, jerry.yeh@dataquest.com

Electronic Engineering Times' Surprise SyncLink Obituary

Dataquest was surprised, to say the least, to see the following story run in *Electronic Engineering Times* this week:

"The SyncLink DRAM consortium has halted the effort to develop a high-bandwidth DRAM for desktop computers. The momentum that's behind the Intel-backed Rambus DRAM and the double-data-rate (DDR) synchronous DRAM left the SyncLink partners facing development costs for a part that was unlikely to penetrate the desktop or server markets, backers said. Masao

Taguchi, who heads DRAM technology development at Fujitsu Ltd., said his company will put its engineering resources into DDR and Direct Rambus DRAMs."

The same issue of *EE Times* reported that Motorola and Apple planned to support SyncLink in their upcoming G4 processor. Also, representatives of Mosaid, the company that is working on the SyncLink demonstration chip, visited Dataquest and discussed their progress with the effort.

DQ Take

The fur flew when members of SyncLink and Fujitsu heard of this news item, and a meeting was immediately scheduled between Fujitsu's Taguchi and the author of the article. We expect to see a retraction this Monday. The SyncLink consortium (www.SLDRAM.com) has assured us that it is continuing to run along on target and that the consortium continues in its intent to displace Rambus as the next-generation DRAM interface.

Amazingly enough, Hambrecht & Quist, a stock brokerage dealing extensively in high-tech businesses, raised its price target for Rambus based on this erroneous story!

The American author Mark Twain put it best after he read a newspaper article that stated that he had passed away: "Rumors of my death are greatly exaggerated."

Jim Handy, Memories Worldwide, jim.handy@dataquest.com

Micron Ships 256Mb DRAM Samples

In a press release from Dell Computer Corporation, Micron Technology Inc. was revealed to have sampled 256Mb DRAMs to Dell for use in Dell's high-end workstations. The parts were said to be the first such samples delivered by Micron, and the headline read that these were the "first to begin architectural development and validation for next-generation Dell servers and workstations."

DQ Take

Micron Technology has a reputation of being a latecomer to the market for any new DRAM density. It appears that the company is trying to get over that image and is taking advantage of the delivery of these parts to show that it is serious about pursuing business a generation ahead of the current state of the art. Micron said that this was a step into moving its 0.25-micron process into production.

Perhaps we will see a change, under Micron's new president Steve Appleton, so that the company reputed to be the technology laggard will become a competitor on an even standing with the others in the top 10 ranking of DRAM manufacturers.

Jim Handy, Memories Worldwide, jim.handy@dataquest.com

DRAM Corner

We welcome DRAM tactical reports from readers. Please send them via e-mail to ron.bohn@dataquest.com.

The "Latest" DRAM Inventory Rumors

By the time this article has appeared, there will probably have been more recent DRAM inventory rumors that will supersede it.

Regardless, at Micron Technology's mid-June 1997 earnings conference call, the company mentioned during the question-and-answer session that it hears there are two to two and a half months of DRAM market inventory. By contrast, Micron's inventory at the very end of May 1997 stood at two to three weeks (versus two to three days at the very end of February 1997). Micron also mentioned that it had heard that Samsung apparently believed the DRAM market inventory level was less than two months.

The point is this—DRAM inventory, a hard-to-verify number, likely has increased as of early summer 1997. As recently as late April or early May, some DRAM suppliers stood convinced that DRAM inventory would be quite tight now—meaning a good third calendar quarter 1997 and an even better fourth quarter. Now that "summer 1997 PC doldrums" is the new refrain, however, many DRAM companies plan to quietly survive until, they hope, demand surges during the September or October 1997.

"Bridled Optimism" Still Prevails at Micron

Meanwhile, Micron remains more upbeat. From Dataquest's perspective, Micron should do all right despite lurking summer doldrums. Micron could do quite well later this calendar year and early next year, especially if 16Mb SDRAM demand surges.

A key reason is Micron's 16Mb DRAM manufacturing efficiencies. For example, Dataquest estimates that Micron likely enjoys a manufacturing cost of $4.25 or less for this cash cow product. Perhaps the cost is even much lower (perhaps below $4).

Also, Dataquest believes that Micron continues to push 16Mb yields to ever-higher levels.

Yield Estimate: Micron's 16Mb DRAM

The following is an estimate by Dataquest of Micron's 16Mb extended data out (EDO) DRAM yield for the February and May 1997. We base the estimate on information derived from the recent conference call, Dataquest estimates, and related sources. All information shown is Dataquest estimates.

- 8-inch wafers per week: 15,000 (stated in teleconference)
- Additions to inventory during the quarter (two to three weeks, minus the two to three days' inventory from the previous quarter): two weeks. (The lower this is, the lower the yield.)
- Weeks in quarter (adjusted for 52-week year): 12.5. (The higher this is, the lower the yield.)

- Dice per 8-inch wafer: about 500. (The higher this is, the lower the yield.)
- Quarterly 16Mb DRAM average selling price: $8.25
- Gross 16Mb DRAM dice per quarter: 94 million
- Dollar additions to DRAM inventory: $124 million
- DRAM sales + DRAM inventory additions: $635 million
- DRAM production value in dollars: $773 million
- Yield (sales + dollar additions to inventory)/DRAM dollar production = 82 percent

Micron has neither confirmed nor denied these estimates, in large part because Dataquest not asked it to do so. We should also note that our detailed model shows a range of yield estimates depending on assumptions. Most scenarios fell within 81 percent to 88 percent. The result shown is likely conservative but reasonable. The key point is that Dataquest believes that Micron was able to achieve 85 percent or better yields on 4Mb DRAMs, which led to its spectacular financial results in late 1994 though mid-1996. The company now shows signs of doing the same with the 16Mb DRAM during the next year or less. Micron's yields on the 16Mb synchronous DRAM, to competitors' chagrin, already approach those of 16Mb EDO DRAMs. As indicated, Micron should do well if 16Mb SDRAM demand surges during the September and October 1997.

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Dataquest's Tactical Memories Newsletter
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Perspective

Memories Worldwide

Event Summary

A Bright Spring for Some

Abstract: *Dataquest's memories forecast shows promise for some and questions for others. The DRAM market is still in oversupply, but a turnaround is expected. The flash market continues to expand, while many SRAM manufacturers face an unattainable PC cache market. This Perspective transcribes the material covered in Dataquest's spring forecast telebriefing.*
By George Iwanyc and Jim Handy

Introduction

This Perspective is a transcription of Dataquest's spring memories forecast telebriefing. Telebriefing participants were:

- Jim Handy, George Iwanyc, and Bruce Bonner of Dataquest's Memories Worldwide program
- Mark Giudici and Evelyn Cronin of Dataquest's Semiconductor Supply and Pricing Worldwide program
- Clark Fuhs of Dataquest's Semiconductor Equipment, Manufacturing, and Materials Worldwide program
- Ron Bohn of Dataquest's Research Operations group

Forecast Highlights

- Dataquest has put together a new forecast for the memory market. This forecast shows the DRAM market continuing to dominate the overall memory market, followed by nonvolatile memories and then by SRAMs.

Dataquest
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- Dataquest forecasts the MOS memory market to hit $111 billion in the year 2000, then to suffer a downturn in 2001, dropping to $99 billion.
- DRAMs in 2001 will be a $67 billion market, down from $82 billion in 2000.
- SRAMs, after their 1996 decline, are back on a 25 percent compound annual growth rate (CAGR) path that will move the market to $14 billion in 2001.
- Of the nonvolatile technologies, flash memory is already nearly twice as large as the next larger market, EPROMs, and will grow at a CAGR of 30 percent to reach $9.5 billion in 2001.
- Dataquest is forecasting moderate growth for mask ROM after a period of stagnation and a flat EPROM business.
- EEPROMs will grow to $3.5 billion in 2001, fueled mainly by worldwide use in the smart card technology so prevalent today in Europe.

Underlying Assumptions

The memory business has been undergoing substantial changes over the past year, and it has been more difficult to tell where the market is going now than it has been in the past. Certain factors that influence this are:

- A significant DRAM overcapacity is still in play, although manufacturers are moderating capacity utilization.
- The transition from the 4Mb to 16Mb DRAM density is nearly complete; however, there will be challenging conversions later this year from extended data out (EDO) to synchronous DRAM (SDRAM), from 5V to 3V, from single in-line memory modules (SIMMs) to dual in-line memory modules (DIMMs), and so on, all of which confuses the art of forecasting.
- Certain DRAM vendors are trying to accelerate their changeover from the 16Mb density to the 64Mb density.
- Intel has announced two new PC-targeted processor modules that incorporate cache SRAMs.
- Flash is displacing EPROM in new system designs.
- There is oversupply in certain segments of the flash memory market as it continues to develop. This market is beginning to see an increasing number of competitors.
- Video games, recently the major market for mask ROMs, are now shifting to the use of CD-ROMs and cheap DRAMs.

Forecast Methodology

Dataquest's forecast methodology includes the following:

- A review of consumption trends using Dataquest's wide range of forecasts for the markets for computing, telecommunications, and other equipment that uses semiconductors
- Consideration of the effects of wafer fabrication capacity and the effects of overcapacity or shortages on the market
- Surveys of manufacturers, not only to review their shipment history but also to determine their production plans and pricing expectations
- Estimates of the impact of technology changes on the market and of suppliers' ability to follow, and users' willingness to accept, those changes
- Review of significant statistical trends in the market

Analysis by Technology

DRAM

It is interesting to compare the year 1997 against the year 1996. Despite a 12 percent increase in unit production and a transition from the 4Mb to the higher-priced 16Mb density that did not happen until the middle of 1996, 1997 revenue is expected to be 2 percent lower than 1996 revenue, at $25 billion this year versus 1996's $26.5 billion. Because profitability in early 1996 was still quite high, 1997 is the year in which Dataquest expects to see the lowest profits in the DRAM market of the past five years. Although manufacturers have been moderating capacity utilization to reduce availability and to increase prices, depreciation of their excess capacity still counts against the bottom line.

Although Dataquest expects to see continuing addition of moderate amounts of capital equipment during 1997, expenditure will be gated by profitability, and major expansion projects that were to be funded out of this year's profits have been put on hold. This will become a problem in the fourth quarter of 1999, when Dataquest forecasts an undersupply, not of the magnitude of the one from 1992 to 1995, but enough to drive up prices and to cause an industry cycle. This undersupply will last only until early 2000, then Dataquest expects a surge of capacity to be put on line, reducing DRAM prices nearer to costs. Through the market's peaks and valleys, Dataquest forecasts a CAGR of 19 percent for DRAMs from 1996 to 2000, where the market will be moving to about the $100 billion level.

In the short term, Dataquest expects to see difficulties stemming from a too-rapid conversion from EDO to SDRAM in PCs in the second half of this year. Suppliers already strong in SDRAM will see their average selling prices (ASPs) rise slightly and will see their share of the market increase, while SDRAM laggards will lose market share and will suffer from growing EDO inventories.

There are two possible scenarios for 1997, one indicating a price fall and the other a price rise. On one hand, the current higher pricing for DRAMs is a tenuous situation that could fall apart at any time. Should any DRAM manufacturer determine that prices are good enough to warrant an increase in unit production, the spot market would again plummet and 16Mb DRAM prices would drop to cost-based levels of as low as $6. On the other hand, manufacturers in Korea, buoyed by the results produced to date by their production cutbacks, believe that they will be able to raise the 16Mb DRAM's price to $12 contract and $15 spot this quarter. Dataquest's forecast assumes the midpoint between these scenarios, with a 16Mb DRAM price of $9.00.

Still, Dataquest's PC group has noted that the first quarter of this year has seen near-record growth, with PC units up 21.3 percent over the first quarter of last year. If this heated market keeps up, there could be a healthy rise in DRAM consumption that would give a needed boost to the market. Although acceptance of DRAM in non-PC applications such as DVD, set-top boxes, and video games is rising significantly, these markets are still very small, and their impact is negligible.

SRAM

Until this year, the PC cache market was the biggest and most attainable target for budding SRAM manufacturers. A few savvy chip designers, with the help of some workstations and contract foundry and back-end manufacturing plants, could compete in this largest portion of the SRAM market. This has changed. Now Intel is bundling the cache with its Pentium II and notebook modules. As does any major purchaser, Intel has limited its qualification efforts, reducing the number of competitors to a rumored three or four players from a field of some 50 SRAM manufacturers. This would imply that the other 47 manufacturers will have to find other markets to target. Some are going after other SRAM markets, while others, such as Alliance, G-Link, and ISSI are moving to DRAMs. Although this is a difficult period for those on the outside, the net effect of this reduced competition will be a price increase in the PC cache SRAM market, causing Dataquest to forecast solid growth in the fast SRAM market from now until the end of the forecast period.

As in most years before, the 1997 slow SRAM market is larger than the fast SRAM market. This situation reversed itself for the first time during the SRAM undersupply of 1995 and returned to normal in 1996. Dataquest anticipates continuing growth of the use of slow SRAMs, and despite a recent lag in the rate of the migration from one density to the next, Dataquest still sees slow SRAMs as a strong market. Many successful SRAM manufacturers will stay with the slow SRAM market. Slow SRAMs are used in an extremely broad range of applications and in most cases are not challenged by any other technology.

Dataquest forecasts total SRAM sales of $5.4 billion this year, up 14 percent from 1996's $4.7 billion market. Growth from 1996 to 2000 will be 25 percent, producing revenue in 2001 of $14.3 billion.

Flash

The flash memory market continues to grow and prosper as the base of large applications grows, with four now breaking away from the pack, as measured by unit consumption. In the personal computer market, a flash BIOS has become standard with the dominance of Pentium-class machines.

The explosion of digital cellular telephone sales has likewise created a boom market for flash manufacturers able to provide high-density, low-voltage devices. High-end rigid disk drives and automotive power train applications persist as large flash users, but with moderate growth. Future large users of flash bits look to be digital still cameras, internetworking routers and hubs, and digital set-top boxes.

Dataquest expects the flash market to grow from a record $2.8 billion in 1996 to $3.4 billion in 1997 and $9.4 billion in 2001, with a five-year CAGR of 30 percent. Unit expansion will start from 1996's 376 million units to 513 million units in 1997, eventually becoming 964 million units in 2001. Average density will break through the 4Mb level in 1997, but Dataquest still expects the 1Mb density to edge out 4Mb devices as the highest unit volume density this year. By 2001 Dataquest expects average density to almost quadruple to 15Mb, driven by high-density applications such as digital photography. Dataquest expects the 128Mb density to be shipping in volume that year.

Other Nonvolatile Memories

Mask ROM has seen hard times with the conversion of video games from cartridges to CD-ROMs, a move that was helped significantly by 1996's DRAM price slide. Lower DRAM prices allowed game console manufacturers to lower the price of the console to a point at which mass consumption was spurred. Although this resulted in a slowing of the mask ROM market, all sectors outside of video games continue to use ROMs in growing numbers, and the market will resume growth after it hits bottom this year. Dataquest forecasts 1997 revenue of $1.4 billion, rising to $2.3 billion in 2001,a modest CAGR of 14 percent.

EPROM is a stronger market than Dataquest has forecast in the past. Despite the appeal of flash memory, EPROM revenue appear to be leveling off, with overall market ASPs rising as competition drops out and as unit volumes decrease very slowly. Dataquest forecasts flat revenue of around $1.3 billion for the EPROM market through the term of the forecast.

The EEPROM market grew a healthy 31 percent last year, fueled by an explosion of consumer electronics devices and increasing use in PCs. Dataquest forecasts a 27 percent CAGR through the term of this forecast, resulting in year 2001 revenue of $3.5 billion. Dataquest expects the EEPROM market to surpass mask ROM revenue this year and for this to continue to be the second-largest nonvolatile market through the term of the forecast.

Conclusion

Overall, the new Dataquest memories forecast is a combination of both optimism and pessimism. Dataquest believes in the overall health of the market and expects the DRAM oversupply to resolve itself and turn into a regular cycle during the term of this forecast. Dataquest expects to see continuing health in the SRAM market, despite some serious adjustments in the supplier base. The nonvolatile market will see growing dominance of flash memory, with EEPROM gaining a significant position. Mask ROM will grow at its pregame rate, and EPROM will continue to slog along.

Questions and Answers

Q: Will you comment on your forecast for the flash market in 1997, based upon the relatively flat first quarter growth in 1997 versus 1996?

Bruce Bonner (BB): We still expect that digital cellular telephones and the new applications coming on line will, in fact, make flash revenue grow faster. Revenue will also increase as the market switches over to higher-density parts that have higher ASPs. For example, the current density in cellular telephones is about 8Mb, but we expect a transition to 16Mb, which has a higher ASP.

Q: I think you mentioned that the average cost to manufacture 16Mb DRAM is about $6. Based on this and your perceptions, what is the average cost to manufacturing 64Mb devices right now, and which companies are able to manufacture 64Mb profitably today?

Jim Handy (JH): I would like clarify that the $6 figure is not a cost to manufacture, but that is what we view as a minimum cost-based price that will not trigger dumping charges. We believe cost is about 10 percent lower than the $6 price. Since 64Mb DRAM is not in mass production by most manufacturers, there is a very broad range of costs to manufacture 64Mb DRAM.

Clark Fuhs (CF): As Jim mentioned, the 64Mb DRAM cost is pretty much all over the map. I believe the average is about five times the 16Mb cost at this point, which would place it in the $25-to-$30 range.

Q: Does Dataquest have a specific embedded flash study, and if so, is there a sneak preview you can give us with the basic growth rates that apply to that market?

JH: We call it system-level integration, and we are actually looking at it through several programs at Dataquest. The ASICs Worldwide program has looked at it (ASIC-WW-DP-9609, ASIC-WW-DP-9705) and the Embedded Microcomponents Worldwide program is deciding whether or not to do something. There is a lot of what some would call embedded flash already in existence, and so we have to decide what to include and what to exclude in those markets. However, I expect that in the next two quarters, you will see a new Dataquest report come out that addresses this issue.

Q: You said that there is some discussion of a half-step DRAM generation, specifically 128Mb DRAM. Would you or any of the analysts present comment on what you think of that proposition?

JH: What's fueling that discussion most of all is the reluctance of DRAM manufacturers to convert to a 32-bit-wide organization, coupled with the granularity needs of PC manufacturers. It's kind of funny that processes are only generated through four times the prior density. Manufacturers do not generate new processes oriented around two times the prior density, probably because of the economics. We think that if 128Mb parts are produced using 256Mb technology it will be in a x16 width, because nobody wants to make a 32-bit-wide 256Mb part.

CF: The DRAM product cycle has been typically driven by economics. The design, the product migration issues, and the transition costs drive the industry to at least a three- to four-year cycle in order to make a certain generation minimally profitable.

When we look at it in terms of comparable growth rates of bits per unit, the industry usually runs about 45 to 50 percent from a technology driven perspective. The growth rate of megabytes per PC has historically been in the low thirties, so the number of DRAM chips per PC is actually coming down. About a year and a half ago, we proposed that the four times DRAM cycles would actually lengthen the five- to six-year time frame because of this difference in growth rates. If that were to lengthen to seven years, then you could envision a profitability cycle that would include a two-times jump in DRAM density.

Q: When do you think the crossover between a 16Mb and 64Mb DRAM will occur, and, with that, please specify which width?

Mark Giudici (MG): The inputs to our pricing survey are being compiled right now. Prior to that survey, we expected mid-1998 to be the potential crossover point using a 4.5-times multiple. With the firming of the DRAM market, that may change.

Evelyn Cronin (EC): One important point is that the 16Mb-to-64Mb price crossover will occur far in advance of the volume crossover. This is one of the things that makes this crossover different from other density crossovers.

Q: Could you give me the percentage of the DRAM market that you think will be synchronous DRAMs in 1997, 1998, and 1999?

JH: There are two ways that we look at this. One is from the production plans that we get from DRAM manufacturers and the other is what the demand appears to be. If you believe that SDRAM is going to be handled by the PC market the same way EDO was, then what you can expect is a pretty violent changeover toward the end of this year. This is what we have been warning all our clients about. Purchasers need to be aware that they need to line up sources of supply, and manufacturers need to be aware that if they are not manufacturing synchronous devices by the end of this year, they are going to be left with a lot of inventory of EDO DRAM.

The production plans that we get from manufacturers indicate that they think there is going to be a graceful transition. We believe that DRAM manufacturers are talking to their customers, so this has a measure of credibility. However, Intel came to us when it made its Rambus announcement late last year and told us that by the end of last year, all high-end and desktop systems were using SDRAM. We think that Intel's SDRAM projection was a little bit premature. We think that Intel is going to push to have SDRAM used in all PCs by the end of this year, and we believe this will occur unless there is too little supply of SDRAM. For the 16Mb density, the synchronous transition is going to be very dramatic late this year. For all densities, 1998 should be at least 90 percent SDRAM.

Q: Could you comment on the dumping charges that have been filed against Korean and Taiwanese SRAM manufacturers and the impact this might have on U.S. producers and SRAM pricing?

JH: The dumping charges are written in a very confusing way. We have a number of American companies being hit with dumping charges, and we do not know how that works. What we are reading into these charges is that there is no legitimate way for Micron to go after Samsung with DRAM, so it used SRAMs as a way to go into that. Micron has made a statement that it filed these charges on behalf of Japanese SRAM manufacturers, and we haven't spoken to Micron about that. The impact it is having is not really anything special.

Where we expect to see a big impact to PC cache manufacturers is in Intel's sourcing of the SRAMs for the Pentium II cartridge and the mobile PC module. If Intel decides to go with manufacturers A, B, and C, then everybody else in the business will be left out. This takes away a very large part of the PC cache SRAM market, which is where the dumping issue was, and makes it into a market that is "hands off" to every small company.

Q: What are your DRAM bit growth assumptions for 1997 and 1998?

JH: Our bit growth assumption is based largely on DRAM manufacturers' responses. They shared these figures with us for the *DRAM Supply/Demand Quarterly Statistics* report (DSDR-WW-MS-97Q2). Bit growth in 1997 is 73 percent, and in 1998, it comes down a little bit to 54 percent. Our overall compound growth rate of bits is 69 percent from 1996 to 2001.

Q: Semiconductor companies have been ordering some new equipment to eventually shrink their line widths from 0.35 micron to 0.25 micron for both 16Mb and 64Mb DRAM. Can you comment on the impact this will have on pricing, and when you expect this to happen?

CF: One-quarter-micron capable equipment is being shipped into the world today, and most companies we talk to will introduce some sort of 0.25-micron process by the end of the year or by early next year. The full impact of that 0.25-micron shrink will not likely be until toward the later part of 1998 into 1999. This is a normal course of this business. Shrinks increase the number of bits that can go on a wafer by about 25 percent a year, on average.

This is a normal course of events and will add to the capacity in the industry as it normally does. It really isn't anything extremely special except during lean times, such as now, when transitions can happen a little faster because manufacturers have time to do it. During tight times, it takes a little bit longer than normal because they do not have time, as they are normally worried about production yields and ramps.

Q: I just wanted to clarify the point of DRAM bit growth. If I recall correctly, that is slightly higher in terms of consumption than we have historically seen in the industry. Could you comment a little about that?

JH: If you look back at our numbers for 1993 to 1996 (shown in Table 1), 69 percent is not out of line with those numbers for the bit growth rate.

Table 1
DRAM Bit Growth Rate, 1993 to 1996

Year	Bit Growth Rate (%)
1993	64
1994	53
1995	83
1996	78

Source: Dataquest (July 1997)

Q: Intel preannounced the fact that it is seeing slow order growth for its new Pentiums. Could you comment on how that is going to affect your forecast for the bit growth rate, the pricing, and the market in general for memories?

CF: Intel's press release says that the leading-edge processors are experiencing stronger demand, so I think that is pretty much counter to your comment. There is no comment in Intel's release about the unit volume. The company made comments about its revenue expectations being down 5 to 10 percent sequentially from the first quarter.

There are a couple of factors that put this into perspective:

- Intel normally makes its price cuts during the second quarter.
- Intel is in a product transition phase.
- There are a couple of other microprocessor companies that are taking aim at Intel.

First quarter PC unit shipments came in slightly above expectations, and it wouldn't be totally unreasonable if PC growth in the second quarter came in a little bit under as a result, but that is probably a normal minor fluctuation in the market. When the final analysis is done by the end of the year, we still feel our PC unit forecast at 18 percent is on course.

Q: I was wondering if you could tell me when you see the fabs that were delayed or put on hold in 1996 and 1997 starting to make announcements again?

CF: Those fabs that were technology or strategically oriented started to reaccelerate last November and December. That was to be expected, and it is why there has been some sequential strength in the equipment market in the first half of this year. Recently, there has been a second wave of fab delays. We think that these will start accelerating again in the second half or so.

Q: If you see SDRAM dominating through 1998, does that mean you see a change over to Rambus in the first quarter of 1999?

JH: What we are looking at with Rambus is the same kind of phenomenon that we saw with SDRAM. SDRAM is a technology that probably could have been manufactured over a year ago. Designers and management organizations have taken a long time to embrace SDRAM, for a number of reasons. They expected it to be more expensive, and it was a different technology. There is also incredible resistance to new design technologies when the old technology is seen as a satisfactory solution.

The same reasons make us anticipate a little later adoption of Rambus than the 1999 date that Intel has told us. We anticipate that there will be minor changes made to the SDRAM architecture, similar to the changes made by EDO to the fast page mode architecture. EDO slipped SDRAM adoption, and we think that with minor changes to the SDRAM architecture it will allow the adoption of Rambus to slip, too. Rambus looks like the technology of the future, but we are skeptical about the 1999 adoption, and we think that 2001 is a more realistic year for the adoption of Rambus technology.

Q: Following up on the synchronous question, if I hear you correctly, you are saying that there is potential for a real SDRAM shortage at the 16Mb density level. How long do you think that shortage might last in light of today's capacity?

JH: Capacity is not the issue. Our position is based on our understanding of the technology differences of SDRAM versus EDO DRAM and what we saw during the fast page-to-EDO conversion. I always tell people that Intel woke up one morning and said that it was going to change all the PCs over to EDO that day. When that happened, it took DRAM manufacturers about two months to get their run rates in line with demand for EDO. During that time, there was an oversupply of fast page mode and a shortage of EDO.

We expect to see the same phenomenon from a run rate management standpoint for SDRAM. However, EDO was usually done with a laser option or bonding option, so it took only about one week from the time somebody decided to adjust the run rate until run rates out of the factory door reflected those adjustments. With SDRAM, every vendor that we know of uses a completely new mask set from EDO, and that takes about two months to process through a fab. Add the two months to process through the DRAM fab to the two months it takes for manufacturers to get production in line with the market's needs, and the result is a four-month crisis when there will be a shortage. That's what we are telling people to brace themselves for, especially on the purchasing side.

Q: What percentage of total DRAM worldwide output is shipped as modules, and what is the growth rate through the year 2000?

George Iwanyc (GI): We believe that the amount of DRAMs shipped in modules to be around 70 to 75 percent. As for a forecast, we will not have those numbers until September or October.

JH: George Iwanyc has just done a report on the module market in which he examines the business of all the third-party DRAM module manufacturers worldwide (*Third-Party DRAM Module Manufacturer Study*, DPGR-WW-FR-

9702, April 21, 1997). That report is available outside the Memories Worldwide program, and if you are interested in the module market, you might want to contact a Dataquest salesperson to get a copy of that.

Q: Who do you see as the biggest beneficiary of Intel's purchase of cache SRAM?

JH: What we know is that the module that Intel gave us to demonstrate its mobile computer module had an NEC SRAM on it. We also know that the Pentium II that it passed around for us to look at had Mitsubishi SRAMs, which is surprising because we didn't know that it was one of the candidates. Now, given that Hitachi and Samsung are the No. 1 and No. 2 SRAM manufacturers and that we know that Samsung took a very strong position in the 32Kx32, then we would expect those two companies to be in on it. We would expect Sony, which also took a very strong position on the 32Kx32, to be in on it, and I would guess that Motorola is a contender on that. There isn't any other company that really comes to mind, so I have named five companies. The limit is expected to be three or four, so who gets left out of that party, I do not know.

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Perspective

Memories Worldwide

Technology Analysis

System-Level Integration ASICs Add Embedded DRAM

Abstract: *In the early 1990s, the first steps toward system-level integration brought microprocessors and SRAM onto ASICs. Advanced silicon process techniques now allow one-transistor DRAM memory to join the other components on-chip in a giant step toward single-chip systems. This Perspective analyzes embedded DRAM technology and presents a forecast for this market through the year 2001.*

By Jordan Selburn

Single-Chip Systems in the Homestretch

There is a strong and accelerating trend in the ASIC industry toward system-level integration (SLI), that is, placing higher levels of the total system functionality on a single chip. Starting in the early 1990s, the widening availability of processor cores such as the ARM and MIPS microprocessors and the Oak DSP has made the first step to SLI a reality. Integration of mixed-signal capability, including digital-to-analog (D/A) and analog-to-digital (A/D) converters has reduced the system chip count further. The next candidate for widespread integration on an ASIC is single-transistor memory; with this embedded DRAM, the single-chip system becomes less of a dream and more of a soon-to-be realizable goal.

Dataquest forecasts that ASICs containing embedded DRAM will account for a significant percentage of the ASIC market by the year 2001. Especially significant is that this segment contains some of the highest added value, and hence the highest potential profit margin, designs, and these devices are going into some of the highest-growth markets, such as graphics controllers and digital video, among others.

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Embedded DRAM Technology

The conventional approach to system memory has placed small memory caches on the logic chips (usually ASICs), with the much larger main memory implemented in standalone DRAMs. The fundamental differences between a silicon process optimized for logic and one optimized for DRAM—primarily an emphasis on interconnect technology versus capacitor construction—have prevented significant integration until recently. Today we are beginning to see a merger of logic and memory in something known as embedded DRAM. This can be defined as a product that includes large amounts (more than 100,000 gates) of random logic and single-transistor (1T) DRAM on a single chip.

What Benefits Does Embedded DRAM Bring?

Most of the advantages to bringing system memory on-chip are quite straightforward. In brief, embedded DRAM allows the following:

- Few discrete components, hence less printed circuit board (PCB) area, higher reliability, and lower assembly costs
- Potentially lower parts cost, particularly if the logic design is I/O-limited (that is, there is some unused silicon area in the die core); note that the overall pin count also decreases by eliminating wide memory buses
- Higher performance through direct access to the DRAM instead of through I/O pairs and PCB traces
- Lower bit-usage requirement through the finer granularity of embedded memory
- Higher performance through system architecture optimization—for example, very wide memory buses such as 256 bits, 512 bits, or even 1,024 bits

Embedded DRAM Implementation

There are two approaches to embedding single-transistor DRAM into an ASIC. Starting with a logic-optimized process, vendors such as Samsung incorporate 1T DRAM through a quasi-merged logic/memory process. This attempts to preserve logic density and performance but does result in somewhat lower memory density. Conversely, most vendors start with a memory process to embed DRAM into logic. At present, there are two ways in which this can be accomplished, differing in the manner in which the charge-storage device is built: stacked capacitor or trench capacitor.

Most standalone DRAMs today are built with stacked capacitors. Layers of dielectric are sandwiched between polysilicon layers to build the capacitors. This technology is well-established and provides for integration of substantial amounts of memory on-chip. This has exacted a cost in logic density and performance from various trade-offs, such as interconnect for DRAM that has traditionally been limited to two layers and is not aggressively pitched, severely restricting logic density.

A more recent innovation is the trench capacitor, which places the dielectric in a trench etched into the substrate. This approach has several advantages over stacked capacitors, such as higher cell capacitance, a smaller impact on logic density, and higher maximum performance. Table 1 compares stacked and trenched capacitor implementations.

Table 1
One-Transistor DRAM Comparison

	Stacked Capacitor	Trench Capacitor
Maximum On-Chip Memory (0.25-Micron Generation)	64Mb	128Mb
Cell Capacitance	25fF	40fF
Maximum Performance	150 MHz	166 MHz

Source: Dataquest (April 1997)

Alternatives to Embedded DRAM

SRAM

Historically, ASICs have put small (relative to DRAM) amounts of memory on-chip with static RAM (SRAM). SRAM on an ASIC can be built of either logic gates (typically on a gate array) or out of dedicated six-transistor (6T) SRAM bit cells (typically for cell-based or embedded array designs). An SRAM memory block is much faster than an equivalent DRAM implementation but can be 10 times larger or more in area. For the 0.35-micron generation, a practical upper bound is about 1Mb of 6T SRAM on-chip. (All references to gate geometry refer to the drawn gate length of the transistor.)

Three-Transistor DRAM

A hybrid approach to large on-chip memory, the three-transistor (3T) DRAM is built with a pure logic-optimized process, allowing integration of significant amounts of memory (up to 16Mb) with no negative impact on logic density. Rather than building a standalone capacitor (that is, stacked or trench), the gate capacitance of one of the three transistors is used for charge storage. The result is a memory block about 40 percent smaller than a 6T SRAM implementation but one that is about 60 percent slower and has slightly higher power consumption. Also, the 3T DRAM needs refresh circuitry, which is unnecessary for SRAM. In the 0.35-micron generation, a practical upper bound is about 2Mb of 3T DRAM on-chip.

Standalone DRAM

The traditional approach to incorporating large blocks of memory in a system is standalone, standard-part DRAMs. As these are commodity parts, the cost is quite low per bit, assuming that all of the available memory on a chip is used; however, the amount of memory on a chip may not correspond well with the user's specific requirements because of the coarse granularity (1Mb, 4Mb, 16Mb, for example) of standard parts. A standalone DRAM solution also offers lower performance, higher power consumption, higher parts count, and more PCB area than an embedded DRAM solution.

There are some recent enhancements to standalone DRAM that can offer substantial improvements. Rambus DRAM, for example, at 500 MB/sec, has much higher performance than standalone DRAM and also reduces the ASIC's pin count, allowing a smaller die in some cases. These enhanced memories, however, generally come at a higher cost and usually do not reduce PCB area or power consumption.

Packaging Solutions

Multichip module (MCM) packages offer another approach to integrating memory with logic. By placing standalone DRAM and an ASIC on a high-performance substrate within a single package, it can look to the outside world as if the memory had been embedded on-chip. Performance and PCB area are usually enhanced in an MCM, although the cost is higher, primarily because of yield issues. At present, MCM remains a potential solution for the future.

Another innovative packaging solution is physically mounting a standalone DRAM directly on the ASIC. For now, however, this remains strictly a research project.

Table 2 shows the current state of the art for embedded DRAM, and represents the memory technology available in the 0.25-micron generation of ASICs. These ASIC products will begin prototype production in the latter half of 1997, with full production beginning to ramp in mid-1998. Figure 1 demonstrates the evolution of embedded memory technology through the 0.18-micron generation. These products will be introduced in 1998, with full production beginning in 1999; the 0.18-micron generation will become the mainstream ASIC technology starting in 2000 to 2001.

Embedded Memory Players

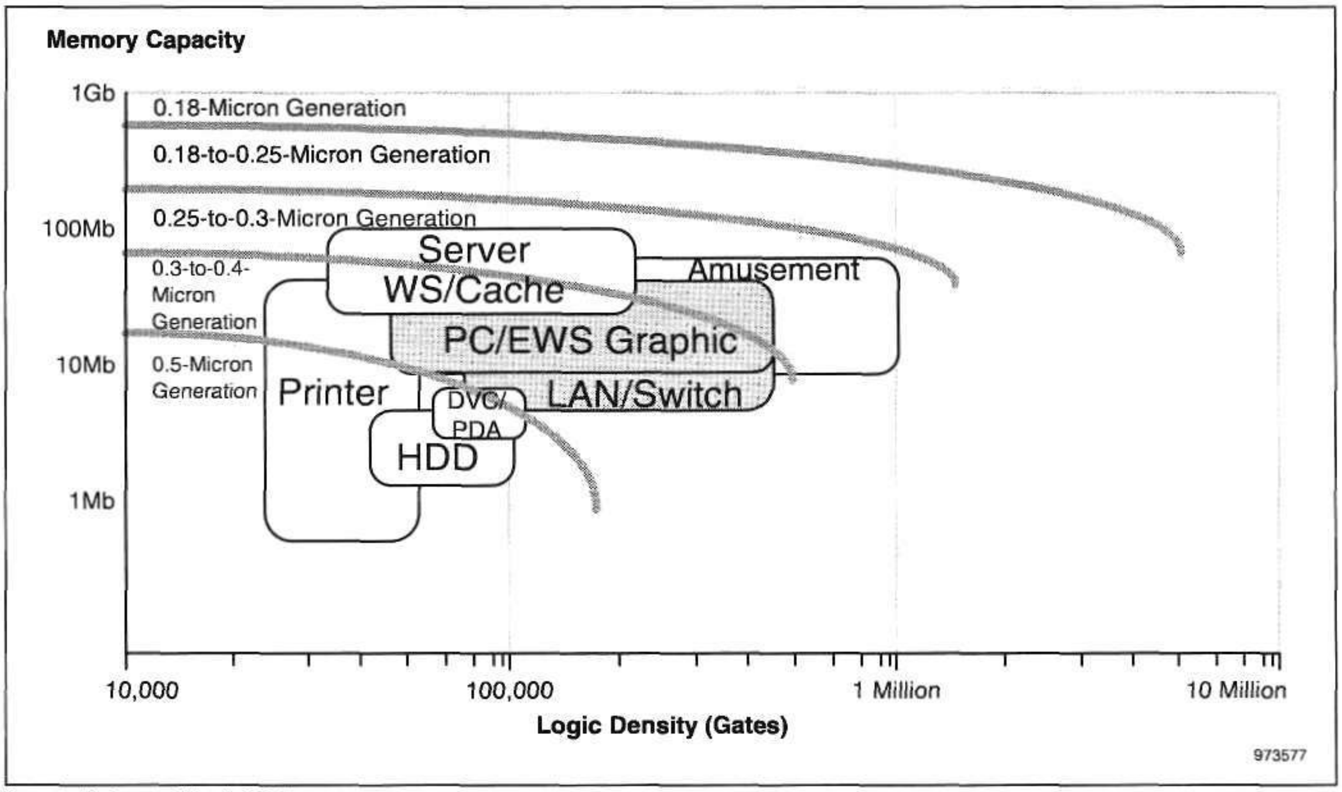
Table 3 shows a sample of ASIC supplier strategies for bringing system memory onto the logic chip. Virtually all of the leading ASIC vendors have either already announced support for embedded 1T DRAM or are exploring the concept and technology.

Table 2
Embedded Memory Comparison

	DRAM Process		Logic Process	
	Stacked Capacitor	Trench Capacitor	3T DRAM	6T SRAM
Maximum On-Chip Memory	+++	+++	+	-
Logic Density	++	++	+++	+++
Maximum Memory Performance	-	-	+	+++
Power Consumption	+	++	+	++
1Mb Approximate Area (0.25-Micron Generation)	2.5 mm^2	2.5 mm^2	16 mm^2	24 mm^2

Note: +++ shows best performance; - shows worst.
Source: Dataquest (April 1997)

Figure 1
Embedded DRAM Trends



Source: Dataquest (April 1997)

Table 3
Representative ASIC Vendors' Memory Offerings

	Stacked Capacitor	Trench Capacitor	3T DRAM	6T SRAM
NEC	X			X
LSI Logic			X	X
Fujitsu	X			X
Toshiba		X	X	X
Lucent Technologies				X
Texas Instruments	X			X
IBM				X
VLSI Technology			X	X
Samsung	X			X

Source: Dataquest (April 1997)

Embedded DRAM Applications

When to Merge Main Memory with Logic

Integrating system memory on-chip with logic and processors has the potential for significant benefits. Some applications require the higher performance attainable through the direct signal path to memory, some portable systems are driven to reduce parts count and board area, and all designs benefit from lower costs. Characteristics of designs that will see a greater degree of these benefits are summarized below:

- I/O-limited designs, where there is unused area within the core area of the die can have memory placed into this area at essentially no cost other than a somewhat lower yield. There is a further advantage in a reduction of the pin count through elimination of the off-chip memory interface. LAN switch chips are an example of this type of design.
- Designs with a performance bottleneck in the main memory interface can eliminate the I/O pairs and intervening printed circuit board wiring by bringing the memory on chip. Embedded memory can also be optimized for performance in that specific application, as opposed to generic standalone DRAM. 3-D graphics controllers fall into this category.
- Portable applications are driven to reduce size and extend battery life. Embedded DRAMs reduce chip count (hence PCB area) and reduce the system power consumption. Digital video camcorders and digital still cameras are typical for this type of design.

Leading designs that will incorporate embedded DRAM are:

- PC graphics controllers
- Workstation graphics controllers
- Digital video camcorders
- Digital still cameras
- LAN switches and hubs
- Hard disk drives
- Personal digital assistants (PDAs)
- Printer controllers

Selected applications, with specific memory requirements and forecasts, are discussed in more detail in the following sections.

When *Not* to Use Embedded DRAM

Despite its advantages, there are still many applications that do not benefit (and may even suffer) from using embedded DRAM. The converse of the characteristics in the above section are contraindications for bringing main memory on-chip. Core-limited designs housed in a desktop system that have large amounts of available PCB real estate and are powered from the wall socket are less likely candidates for embedded DRAM; for the foreseeable future, standalone DRAM will continue to offer a substantially lower price per bit than any embedded DRAM. Examples of this type of system include set-top boxes and desktop PC core logic, among others.

Specific Application Requirements

The following three examples from the computer (PC graphics controller), consumer (digital video camcorder), and communications (LAN/WAN switches and hubs) markets illustrate the spectrum of needs for and uses of embedded memory.

PC Graphics Controllers

Among the first applications to bring substantial amounts of memory onto the die are graphics controllers. The performance requirements as well as amount of memory used for graphics continue to increase as monitor resolutions improve and greater bit-depths (from 8- to 16- and ultimately 24-bit color) become common. As a consumer product, PCs also need to continue to bring these expanding capabilities to the market very cost-effectively. A typical mobile PC graphics system (shown in Figure 2) in 1997 has the following memory requirement:

- 1024 × 768 pixels at 16 bits/pixel: 1.6MB
- Multimedia and video clips: 0.2MB
- 3-D texture buffer: 0.2MB
- Total: 2.0MB

This amount could easily increase to 4MB by the year 2000.

Mobile PC systems, which are driven to reduce chip count and power consumption in addition to the performance and cost requirements mentioned, have already embraced embedded DRAM. The first product in this market, an application-specific standard product (ASSP) with 1.1MB of DRAM on-chip, began production in 1996.

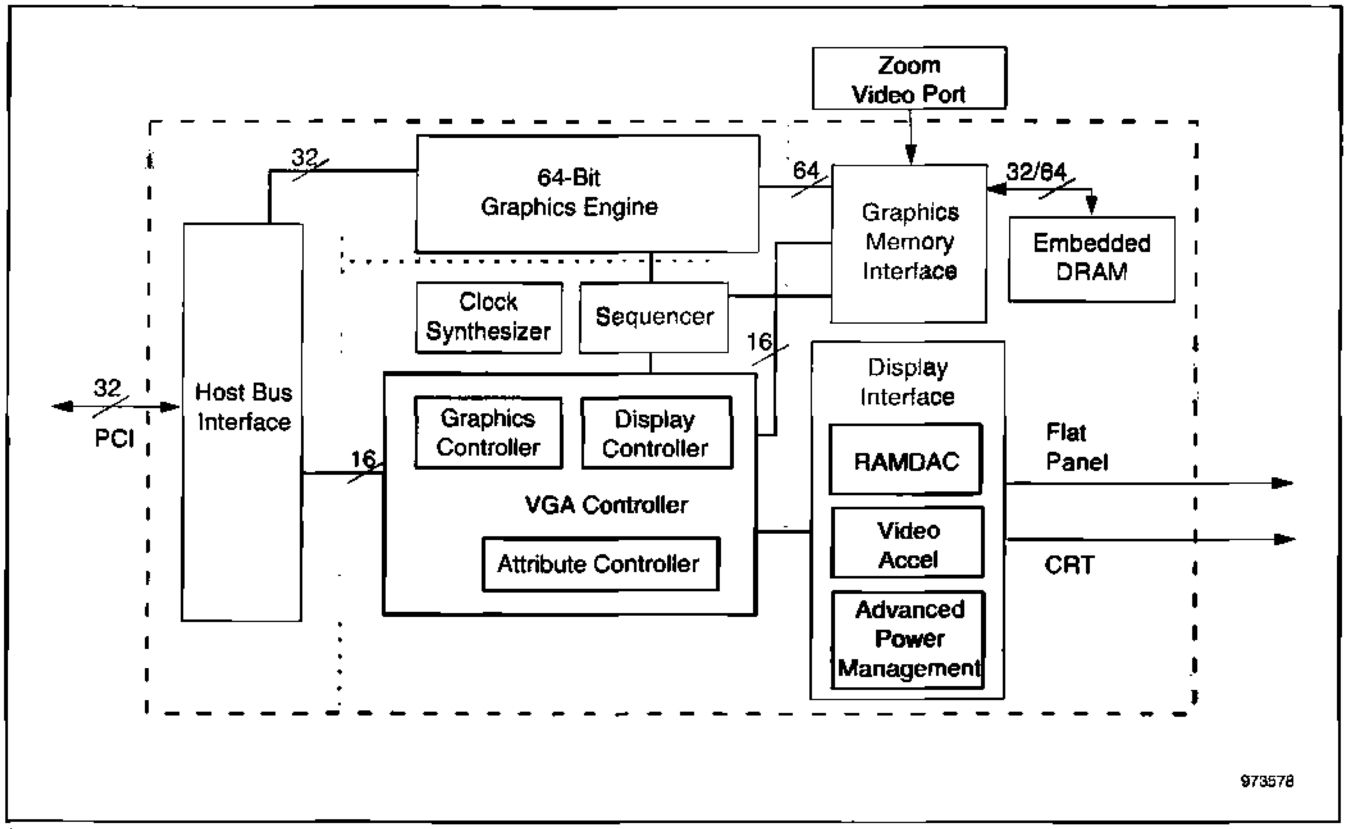
Desktop systems have even more demanding requirements than mobile PCs, with higher resolution, greater color depth, and additional multimedia. In 1997, an average new desktop PC has 2MB to 4MB of video memory, and this is expected to double by 2000. However, until the video performance requirements demand embedded DRAM (not until sometime after 2001), this market segment will continue to use the lower-cost standalone video RAM (VRAM) or synchronous graphics RAM (SGRAM) memory.

With the advent of digital television, there will be a new market for graphics controllers very similar to PC graphics. Like the desktop PC, this market is driven primarily by cost and will not move to embedded DRAM until performance needs require it; this, combined with a production ramp still several years off, makes digital TV only a very minor contributor to the embedded DRAM market until after 2001.

Digital Camcorders

Digital video camcorders (DVCs), introduced in the mid-1990s, have to balance performance, low power dissipation, small form factor, and cost. Second-generation camcorders, using 0.35-micron ASICs, have a system architecture shown in Figure 3. The total amount of DRAM in the system varies between 1MB and 2MB, depending on the specific camcorder, and is split about evenly between the error-correction and shuffling functions. The 1997 retail price for a DVC is about $2,000, which is over the spending limit of most consumers outside of the Japanese market. Integration of system memory is essential to make DVCs cost-effective enough to become a household item worldwide.

Figure 2
Graphics Controller Block Diagram

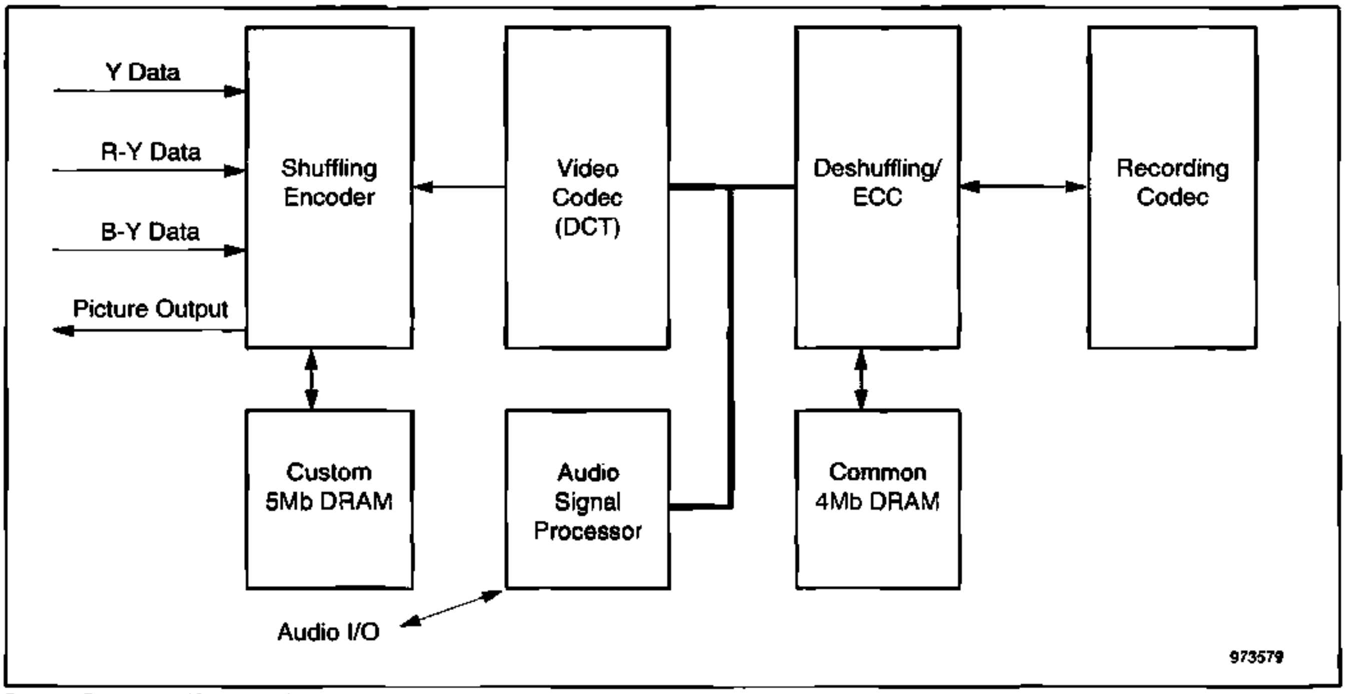


Source: Dataquest (April 1997)

Trends in the digital video camcorder market include MPEG encoding in the third generation of DVC (MPEG-1, with MPEG-2 in a following generation sometime after 2000), which will be introduced in 1998. This generation will be implemented in the 0.25-micron ASICs introduced in 1997, which becomes the mainstream ASIC technology in 1999 to 2000. Memory usage will increase to about 4MB to accommodate the needs of the MPEG encoder and the increased resolution of the third-generation DVC. SRAM is also used extensively in DVCs and, with the improved performance of embedded over standalone DRAM, could be replaced by embedded DRAM in a unified memory architecture for further die cost reductions.

Tabletop digital videocassette recorders (DVCRs) are unlikely to acquire any significant market penetration before the end of the decade; the prospect of recordable DVD may severely impact the possibility of any sizable DVCR market. As in the PC market, the lower cost of standalone DRAM will push the introduction of embedded memory into either of these products past 2001. The possibility exists, however, that some manufacturers may opt to use a common system for both portable and set-top products; this would accelerate the use of embedded DRAM in the DVCR and recordable DVD market somewhat.

Figure 3
Digital Video Camcorder Block Diagram



Source: Dataquest (April 1997)

LAN Switches and Hubs

The telecommunications market has the LAN and wide area network (WAN) market as its earliest adopter of embedded DRAM. Routers, which typically offer a small amount of base memory standard for data storage, with optional upgrades (through memory modules similar to PCs), are not a good candidate to bring main memory on-chip. In contrast, LAN hubs and switches use memory for program storage as well as buffering, and in this very competitive market are pushed to continually bring down the cost per port. As LANs move to 100 Mbps and eventually to Gigabit Ethernet, memory performance will become another factor accelerating the move to embed DRAM. Typical memory usage for LAN switches is 2MB for an eight-port switch; although the per-port memory requirement will remain about constant, the aggregate demand for ports is expanding rapidly. Dataquest predicts that the number of ports sold annually will increase by about two times from 1997 to 2001.

The WAN market, particularly remote access servers and data concentrators, also requires large amounts of memory and, like LANs, will begin to become a factor in the embedded memory market by the end of the decade. Home offices and telecommuting will drive substantial growth for WANs, and several million ports are expected to be sold in 2000. WANs use the memory for data buffering and program storage and have typically 4MB to 32MB per system.

Public switch networks, in contrast to LANs and WANs, typically have a very long life cycle. With systems in use for 10 to 20 years or more, this application segment will not be significant for embedded DRAM before the year 2001.

Embedded DRAM Forecast

Methodology and Assumptions

The following forecast was calculated in a demand-driven approach. For the years involved in the forecast (1997 to 2001), Dataquest analyzed the markets using embedded DRAM most intensively. The total logic and memory contents were forecast (based on application forecasts and semiconductor content analysis) for each application; then, a percentage of this total was forecast to be realized as embedded DRAM. It is important to note that this approach allows for the differing rates of embedded memory adoption for each application, taking into account application-specific factors such as design lifetime, advantages and disadvantages of different memory solutions, and technical requirements, among others.

For the baseline case (see below for a discussion of forecast variance), major assumptions included a predictable decrease in the price per bit of standalone memory and production availability of 0.25-micron drawn gate length ASICs beginning in 1998, becoming mainstream in 1999 to 2000.

1997-to-2001 Forecast

Table 4 and Figure 4 show the five-year forecast for embedded DRAM broken out by application. The expected year 2000 revenue of over $4 billion shows 40-times growth from 1997; while this is a very rapid ramp, this growth reflects the strength of the SLI trend, and the revenue still represents only about 4 percent of the total standalone DRAM forecast.

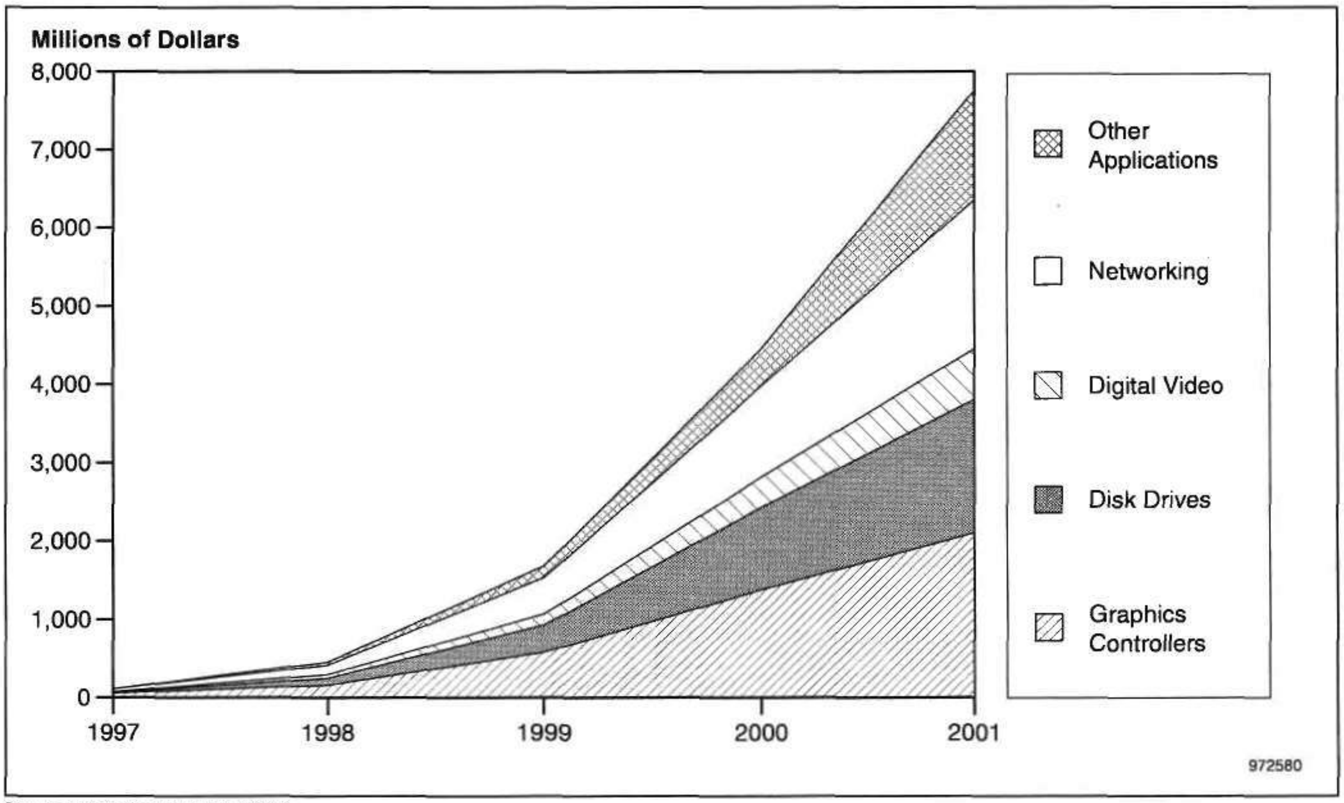
On an application basis, the growth in the embedded DRAM market is dominated by three applications: graphics controllers, disk drive controllers, and networking (LAN/WAN hubs and switches), which will account for almost 75 percent of the total in 2000.

Table 4
Worldwide Embedded DRAM Revenue Forecast by Application
(Millions of Dollars)

	1997	1998	1999	2000	2001
Graphics Controllers	60	160	580	1,380	2,100
Disk Drives	5	90	350	1,050	1,700
Digital Video	10	50	140	390	650
Networking	35	120	460	1,160	1,900
Other Applications	0	40	150	480	1,400
Total Embedded DRAM	110	460	1,680	4,460	7,750

Source: Dataquest (April 1997)

Figure 4
Embedded DRAM Forecast



Source: Dataquest (April 1997)

Forecast Variance

For each application, Dataquest also evaluated risk factors in the forecast (note that risk refers to upside as well as downside potential). These have been aggregated and result in the total embedded DRAM forecast distribution in Figure 5. Downside scenarios include:

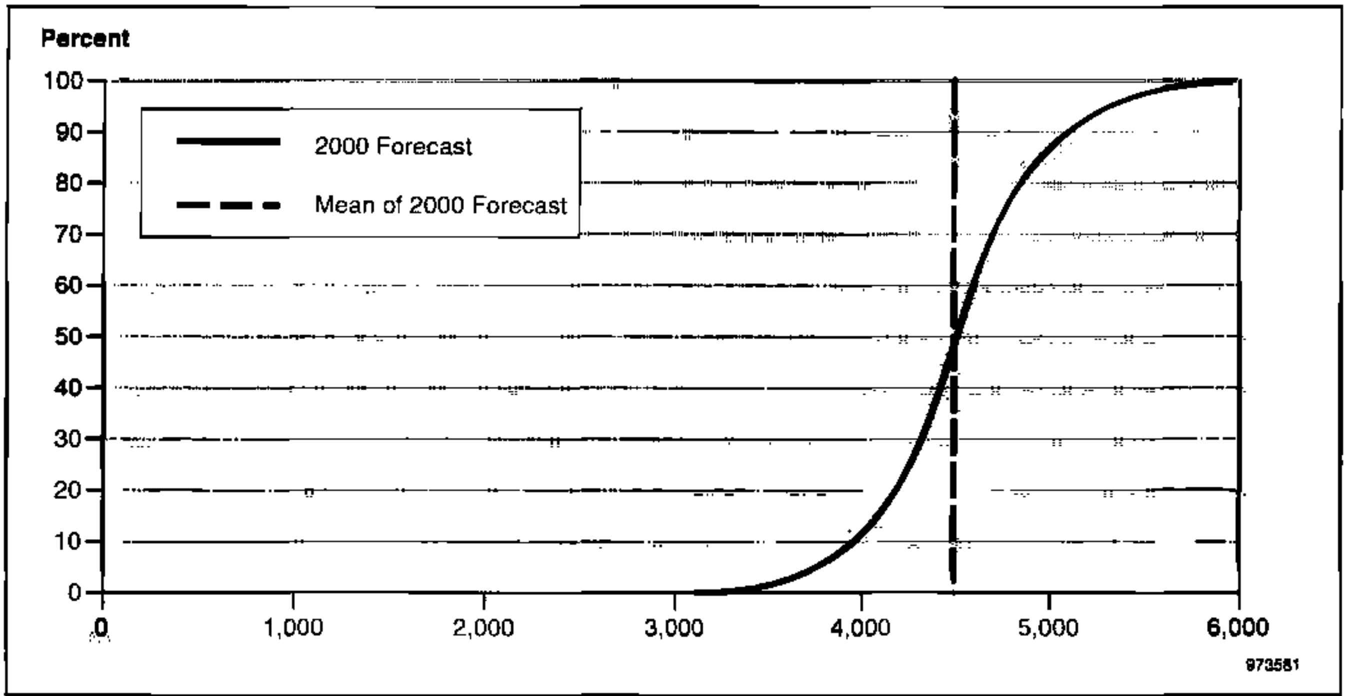
- A faster-than-expected decline in the price of standalone DRAMs, making embedded memory less cost-competitive in some markets
- Delays in the production ramp of 0.25-micron ASIC technology
- Mainstream, cost-effective production capability of alternate technologies such as MCMs

Conversely, upside scenarios to the baseline include:

- A lack of memory production capacity, leading to a price increase in standalone DRAMs
- Accelerated introduction of 0.18-micron ASIC technology, with even greater levels of embedded DRAM
- Increasing demand for memory-intensive, highly cost-sensitive consumer applications

Figure 5 shows the cumulative probability distribution of the embedded DRAM forecast for 2000; that is, based on the above factors, there is a 10 percent probability that the worldwide revenue will be below about $3,900 million and a similar probability that the revenue will exceed about $5,100 million. Equivalently, the 2000 forecast can be considered as normally distributed, with a mean of about $4,500 million and a standard deviation of about $450 million.

Figure 5
Embedded DRAM Revenue Forecast Cumulative Probability Distribution, 2000



Source: Dataquest (April 1997)

Dataquest Perspective

Just as embedded microprocessors represented a quantum leap in ASIC capability, embedded DRAM brings system-level integration one giant step closer to fulfillment. Although the technology enabling practical embedded DRAM is relatively recent and some technical trade-offs and questions remain, it is clear that this is a market poised for explosive growth. Many of the application areas with the highest growth potential, such as graphics controllers, require this technology to realize that growth. Within a few years, embedded DRAM will join processor cores as part of the technology portfolio required of an ASIC vendor in pursuit of high-end business.

The embedded DRAM scenario is somewhat similar to that of embedded 6T SRAM. SRAM was brought onto the ASIC in about 1990. Today, seven years later, a majority of ASICs (and virtually all of the SLI designs) contain some 6T SRAM. Embedded DRAM will see a ramp at least as fast as SRAM as the demand for memory bits continues to skyrocket. While embedded DRAM is clearly going to have a profound influence on the ASIC industry, the standalone DRAM industry should remain relatively untouched by this trend over the next five years.

Looking qualitatively beyond 2001, Dataquest sees continued strong growth for embedded DRAMs—to the point where a majority of SLI ASICs and ASSPs will contain some amount of embedded 1T memory. Even programmable logic is likely to embrace this technology at some point beyond 2001 in the form of large fixed memory blocks. This likelihood should serve as a warning flag to all industry participants that they must develop an embedded DRAM solution or risk relegation to a low-margin, commodity niche of the ASIC market.

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Memories Worldwide

Market Analysis

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- *Taiwanese Suppliers Ramp Lithography for 64Mb DRAM*
- *Is Intel Still Backing Rambus?*
- *Dongbu Entering Semiconductor Business*
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  - *- A Peek into Rambus' IPO Prospectus*

Taiwanese Suppliers Ramp Lithography for 64Mb DRAM

Taiwanese DRAM manufacturers are starting to transition from 64Mb from 16Mb devices in parallel with converting from 0.45-micron to 0.35-micron process lithography. This is expected to make 64Mb memories cost-effective compared to 16Mb chips when using 8-inch wafers. This continues the inexorable "shrink" DRAM trend shown in Figure 1. The following section describes the status of specific Taiwan companies.

ProMOS Technologies

ProMOS Technologies, a joint venture between Mosel Vitelic Inc. and Siemens, plans to ship its first 64Mb in October 1997. This will also be the first Taiwanese 64Mb shipment. Two production lines will be ready for 64Mb using 0.35-micron process technology. A 0.25-micron line will be used for company's 256Mb DRAM, with a pilot run planned to start in fourth quarter 1998.

TI-Acer

TI-Acer's 8-inch wafer fab (Fab 1B) is now using 0.35-micron process technology and plans to upgrade to a 0.28-micron process. The company is now producing 16Mb SDRAM using 0.35-micron process technology. Pilot

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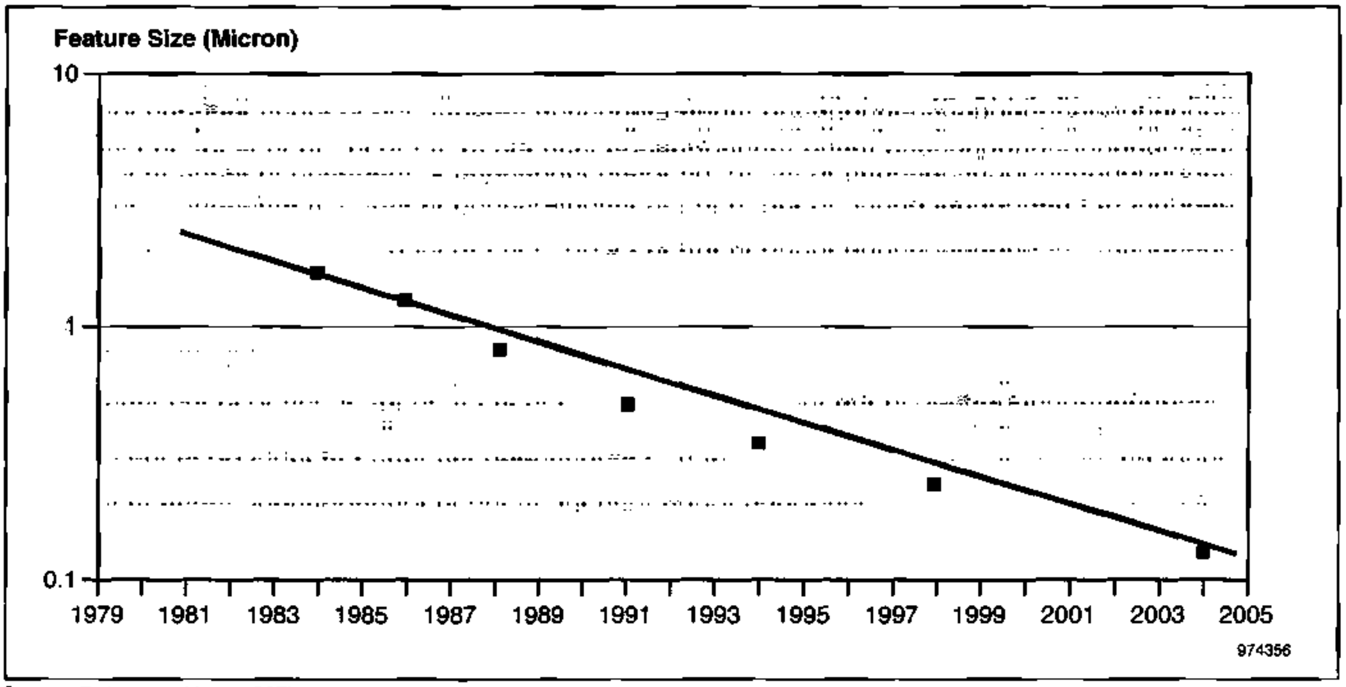
production of 64Mb SDRAM will start next month. Fab 2 is now in operation, after having been delayed.

Figure 1
DRAM Feature Size versus Time



Source: Dataquest (June 1997)

Vanguard International Semiconductor Corporation

Vanguard has completed the process migration from 0.5-micron to 0.35-micron technology. The company is starting 16Mb SDRAM pilot production now, and 64Mb DRAM pilot production will start in the first quarter of 1998. The company acquired design technology from Etron Technology for 8Mb synchronous graphics RAM (SGRAM) products.

Nan Ya Technology Corporation

Nan Ya produces 22,000 wafers per month for 16Mb DRAM with a 0.35-micron process technology and is expected to reach full capacity of 30,000 wafer per month in the fourth quarter of 1997. The company will start 64Mb pilot production on the second quarter of 1998.

Taiwan Semiconductor Mfg. Co.

TSMC now produces 16Mb DRAM for Fujitsu and expects to produce 64Mb DRAM in the fourth quarter of this year. All the company's 8-inch fabs are running 0.35-micron process technology. Fab 5 will shift its target to 0.25 micron in 1998.

United Microelectronics Corporation

UMC continues to be the world's largest 4Mb DRAM supplier because of a delay in ramping 16Mb DRAM. Shipments of 16Mb DRAM will begin this month. UMC is producing Alliance's and Taiwan Memory's 16Mb DRAM products.

Winbond Electronics Corporation

Winbond expects to ship Toshiba's 64Mb DRAM from Fab 4, with a maximum capacity of 15,000 wafers per month, in the third quarter of 1998. Most of its 64Mb DRAM output will carry Toshiba's brand name; the rest will be Winbond's.

Powerchip Semiconductor Corporation

Powerchip's fab produces 16Mb DRAM; the company expects to start 64Mb DRAM production in the fourth quarter of 1997. Powerchip is a joint venture between Taiwan's UMAX Group, Japan's Mitsubishi Electric, and Kanematsu Corporation.

By Jerry Yeh, Semiconductors Asia/Pacific, Taiwan, jerry.yeh@dataquest.com

Is Intel Still Backing Rambus?

The following comes from an interview in *Electronic Buyers' News* of Intel's new CEO, Craig Barrett (*Electronic Buyers' News*, June 9, 1997, page 8). It shows that Intel may not be as firmly committed to Rambus as some would expect.

EBN: What generation do you see the Rambus 2 or equivalent memory being in (used in PCs)?

Barrett: Essentially, you have all of the DRAM suppliers out looking at what it takes and figuring out what they are going to do, and Rambus is one solution. There are other solutions that people are betting on in that area. Everyone is in the development stages right now.

EBN: You're open, then, to other solutions?

Barrett: We may have a favorite solution, but I think these things are never over until they're over.

DQ Take

Dataquest is advising clients that we believe that the conversion of Intel PCs to Rambus should not be expected until 2001. We base this on several inputs, mainly the optimistic dates given out by Intel in other forecasts of DRAM technology changes and the inherent reluctance of system designers to make revolutionary design changes before absolutely necessary. Dataquest believes that there will be upgrades to the synchronous DRAM (SDRAM) interface, similar to the extended data out (EDO) and fast page mode (FPM) upgrades to page mode DRAM, that will delay the acceptance of Rambus by two years. By that time, there is the possibility that another option will have been proven feasible, possibly SyncLink or something as yet undisclosed, which could give Rambus a run for its money. In the meantime, Rambus is the most likely contender, and all it will have to do is to wait for the inevitable conversion from SDRAM to the next-generation interface.

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Dongbu Entering Semiconductor Business

A recent Dow Jones International News Service article about South Korea's Dongbu Group, a company focused on the construction, financial, chemical, and steel industries, stated that the company plans to move into the semiconductor industry through a technological alliance with foreign electronics companies.

According to a spokesperson quoted in the article, Dongbu is considering the manufacture of 256Mb DRAMs by obtaining related technology from overseas. The group has been in contact with such companies as IBM. The group's goal is to start commercial DRAM production by the year 2000.

DQ Take

This is an interesting time for a new entrant to decide to enter the DRAM market. The market is in serious overcapacity, and it takes some nerve to suggest entry into the market when conditions are so tough. Still, Dongbu has the capital resources of a large conglomerate, a recipe that has proven successful for the three current Korean DRAM manufacturers, so it should have a chance at making its mark on the world.

Jim Handy, Memories Worldwide, jim.handy@dataquest.com

TI/Vanguard Cross-License Agreement

Texas Instruments Inc. and Vanguard announced that they have reached a 10-year worldwide semiconductor cross-license patent agreement. Under the agreement, Vanguard and TI will have the use of each other's patents involved in making semiconductors. TI will receive royalty payments throughout the life of the agreement. TI also said it signed a 10-year semiconductor patent cross-license agreement with NEC, under which TI will receive royalty payments from 1996 through 2005. Financial terms were not disclosed for either agreement.

DQ Take

Vanguard had been restricted early in its history to shipping DRAMs only to countries that did not honor U.S. patent rights. Dataquest would suspect that the discounts required by the purchasers of these devices may have been more significant than the royalties TI was seeking. It would be the purchaser's responsibility to see that the DRAMs did not get built into a system that was shipped to the United States or Europe—quite a tough restriction! TI reports that this is the first semiconductor patent agreement between TI and a Taiwanese company other than TI's joint venture with the Acer Group. We can take this to mean that TI is expecting other, similar agreements to follow.

Morris Chang, chairman and CEO of Vanguard, stated that the cross-license agreement with TI is fair to both sides. We take this to mean that the royalty burden carried by Vanguard will not deter the company from competing in this cost-driven market.

Jim Handy, Memories Worldwide, jim.handy@dataquest.com

DRAM Corner

We welcome DRAM tactical reports from readers. Please send them via e-mail to ron.bohn@dataquest.com.

A Peek into Rambus' IPO Prospectus

The information in this section is based not on rumors but rather on the prospectus dated April 24, 1997, for the initial public offering of Rambus Inc. stock. This report focuses on the development status of Rambus licensees, and future articles will examine other portions of the prospectus. The company was founded in March 1990, and its fiscal year ends on September 30.

Top-Level View

At the outset, it should be noted that Rambus neither manufactures nor sells semiconductors that use its high-speed chip-to-chip interface technology. Instead, Rambus licenses its technology on a nonexclusive basis to worldwide semiconductor companies that manufacture and sell Rambus DRAMs (RDRAMs) and logic ICs containing Rambus application-specific IC (ASIC) cells, or RACs, to systems companies. Products to date serve consumer multimedia, PC multimedia, and workstation multimedia applications (that is, not PC main memory). Systems companies need no Rambus license.

RACs have generated most of Rambus' revenue, which totaled just over $14 million for calendar year 1996 and nearly $6 million for calendar first quarter 1997. The company generates revenue from contract fees and from royalties. In terms of financial accounting, this means contract revenue is recognized on the income statement along with royalty revenue. Also, deferred contract revenue is reported on the balance sheet. Significant royalty revenue streamed to the company primarily from NEC, starting calendar fourth quarter 1996 ($1.4 million) and continuing through first quarter 1997 ($1.5 million). This revenue mostly derived from RACs used in Nintendo's 64-bit game system.

The maximum royalty rate for the RDRAM is about 2.5 percent. The maximum rate for the RAC is about 5 percent. The rates apparently vary on a company-by-company basis, depending on original agreements. The rates can decline on the basis of time or volume shipments.

RDRAM Licensees

The following summarizes the status of development of each of the 10 RDRAM licensees as of April 24, 1997:

- Hitachi: 64Mb RDRAM in development
- Hyundai: 16/18Mb RDRAM and 64Mb RDRAM in development
- LG Semicon: 16/18Mb RDRAM starting production; 64Mb RDRAM in development
- Micron: 64Mb RDRAM starting development

- Mitsubishi: 64Mb RDRAM starting development
- MoSys: Specialized 16Mb multibank RDRAM in development
- NEC: 16/18Mb RDRAM in production; 64Mb RDRAM in development
- Oki: 16/18Mb RDRAM starting production; 64Mb RDRAM in development
- Samsung: 16/18Mb RDRAM and 64Mb RDRAM in development
- Toshiba: 16/18Mb RDRAM in production; 64Mb RDRAM in development.

Related Licensee Information

RAC licensees include Chromatic Research, Cirrus Logic, IBM, Intel, LSI Logic, and SGS-Thomson, as well as LG Semicon, NEC, and Toshiba. In addition to the RDRAM and RAC licensees, two other companies are developing products using Rambus technology on a confidential basis. Meanwhile, TSMC, a nonlicensee, has developed and will be able to produce RACs for fabless Rambus licensees.

Intel License

The Intel license centers on the development of a main memory controller. The two companies are working to develop an extension of the Rambus interface technology optimized for the PC main memory segment. The "risk factor" discussion in the prospectus highlights the lack of any assurance whatsoever about any element of the November 1996 agreement between the two companies. The anticipated development for this new RDRAM technology—assuming resolution of technical barriers—is two years from the prospectus date.

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SMART Modular Shows Promise of Growth for 1997

SMART Modular Technologies Inc. announced results for its second quarter, which ended April 30, 1997. Net sales for the fiscal quarter increased 38 percent to $143.7 million from $104.1 million in the second quarter of fiscal year 1996. Net income for the second quarter rose 59 percent to $9.5 million from $6.0 million earned in the same quarter last year.

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Figure 1 shows SMART's net sales and net income for the last six fiscal quarters. Over this period, SMART has outperformed its third-party competitors, while navigating a difficult DRAM market. Comparing SMART's results to its third-party competitors and the DRAM industry as a whole shows that from calendar year 1995 to 1996, SMART's DRAM module revenue grew 47 percent, while third-party DRAM module revenue declined 12 percent and DRAM IC revenue declined by almost 40 percent. So far in 1997, SMART continues to grow in a relatively flat DRAM market, with a 9 percent growth rate from the fiscal first quarter to the second quarter.

Strong unit growth, strong regional growth in Europe, and continued interest by PC OEMs in subcontracting DRAM module manufacturing for their options and upgrade business are driving SMART's success. Is SMART the only company benefiting? No. Kingston Technology, Simple Technology,

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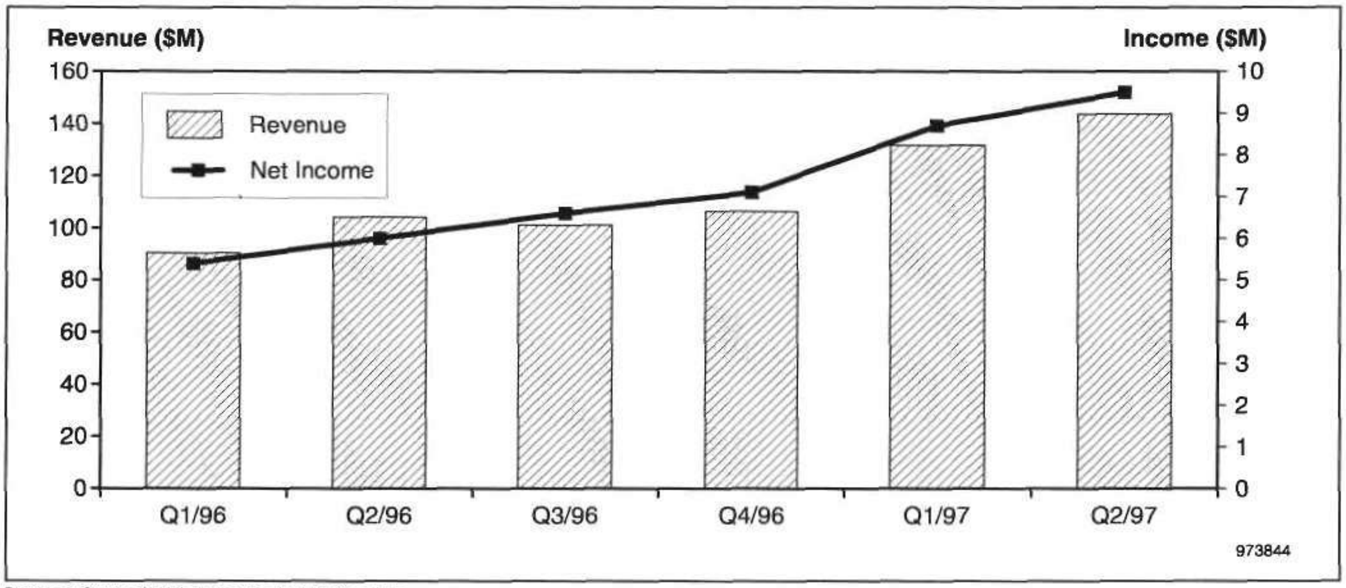
Viking Components, and many other third-party companies are also profiting from OEMs that outsource module manufacturing. The main difference between SMART and the other companies mentioned is their business models. SMART focuses on the OEM channel, while most of its competitors derive the majority of their revenue from the distribution and reseller channel.

Figure 1
SMART Modular Quarterly Revenue and Net Profit



Source: SMART Modular Technologies Inc.

The difference in business models explains the revenue growth discrepancy. A strong OEM market helps third-party companies, but it especially helps SMART. A strong distribution and reseller market would benefit SMART's competitors more than it would SMART. In any case, the three factors driving SMART's success, strong unit growth, growth in Europe, and continued growth in OEM business, are also true for the third-party market as a whole. This bodes well for a return to revenue growth in the third-party market in 1997.

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EEPROM and Cash Cards Ready for Takeoff

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Siemens announced that it is developing a highly sophisticated memory chip for Visa International, designed for use in prepaid card applications with small transaction values, such as in electronic purses. New functionality includes improved security through dynamic data authentication. Siemens will begin delivering these new chips to Visa during 1997. The new chip is backward-compatible with another Siemens chip that is already in use in

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Meanwhile, Microchip Technology Inc. unveiled its 32Kb serial EEPROM. designed to enhance functionality for memory-intensive applications such as digital cellular phones and data acquisition systems.

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The company also has plans to invest in a third plant by the year 2000, which will make 15,000 eight-inch SRAM wafers a month.

DQ Take

Although the current market is not welcoming to new DRAM investment, Winbond appears to believe that the problems of today's overcapacity will be short-lived enough that this company should enter the market in a big way in 1998. We wish it luck. Although Dataquest sees a DRAM shortage looming in late 1999, the 1998 market is expected to be oversupplied until late 1998 and should be in balance from late 1998 to late 1999. This move of Winbond's indicates that it plans to be an important supplier for the long term. It can't hurt that Winbond is in a DRAM technology exchange alliance with Toshiba Corporation. With this combination of financing and leadership technology, the company should do well if it can weather the near-term storm.

Meanwhile, Samsung is starting to purify the air in the clean room of its Austin, Texas, 64Mb DRAM fab. Samsung's $1.3 billion plant should be in pilot production by fall

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DRAM Corner

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A Taste of DRAM Profitability

May has been a good news/bad news month for suppliers of DRAM. The bad news is that few 16Mb suppliers have been able this month to push contract pricing above the $10 level. Meanwhile, spot pricing in locales like Singapore has moved toward the $7 level. The good news, however, is that a growing set of 16Mb suppliers is returning to profitability because of continuing improvement in 16Mb manufacturing costs. Companies prefer not to reveal DRAM profit margins. Sketchy reports circulate, however, that some DRAM suppliers are either approaching profitability for the first time in about a year or are about to widen what have been scanty profit margins.

Micron Technology Inc.

For example, Micron Technology now ranks among the lowest-cost manufacturers of 16Mb DRAM. The company likely enjoys a manufacturing cost under $5 for this part. Micron apparently is executing well its strategy of dramatically increasing the number of 16Mb dice per eight-inch wafer. The company had been getting fewer than 500 16Mb dice per eight-inch wafer, with a long-term goal of getting more than 600 per wafer. Micron might have achieved that goal already. If so, the company might set an even higher goal—nearly 700 16Mb dice per eight-inch wafer.

Although Micron has been marginally profitable on 16Mb DRAM for a while, the market timing is especially good for the company right now. Competitors' low yields on 64Mb devices quite likely mean healthy 16Mb demand for the rest of 1997 and well into 1998. Many Japan-based and Korea-based suppliers have downplayed the 16Mb market during this year—which creates an ideal scenario for companies like Micron, Texas Instruments, and Siemens, which have continued to ramp up the high-yield 16Mb device. Although Micron's DRAM profits would skyrocket with a $10-plus price for the 16Mb device, the company should do well if pricing stays above the range of $6.50 to $7 for the next several quarters.

Micron 's fiscal third quarter 1997 ended on May 31. During May, the company likely did a skillful job of reducing DRAM inventory. In mid-June, the company will announce quarterly financial results. As usual, we should learn a lot about the state of the DRAM market from this, including profitability at that time.

NEC Corporation

Unofficial reports indicate that NEC is now garnering a wider profit margin from DRAM. The company is setting the stage now for a 64Mb DRAM ramp; however, DRAM profits will center on the high-yield 16Mb part during calendar year 1997. NEC is doing a good job of generating profit on today's cash cow (the 16Mb part) while positioning itself for a long-term market leadership position in the next-generation 64Mb density.

A looming question for NEC and other suppliers will be the timing of the 5:1 64Mb price crossover. Will this occur during third quarter 1997, meaning that the 4:1 crossover will occur during first half 1998? Or will the 5:1 or 4.5:1 crossover to 64Mb DRAM occur during first half 1998—meaning a 4:1 crossover to 64Mb DRAM during late 1998? The answer is a function of 64Mb DRAM yields, which today for most suppliers are well under 50 percent.

Like Samsung, NEC has its foot firmly in both the 16Mb and 64Mb markets as of midyear 1997. These companies, among others, must manage carefully the trade-off between today's DRAM profit generator—the 16Mb part—and the longer-term profit stream from the 64Mb device. Once DRAM companies achieve 60 percent to 65 percent yields on 64Mb devices—with continuous yield improvements to follow—64Mb DRAM will displace the 16Mb device as the profit generator. As with profits, companies dislike revealing yield rates, so the best way of gauging these trends will be to monitor for the 5:1 and 4.5:1 crossover to 64Mb DRAM.

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- *Rambus' IPO Makes a Big Splash*
- *Hyundai Electronics Announces 1Gb Synchronous DRAM*
- *DRAM Corner*
  - *- Rumors Swirl about 16Mb Spot Pricing Decline in Asia*

Rambus' IPO Makes a Big Splash

Rambus Inc. announced on Wednesday, May 14, its initial public offering (IPO) of common stock on the Nasdaq Stock Market under the trading symbol RMBS. Rambus raised $33 million with this offering, based on the sale of 2,750,000 shares of common stock at the IPO price of $12.00 per share. More than 18.7 million Rambus shares are still privately held. Rambus closed at $30-1/4, up about 150 percent, on its first day of trading.

DQ Take

Rambus is a new name on the trading floor, but it is not in the DRAM world. Revenue from ICs (DRAM and application-specific ICs, or ASICs) incorporating Rambus interface technology was $477 million in 1996, up from $13 million in 1995. A significant portion of this revenue was from the Nintendo 64 game console, which incorporates three chips using Rambus technology.

Judging by the first day of trading, the financial world is confident Rambus will enjoy strong revenue growth. Rambus is unable to discuss growth predictions because of the Securities and Exchange Commission-mandated quiet period following its IPO, but it is doubtful that Wall Street analysts are basing their Rambus earnings model only on the sales of Nintendos.

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The big opportunity for Rambus is the PC. Rambus already has a nu design-wins in add-in graphics cards, but the prize is main memory. In endorsement of a Rambus-based next-generation main memory, Direct RDRAM, makes this a possibility. Even so, the possibility of a Rambus-based main memory is still at least two years away.

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Hyundai Electronics Announces 1Gb Synchronous DRAM

Hyundai Electronics officially announced the successful development of a fully working 1Gb synchronous DRAM (SDRAM) chip using the new silicon-on-insulator (SOI) technology. One gigabit could store over 8,000 newspaper pages, 160 books (320,000 two-hundred-word pages), 400 still pictures, or 16 hours of audio data.

DQ Take

Hyundai is the world's second chip producer to develop a fully working die, following Samsung Electronics, which demonstrated its sample last year. The Hyundai chip, however, is the world's first 1Mb DRAM developed on the SOI technology. Simply put, in this new technology, circuits are designed on a silicon layer superimposed on an insulator, which in turn is put on the ordinary "bulk" wafer.

The main benefit of SOI is low power consumption, a key requirement for high-performance chips. The new chip consumes less power than Samsung's because the insulator placed between the two silicon layers minimizes electrical leakage. The Hyundai chip can operate on a supply voltage of 1.8V, while Samsung's bulk wafer-based chip operates on a 2.5V supply. Lower power consumption will be increasingly important as semiconductor demand increases for portable equipment, such as notebook PCs. The new technology also increases performance. The maximum speed of the Hyundai chip is 15ns, about 20 percent faster than Samsung's. Hyundai invested 55 billion won in the 1Gb DRAM project, employing 170 researchers for two years.

Dataquest estimates that Hyundai's new chip has shown that SOI technology, which has thus far been used for nonmemory chips, can also be used for memory-chip production. The SOI-based chip may emerge as the dominant chip structure in the future because it lends itself to developing what is called merged memory logic (MML) chips, logic chips embedded with memory chips. MML chips are used more and more in building electronics devices because they can reduce equipment size. Dataquest forecasts that Hyundai's 1Gb DRAM will be used first in future-generation PCs and workstations. It will also find its way to other products that require the ability to rapidly process vast amounts of data, such as videoconferencing systems with interpretation ability, medical systems, satellite telecommunications, personal digital assistants, high-definition TV, 3-D graphics, and other digital multimedia products. The new chips will be commercially available around the turn of the century, with full-scale production expected around 2005.

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DRAM Corner

Rumors Swirl about 16Mb Spot Pricing Decline in Asia

Spot pricing for 16Mb DRAM weakened in some parts of Asia during early May 1997. The rumor network remains busy searching for answers to why prices moved downward and who caused the drop. The U.S. DRAM spot price trend is shown in Figure 1.

We should note that 16Mb pricing in Korea has been relatively stable—contract pricing runs in the range of $10 to $12—with 64Mb extended data out (EDO) pricing at the five-times multiple versus 16Mb EDO. Korea remains concerned about DRAM inventory. Right now, SDRAM represents less than 20 percent of the DRAM market for Korean-based suppliers, but they target a 40 percent-plus share for SDRAM by year-end 1997.

In Singapore, 16Mb DRAM pricing during early May ranged from $7 to $8. Additional downward pressure exists. Reports of inventory adjustment circulated. The news was not all negative, however, because demand for 64Mb parts has started to surge. Singapore's 16Mb inventory adjustment likely reflects a shift by major DRAM users there to the next-generation 64Mb device.

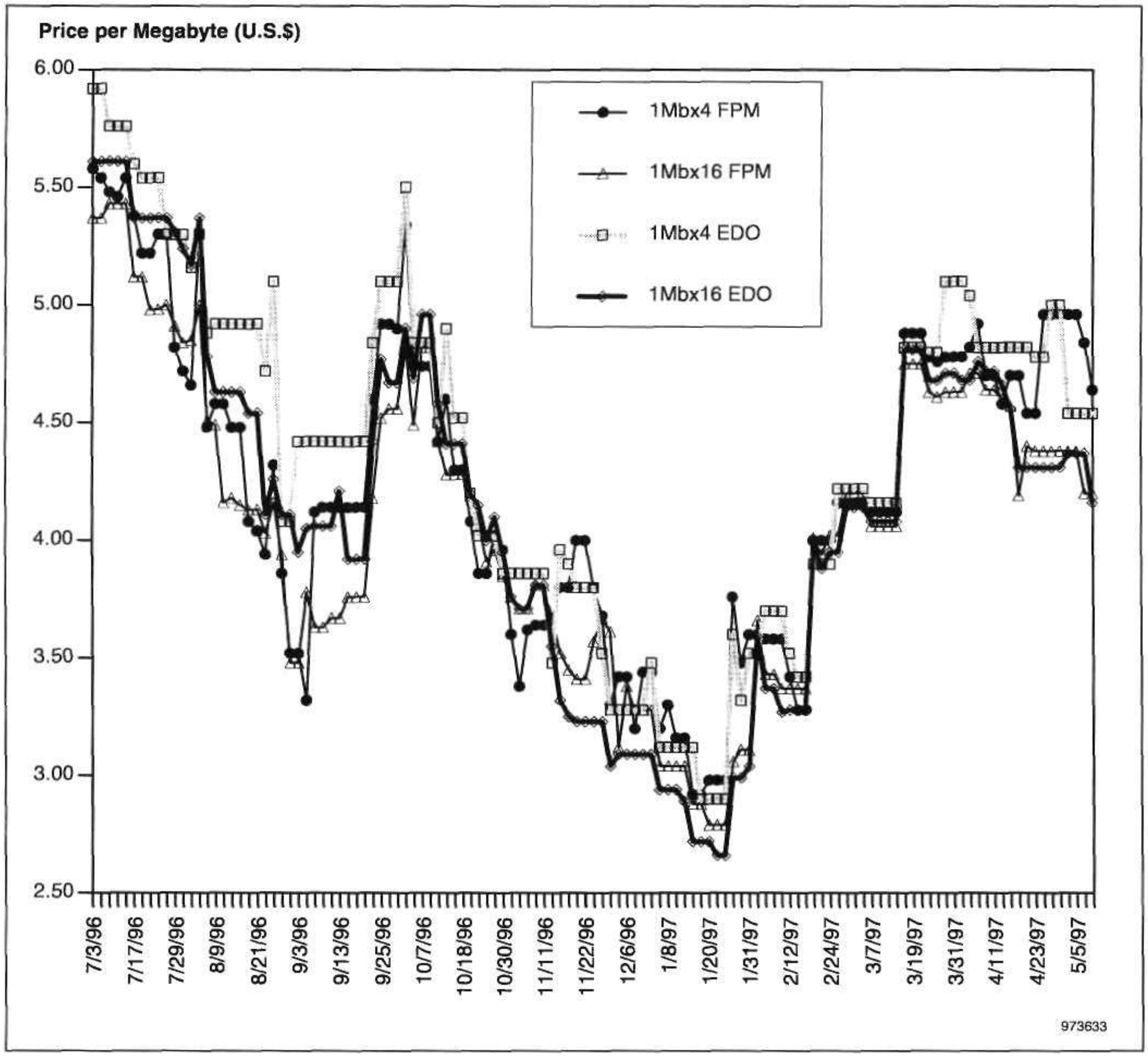
Any spot price move in Taiwan generates talk, so Dataquest has received several reports about Taiwan pricing. Prices for 4Mbx4 in Taiwan fell to $7.50 during the week of May 5, with under $7 possible for mid-May. Meanwhile, the price for 1Mbx16 stood at $8, and for 2Mbx8 at $7.20, during the week of May 5. Suppliers' spot pricing in Taiwan shows little range.

Some reports indicated that non-Asian suppliers had shipped more 16Mb DRAM into local markets than had been expected by other suppliers. For example, Micron Technology's fiscal third quarter 1997 ends May 29—so Micron might be reducing its DRAM inventory during this month. Asian-based suppliers constantly monitor all trends in Asia, and anything involving Micron, Siemens, or Texas Instruments captures quick notice.

The rumor network offered some demand-side explanations for the 16Mb price drops in Taiwan and other parts of Asia. First, the Pentium MMX price decrease was less than expected—which ostensibly means that the early May 1997 MMX price cuts fueled less DRAM demand than anticipated. Second, suppliers believe customers are about to place large orders for Pentium II or K6—which means big DRAM orders should materialize soon.

Another possible cause centers on systems OEMs. Reports circulate that at least one major system OEM recently sold a lot of 16Mb DRAM into the Asian spot markets. This report caused consternation for DRAM suppliers for several reasons. First, the demand picture becomes cloudy. How strong was demand over the past month or so if extra DRAM is now available? Second, what impact will spot pricing trends have on suppliers' efforts to increase contract pricing? The answer might be none, because systems OEMs periodically need to adjust inventory levels—so this might be a single-time occurrence. Regardless, hard-to-verify reports continue to swirl about DRAM inventory levels.

Figure 1
Spot Prices for 4Mb and 16Mb DRAM



Source: American IC Exchange

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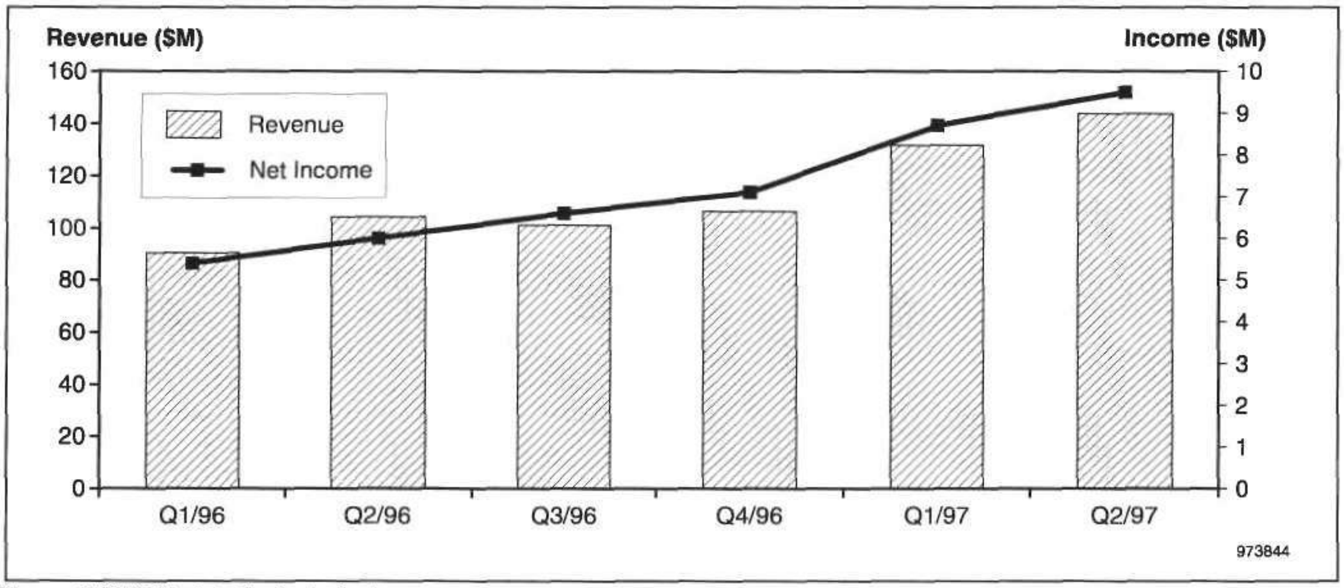

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The company also has plans to invest in a third plant by the year 2000, which will make 15,000 eight-inch SRAM wafers a month.

DQ Take

Although the current market is not welcoming to new DRAM investment, Winbond appears to believe that the problems of today's overcapacity will be short-lived enough that this company should enter the market in a big way in 1998. We wish it luck. Although Dataquest sees a DRAM shortage looming in late 1999, the 1998 market is expected to be oversupplied until late 1998 and should be in balance from late 1998 to late 1999. This move of Winbond's indicates that it plans to be an important supplier for the long term. It can't hurt that Winbond is in a DRAM technology exchange alliance with Toshiba Corporation. With this combination of financing and leadership technology, the company should do well if it can weather the near-term storm.

Meanwhile, Samsung is starting to purify the air in the clean room of its Austin, Texas, 64Mb DRAM fab. Samsung's $1.3 billion plant should be in pilot production by fall

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DRAM Corner

We welcome DRAM tactical reports from readers. Please send them via e-mail to ron.bohn@dataquest.com.

A Taste of DRAM Profitability

May has been a good news/bad news month for suppliers of DRAM. The bad news is that few 16Mb suppliers have been able this month to push contract pricing above the $10 level. Meanwhile, spot pricing in locales like Singapore has moved toward the $7 level. The good news, however, is that a growing set of 16Mb suppliers is returning to profitability because of continuing improvement in 16Mb manufacturing costs. Companies prefer not to reveal DRAM profit margins. Sketchy reports circulate, however, that some DRAM suppliers are either approaching profitability for the first time in about a year or are about to widen what have been scanty profit margins.

Micron Technology Inc.

For example, Micron Technology now ranks among the lowest-cost manufacturers of 16Mb DRAM. The company likely enjoys a manufacturing cost under $5 for this part. Micron apparently is executing well its strategy of dramatically increasing the number of 16Mb dice per eight-inch wafer. The company had been getting fewer than 500 16Mb dice per eight-inch wafer, with a long-term goal of getting more than 600 per wafer. Micron might have achieved that goal already. If so, the company might set an even higher goal—nearly 700 16Mb dice per eight-inch wafer.

Although Micron has been marginally profitable on 16Mb DRAM for a while, the market timing is especially good for the company right now. Competitors' low yields on 64Mb devices quite likely mean healthy 16Mb demand for the rest of 1997 and well into 1998. Many Japan-based and Korea-based suppliers have downplayed the 16Mb market during this year—which creates an ideal scenario for companies like Micron, Texas Instruments, and Siemens, which have continued to ramp up the high-yield 16Mb device. Although Micron's DRAM profits would skyrocket with a $10-plus price for the 16Mb device, the company should do well if pricing stays above the range of $6.50 to $7 for the next several quarters.

Micron 's fiscal third quarter 1997 ended on May 31. During May, the company likely did a skillful job of reducing DRAM inventory. In mid-June, the company will announce quarterly financial results. As usual, we should learn a lot about the state of the DRAM market from this, including profitability at that time.

NEC Corporation

Unofficial reports indicate that NEC is now garnering a wider profit margin from DRAM. The company is setting the stage now for a 64Mb DRAM ramp; however, DRAM profits will center on the high-yield 16Mb part during calendar year 1997. NEC is doing a good job of generating profit on today's cash cow (the 16Mb part) while positioning itself for a long-term market leadership position in the next-generation 64Mb density.

A looming question for NEC and other suppliers will be the timing of the 5:1 64Mb price crossover. Will this occur during third quarter 1997, meaning that the 4:1 crossover will occur during first half 1998? Or will the 5:1 or 4.5:1 crossover to 64Mb DRAM occur during first half 1998—meaning a 4:1 crossover to 64Mb DRAM during late 1998? The answer is a function of 64Mb DRAM yields, which today for most suppliers are well under 50 percent.

Like Samsung, NEC has its foot firmly in both the 16Mb and 64Mb markets as of midyear 1997. These companies, among others, must manage carefully the trade-off between today's DRAM profit generator—the 16Mb part—and the longer-term profit stream from the 64Mb device. Once DRAM companies achieve 60 percent to 65 percent yields on 64Mb devices—with continuous yield improvements to follow—64Mb DRAM will displace the 16Mb device as the profit generator. As with profits, companies dislike revealing yield rates, so the best way of gauging these trends will be to monitor for the 5:1 and 4.5:1 crossover to 64Mb DRAM.

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Perspective

Memories Worldwide

Market Analysis

Flash Memory Digital Film Standards Battle Heats Up

Abstract: *The flash memory industry is struggling to decide which of three competing standards will be used for the emerging "digital film" market. This Perspective discusses the merits and motivations of each and the market size for the winner.*
By Bruce Bonner and Jonathan Cassell

The Players

A full-blown standards war is now in progress in the flash memory market. The three camps all are well-armed, strong, and motivated to win and have a "take no prisoners" attitude. The three groups and their leaders are:

- CompactFlash—SanDisk
- Miniature Card—Intel, Advanced Micro Devices, Fujitsu, and Sharp
- Solid-State Floppy Disk Card (SSFDC)—Toshiba and Samsung

Each of these standards is backed with a trade association, and all have shipped product to prime the market.

The Products

The three products are very different, with totally different design philosophies guiding each one.

CompactFlash

The CompactFlash card is a solid-state disk drive, and its sponsor is SanDisk Corporation, which was founded in 1988 with a product like this in mind. The basic assumption is that flash memory is a just a medium, like the

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platters in rigid disk drives (RDDs), and should be somewhat imperfect to give the lowest cost per bit, just like RDDs. In order to realize this goal, the company uses a high-level RDD interface, the AT Attachment (ATA) standard, to allow for efficient management of the flash media. This also has the advantage of being hardware compatible with all computer systems that support RDD use—which is virtually all of them! This is music to the ears of those who have an allergy to software drivers and the problems they cause in complex system setups. A Motorola 68000 microcontroller core is used in the card to control the ATA interface, data flow, and media management. Physically, it uses a pin-and-socket connector like the PCMCIA cards from which it evolved.

Miniature Card

The Miniature Card is sponsored by Intel and Advanced Micro Devices (in one the few instances in which these silicon adversaries have agreed on anything without a judge in the middle), with Fujitsu and Sharp. The card is a housing for either a single flash device or a few. A small amount of glue logic may be included, but long term, this function will probably be absorbed by the flash chips. The PC requirement for RDD emulation is fulfilled with drivers, and these are included as plug-and-play with Microsoft's Windows 95 operating system. The guiding principle for this approach is to reduce the overhead cost of the assembly, so no processor is included. Lowering the overhead cost of delivering flash "bits" to the user is this standard's way of minimizing cost per bit. The media management function is performed by the system processor (Pentium or K6?) executing the drivers. The card is physically about the same size as the CompactFlash specification, but it uses an elastomeric connector instead of the traditional pin-and-socket connector to make it more consumer-friendly.

Solid-State Floppy Disk Card

The SSFDC is sponsored by memory powerhouses Toshiba and Samsung, which also call it "Smart Media." The guiding strategy is similar to that of the Miniature Card, to lower overhead cost for the lowest possible cost per bit. The card's only component is a single flash chip, and the software drivers are similar in many ways to the Miniature Card's. The unique aspect of SSFDC is that it is not an assembly but is instead a large semiconductor package that lowers the cost of construction significantly compared to the other two. Electrical connection is made with metallic pads on the surface of the SSFDC in a manner similar to smart cards, also known as IC cards. The interface is optimized for the NAND flash memories being marketed by Toshiba and Samsung. Both the NAND chips and the SSFDC interface are serial, instead of the bytewide or wordwide configurations of Miniature Card or CompactFlash card, which could lower the cost of both the chips and cards.

The Market

The primary market for "flash film" is for use with digital still cameras, which capture images directly to digital form for use in Internet communications and desktop publishing.

The value of flash is as nonvolatile data storage of images, offering low power, high shock resistance, and small size, compared to mechanical alternatives.

Current implementations tend to use 2MB of flash for about 20 images. The number of pictures is limited by both the cost of higher-resolution charge-coupled devices for image sensing and the cost of flash. Dataquest believes that the flash sweet spot for digital photography will be the capacity (density) of the lowest-cost-per-bit flash memory. Samsung is now shipping a 32Mb (4MB) NAND flash chip and is starting to sell a 64Mb (8MB) device. Because of the rapid advances being made in flash memory technology, such as the use of multilevel cell technology, Dataquest believes that flash will not be a limiting factor but that it will be used in higher densities when it is available for those users that need the extra capacity and are willing to pay a premium for it.

As shown in Table 1, Dataquest believes that two scenarios should be considered for the digital still camera market. Scenario A, with the systems being used simply as PC peripherals, is most likely. In Scenario B, the cameras are used to replace existing silver halide-film cameras in some manner. Because of the inferior quality of the digital images, Dataquest believes this scenario is much less likely. The card forecast in the table assumes that cards will be used in more generic applications, not just in digital cameras, and that two cards per system will be used in the systems that take advantage of the cards.

Table 1
Projected Shipments of Digital Still Cameras and Small-Form-Factor Flash Memory Cards (Thousands of Units)

	1994	1995	1996	1997	1998	1999	2000
Scenario A, Digital Still Cameras	30	254	1,100	1,914	4,154	4,984	5,981
Scenario B, Digital Still Cameras	30	254	1,100	2,667	5,670	10,524	13,902
Small-Form-Factor Cards	-	-	-	229	4,912	11,631	17,895

Source: Dataquest (May 1997)

Dataquest Perspective

It is really easy to get drawn into the heat of this battle, but before this happens, consider: This market may never happen! Digital film has competition for downloading images to the PC from Universal Serial Bus, infrared links, and wireless technologies. Sure, nobody wants to run out of film at the bottom of the Grand Canyon, but how often does that occur? Maybe all the cameras *will* have card slots, but they won't be used very often. Instead, the flash companies can start selling insurance on lost picture opportunities. They could end up making more money that way, considering semiconductor boom-and-bust cycles.

What if this technology does take off? According to Dataquest's *Flash Memory Applications* Market Trends Report (MMRY-WW-MT-9701, May 1997), even an optimistic forecast for digital film usage still makes it only a small percentage (10 percent) of the flash "bit" market. Anything but resounding success will leave the loudest proponents with big hangovers.

Which will win? Table 2 tabulates the strengths and weaknesses of the market leaders. Right now, CompactFlash has the most design-wins, but the *real* test will be who ships the most first and creates a legacy installed base that drives consumer purchase decisions. If Intel and AMD, both of which have demonstrated consumer and OEM marketing prowess, really wake up, this situation could change fast. TV ads might show dancing fab workers hawking flash chips instead of processors. Change the channel!

Table 2
Competitive Strengths and Weaknesses for Small-Form-Factor Flash Memory Card Market Leaders

	Miniature Card	CompactFlash	SSFDC
Sponsors	Intel, AMD, Fujitsu, Sharp	SanDisk	Toshiba, Samsung
Card Cost	Almost best, but has printed circuit board assembly and multipart case	Worst, a microcontroller in each card with printed circuit board assembly and multipart case	Best, same as chip package
Software Support	Good, included in Windows 95	Best, ATA support everywhere	Good, included in Windows 95
Flash Memory Technology for Mass Storage	Worst, writes 100 KB/sec	In middle position, has low cost per bit but writes 100 KB/sec	Best, able to write 1 MB/sec; has low cost per bit because of highest density
Marketing Capability	Best, already on TV for consumers and good with OEMs for design-wins	Good with OEMs	Good with OEMs
Power Position	Intel is world's largest semiconductor company, very profitable	SanDisk was first in this market, has relationships with key OEMs but is smallest	Samsung is world's largest memory company

Source: Dataquest (May 1997)

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Perspective

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Market Analysis

Dataquest's Tactical Memories Newsletter —Vol. II, No. 10

- *Rambus' IPO Makes a Big Splash*
- *Hyundai Electronics Announces 1Gb Synchronous DRAM*
- *DRAM Corner*
  - *Rumors Swirl about 16Mb Spot Pricing Decline in Asia*

Rambus' IPO Makes a Big Splash

Rambus Inc. announced on Wednesday, May 14, its initial public offering (IPO) of common stock on the Nasdaq Stock Market under the trading symbol RMBS. Rambus raised $33 million with this offering, based on the sale of 2,750,000 shares of common stock at the IPO price of $12.00 per share. More than 18.7 million Rambus shares are still privately held. Rambus closed at $30-1/4, up about 150 percent, on its first day of trading.

DQ Take

Rambus is a new name on the trading floor, but it is not in the DRAM world. Revenue from ICs (DRAM and application-specific ICs, or ASICs) incorporating Rambus interface technology was $477 million in 1996, up from $13 million in 1995. A significant portion of this revenue was from the Nintendo 64 game console, which incorporates three chips using Rambus technology.

Judging by the first day of trading, the financial world is confident Rambus will enjoy strong revenue growth. Rambus is unable to discuss growth predictions because of the Securities and Exchange Commission-mandated quiet period following its IPO, but it is doubtful that Wall Street analysts are basing their Rambus earnings model only on the sales of Nintendos.

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The big opportunity for Rambus is the PC. Rambus already has a number of design-wins in add-in graphics cards, but the prize is main memory. Intel's endorsement of a Rambus-based next-generation main memory, Direct RDRAM, makes this a possibility. Even so, the possibility of a Rambus-based main memory is still at least two years away.

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Hyundai Electronics Announces 1Gb Synchronous DRAM

Hyundai Electronics officially announced the successful development of a fully working 1Gb synchronous DRAM (SDRAM) chip using the new silicon-on-insulator (SOI) technology. One gigabit could store over 8,000 newspaper pages, 160 books (320,000 two-hundred-word pages), 400 still pictures, or 16 hours of audio data.

DQ Take

Hyundai is the world's second chip producer to develop a fully working die, following Samsung Electronics, which demonstrated its sample last year. The Hyundai chip, however, is the world's first 1Mb DRAM developed on the SOI technology. Simply put, in this new technology, circuits are designed on a silicon layer superimposed on an insulator, which in turn is put on the ordinary "bulk" wafer.

The main benefit of SOI is low power consumption, a key requirement for high-performance chips. The new chip consumes less power than Samsung's because the insulator placed between the two silicon layers minimizes electrical leakage. The Hyundai chip can operate on a supply voltage of 1.8V, while Samsung's bulk wafer-based chip operates on a 2.5V supply. Lower power consumption will be increasingly important as semiconductor demand increases for portable equipment, such as notebook PCs. The new technology also increases performance. The maximum speed of the Hyundai chip is 15ns, about 20 percent faster than Samsung's. Hyundai invested 55 billion won in the 1Gb DRAM project, employing 170 researchers for two years.

Dataquest estimates that Hyundai's new chip has shown that SOI technology, which has thus far been used for nonmemory chips, can also be used for memory-chip production. The SOI-based chip may emerge as the dominant chip structure in the future because it lends itself to developing what is called merged memory logic (MML) chips, logic chips embedded with memory chips. MML chips are used more and more in building electronics devices because they can reduce equipment size. Dataquest forecasts that Hyundai's 1Gb DRAM will be used first in future-generation PCs and workstations. It will also find its way to other products that require the ability to rapidly process vast amounts of data, such as videoconferencing systems with interpretation ability, medical systems, satellite telecommunications, personal digital assistants, high-definition TV, 3-D graphics, and other digital multimedia products. The new chips will be commercially available around the turn of the century, with full-scale production expected around 2005.

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DRAM Corner

Rumors Swirl about 16Mb Spot Pricing Decline in Asia

Spot pricing for 16Mb DRAM weakened in some parts of Asia during early May 1997. The rumor network remains busy searching for answers to why prices moved downward and who caused the drop. The U.S. DRAM spot price trend is shown in Figure 1.

We should note that 16Mb pricing in Korea has been relatively stable—contract pricing runs in the range of $10 to $12—with 64Mb extended data out (EDO) pricing at the five-times multiple versus 16Mb EDO. Korea remains concerned about DRAM inventory. Right now, SDRAM represents less than 20 percent of the DRAM market for Korean-based suppliers, but they target a 40 percent-plus share for SDRAM by year-end 1997.

In Singapore, 16Mb DRAM pricing during early May ranged from $7 to $8. Additional downward pressure exists. Reports of inventory adjustment circulated. The news was not all negative, however, because demand for 64Mb parts has started to surge. Singapore's 16Mb inventory adjustment likely reflects a shift by major DRAM users there to the next-generation 64Mb device.

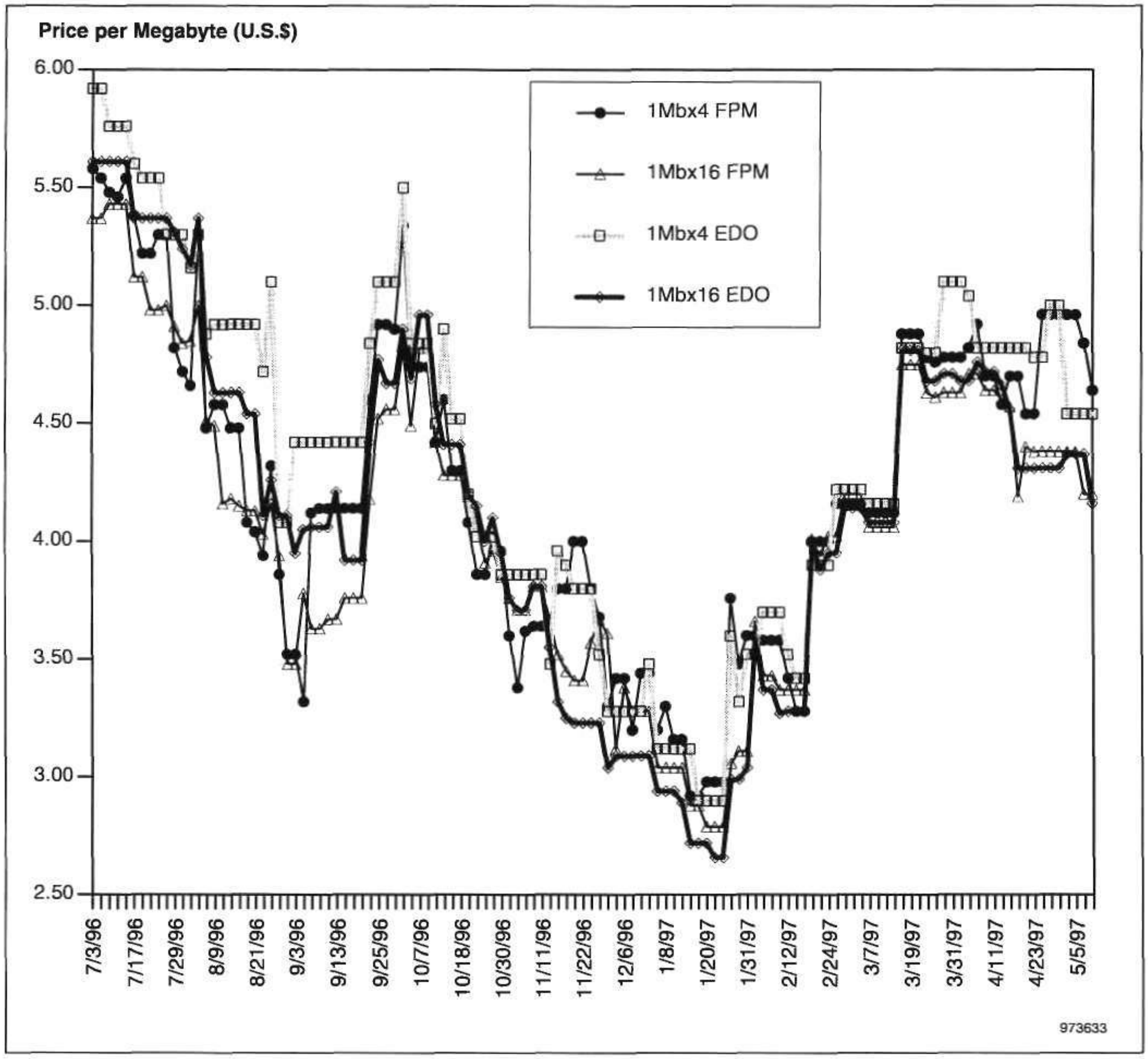
Any spot price move in Taiwan generates talk, so Dataquest has received several reports about Taiwan pricing. Prices for 4Mbx4 in Taiwan fell to $7.50 during the week of May 5, with under $7 possible for mid-May. Meanwhile, the price for 1Mbx16 stood at $8, and for 2Mbx8 at $7.20, during the week of May 5. Suppliers' spot pricing in Taiwan shows little range.

Some reports indicated that non-Asian suppliers had shipped more 16Mb DRAM into local markets than had been expected by other suppliers. For example, Micron Technology's fiscal third quarter 1997 ends May 29—so Micron might be reducing its DRAM inventory during this month. Asian-based suppliers constantly monitor all trends in Asia, and anything involving Micron, Siemens, or Texas Instruments captures quick notice.

The rumor network offered some demand-side explanations for the 16Mb price drops in Taiwan and other parts of Asia. First, the Pentium MMX price decrease was less than expected—which ostensibly means that the early May 1997 MMX price cuts fueled less DRAM demand than anticipated. Second, suppliers believe customers are about to place large orders for Pentium II or K6—which means big DRAM orders should materialize soon.

Another possible cause centers on systems OEMs. Reports circulate that at least one major system OEM recently sold a lot of 16Mb DRAM into the Asian spot markets. This report caused consternation for DRAM suppliers for several reasons. First, the demand picture becomes cloudy. How strong was demand over the past month or so if extra DRAM is now available? Second, what impact will spot pricing trends have on suppliers' efforts to increase contract pricing? The answer might be none, because systems OEMs periodically need to adjust inventory levels—so this might be a single-time occurrence. Regardless, hard-to-verify reports continue to swirl about DRAM inventory levels.

Figure 1
Spot Prices for 4Mb and 16Mb DRAM



Source: American IC Exchange

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Perspective

Memories Worldwide
Market Analysis

Dataquest's Tactical Memories Newsletter —Vol. II, No. 9

- *Third-Party DRAM Module Market Returns to Growth in 1997*
- *SanDisk Wins Key Decision against Samsung NAND Flash*
- *Macronix Introduces "Less Is More" Flash Memory*
- *DRAM Corner*
    - *- DRAM Market Unnerved by "96-Hour" Price Decline*
    - *- Last Month's SDRAM Shortage—This Month's Oversupply?*
    - *- The "Bridled Optimism" of American DRAM Suppliers*

Third-Party DRAM Module Market Returns to Growth in 1997

There are two distinct providers of DRAM memory modules, DRAM manufacturers and third-party module manufacturers. Traditionally, there has been little overlap between the markets served by third-party module manufacturers and DRAM manufacturers. Third-party module manufacturers are typically privately held companies that sell 75 percent of their modules into the memory module aftermarket. Aftermarket memory modules augment the base memory a computer is shipped with. DRAM manufacturers differ in that they sell their modules almost exclusively to major OEMs.

Figure 1 shows Dataquest's ranking of the top five third-party companies, based on DRAM module revenue.

Third-party DRAM module manufacturers enjoyed strong revenue growth over the last five years. Third-party DRAM modules sales grew from $2 billion in 1992 to $6.1 billion in 1996. This represents a 32 percent compound annual growth rate (CAGR). Looking at 1996, third-party DRAM module companies had a relatively successful year. While revenue did decline by 12 percent, all companies Dataquest spoke with indicated strong unit growth.

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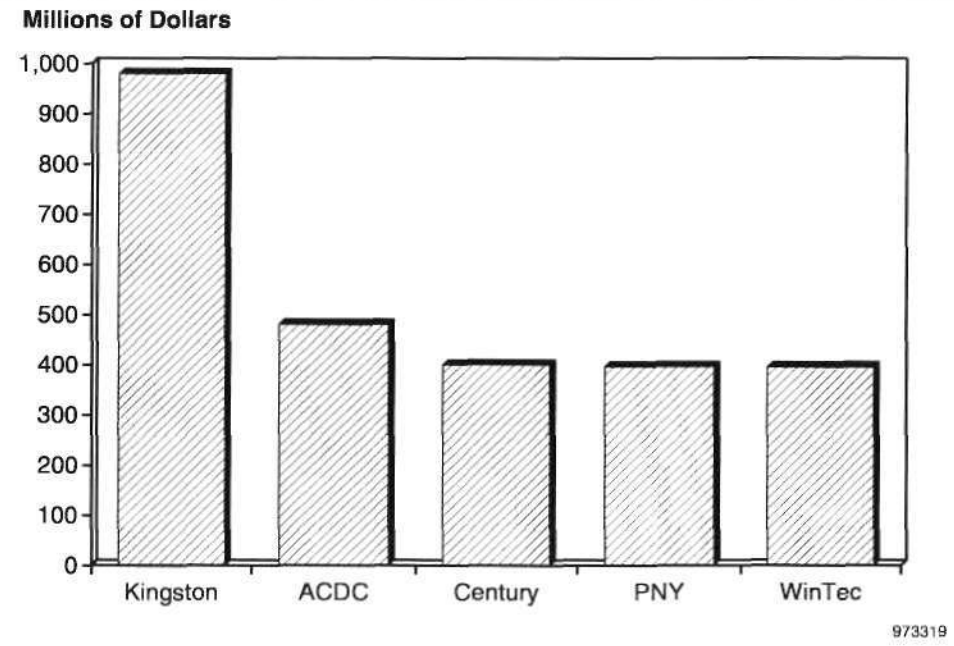
The revenue decline looks bad, but when compared with DRAM manufacturers, whose DRAM revenue declined by 40 percent in 1996, the positive aspect of the year becomes apparent. The primary reason for the revenue decline was the approximately 80 percent fall in DRAM IC prices. While this drove DRAM module pricing, and ultimately company revenue, down, many third-party companies indicated that it helped improve profitability.

Figure 1
Top Five DRAM Module Company Revenue for 1996



Source: Dataquest (May 1997)

Table 1 shows Dataquest's ranking of the top five third-party companies, based on DRAM module revenue.

Table 1
Third-Party DRAM Module Company Ranking, 1996

	1996 Revenue ($M)	Market Share (%)
Kingston	980	16
ACDC	480	8
Century	400	7
PNY	396	6
WinTec	395	6

Source: Dataquest (May 1997)

Dataquest believes the third-party DRAM module market will return to growth in 1997. DRAM density transitions, like the recent transition from 4Mb to 16Mb DRAM ICs, create a need for DRAM module manufacturing flexibility. The acceptance of new and upcoming PC features, such as multimedia extensions (MMX), Accelerated Graphics Port (AGP), Universal Serial Bus (USB), and 3-D graphics, enable the development of new, memory-hungry software. This, coupled with the natural progression toward expanding main memory size and a slowdown in DRAM IC price declines, creates an environment that third-party module manufacturers can leverage. The combined impact of these market conditions is the basis for Dataquest's 1997 forecast of 14 percent growth for DRAM modules manufactured by third-party companies.

The Dataquest Focus Report *Third-Party DRAM Module Manufacturer Study* (DPGR-WW-FR-9702, April 1997) expands on this topic, providing analysis of the industry, market trends, technology, major and regional issues, business models, plus vendor profiles and a listing of third-party manufacturers.

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SanDisk Wins Key Decision against Samsung NAND Flash

SanDisk announced on April 29 that it has received notification from the U.S. Patent Office confirming the patentability of U.S. Patent 5,172,338 claims (the '338 patent). This comes after both Samsung and SanDisk had filed petitions for re-examination of the '338 patent with the U.S. Patent Office. This in turn clears the way for the U.S. International Trade Commission (ITC), which had already ruled in SanDisk's favor against Samsung because of the '338 patent, to bar sales of Samsung NAND flash memory chips in the United States. The ITC is scheduled to give a final ruling in late May.

DQ Take

A curious aspect of the case is SanDisk's choice of Samsung as its first offshore target for this intellectual property (IP) licensing campaign, and not the other NAND proponent, Toshiba. The company says it chose Samsung because it is the toughest, and SanDisk wanted a definitive win or lose decision at the beginning to make subsequent battles easier. Its signing up Intel first (not a legal wimp) is consistent with this apparent strategy. But inquiring minds may think this also had something to do with the partnership with LG Semicon, an arch rival of Samsung. One can assume that a lot of behind-the-scenes discussion is now taking place with all these parties.

These IP battles have more to do with which company has the biggest *collection* of relevant patents and little to do with one specific patent. Samsung is actually a weak flash memory player in this case because it only recently entered the flash market. Toshiba, on the other hand, *invented* flash and has to have an extensive patent portfolio. Usually the way IP contests end up is with the realization that both parties are infringing the other's rights, so they execute mutual cross-licenses. Some royalties may go to the stronger one (SanDisk says Intel is paying it, which is an eye-opener), but mostly these are "kiss and make up" exercises as each works to expand the market instead of killing its competitors. If Dataquest were in Samsung's shoes, getting its friend Toshiba to go after SanDisk would be on top of the things-to-do list. The Japanese aversion to litigation may be overcome with the knowledge that SanDisk wants to go after Toshiba next.

For Samsung NAND flash customers, this is a major concern. For now, they can use Toshiba parts, but this may be true only until SanDisk wins against Toshiba, too. Samsung needs either to change its design, pay up, or defeat SanDisk quickly to maintain its momentum in the flash market. The other thing to watch here is the possibility of SanDisk's becoming much more of an IP licensing company, which is only a short hop from being the fabless semiconductor company it likes to think it is now. Dataquest will keep its clients informed on this unfolding situation.

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Macronix Introduces "Less Is More" Flash Memory

Macronix is introducing what it calls a multiple-time programmable read-only memory, in other words, an MTP ROM. It's a 100-cycle flash memory with initial densities of 512Kb and 1Mb, based on a pair array contactless AND architecture. The organization is x8, access times are 70ns to 150ns, and it uses a 5V read mode supply voltage, with 12V required for erase and program operations. Packaging is either PDIP, PLCC, or TSOP, with the exact pin-outs compatible with other Macronix erasable programmable ROMs (EPROMs), mask ROMs (MROMs), and flash memories. Target pricing is between OTP and UV-EPROMs for similar models.

DQ Take

This product is a tactical move by Macronix to capture more of the EPROM market, not the flash market. From a purist's standpoint, EPROM should have disappeared already because flash memory does exactly the same thing, just better. There is no dispute on this with regard to true EPROMs, which have windowed ceramic packages and are very inconvenient to erase and reprogram. The only thing that has kept them going are legacy designs and a lower price than flash. Plastic-packaged EPROMs, also known as one-time programmable (OTP) memories, have the benefit of even lower prices but still being programmable for downloading the latest code into an application at time of manufacture. For totally stable code with higher volumes, making the transition to MROMs gives the lowest possible nonvolatile memory price per bit. Dataquest estimates the potential market for MTP ROM consumption is about $1 billion a year, which makes it a smart move by Macronix to be the first to offer it.

In contrast to the view that this device is a superior EPROM, many designers will look at the MTP ROM and see a broken flash chip. The limited number of cycles is all right if you know that's what's needed, but many times the same flash device will be used in multiple products in a company. Unless it is a situation of high volumes, it probably is not worth the trouble and risk for most users.

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DRAM Corner

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DRAM Market Unnerved by "96-Hour" Price Decline

16Mb DRAM pricing declined recently—for about 96 hours—which caused a flurry of rumors last week. For example, reports circulated that the contract price for 16Mb DRAM had dropped to a range of $8 to $9 in Taiwan. The U.S. contract price ran from $8.50 to $9. Pricing for 16Mb firmed up within days; however, the market's swift and immediate response during the week of April 18 reflects considerable uncertainty in the DRAM market. Also, more reports circulate that 64Mb prices will head toward the $40 level during second half 1997 for major customers.

Late April Events

Dataquest believes the following happened:

- Japanese companies increased 16Mb DRAM shipments somewhat in advance of the Golden Week holiday (which started April 26 and ends May 4).
- Korean companies increased 16Mb shipments marginally at the same time, and likely so did some American-based suppliers.
- Meanwhile, users delayed orders or reduced DRAM inventory during mid-April in expectation of the Pentium price cuts that Intel made at the end of April; suppliers expect users to place big orders during May.

DRAM Rumor at Work

Meanwhile, for several days, suppliers struggled in an effort to "understand" the disconcerting price decline. First, everyone in Asia pointed at each other for "quietly unloading" a lot of DRAM into the market. This was not exactly true. Next, everyone in Asia pointed at non-Asian-based suppliers for causing the price drop. Then, by the time the market learned that this was not very accurate, some DRAM suppliers regained confidence. Now they believe that the May market for DRAM will be great!

May Outlook

For example, on the expectation of big May orders, some suppliers will seek a $12 contract price for 16Mb DRAM this month in select Asia locales. If they succeed, they will try to transfer the pricing momentum to the American market. Japan-based suppliers will certainly experience a somewhat fitful Golden Week holiday—they still fear that somewhere, someone will flood the market with DRAM during their holiday—but this is not likely. Other suppliers welcome Japan's holiday because it means they can start May negotiations with lofty 16Mb pricing quotes—and wait until later in the month to see where negotiations go.

Last Month's SDRAM Shortage—This Month's Oversupply?

During mid-March, the market seemed headed toward a 1997 shortage of synchronous DRAM (SDRAM). The "whispers" were that Intel would introduce the 440LX chipset sooner than originally expected—perhaps by late second quarter 1997. The 440LX will support SDRAM for the Pentium Pro and Pentium II. The expectation was that if this chipset arrived by early summer, there would be explosive SDRAM demand and a concomitant second half 1997 shortage.

A Change in Expectation

As of early May, however, the concern about a 1997 SDRAM shortage has diminished somewhat. Intel will not accelerate introduction of the 440LX. The chipset likely will be available during the middle of the third quarter (August 1997). This will make SDRAM more of a "post-1997 story" than some suppliers had hoped. Under this scenario (third quarter 440LX availability), suppliers well geared for SDRAM this year should experience impressive—but not overwhelming—1997 SDRAM demand.

Beneficiary

If the migration to SDRAM pushes into 1998, Micron Technology might benefit. The supplier enjoys a 16Mb extended data out (EDO) DRAM manufacturing cost advantage versus most other suppliers. Micron really wants to milk this cash cow for as long as possible—as long into calendar 1998 as possible. Micron should benefit—especially in terms of DRAM profit margin—from any SDRAM delays.

Meanwhile, the already complicated SDRAM market will become more complicated next year. This year, Intel needs DRAMs that support 66-MHz speeds. Some prospective customers confront a challenge in terms of genuine second sources. Next year, the yardstick jumps to 100 MHz, which means a host of technical and sourcing issues.

The "Bridled Optimism" of American DRAM Suppliers

DRAM suppliers relish the dramatic change in market conditions as compared to nine to 12 months ago. Recent price fluctuations caused high blood pressure for a few days, but overall business conditions signal a return to prosperity. Most DRAM suppliers based in Japan and Korea seemed pleased with 1997 business conditions. Typically, within all DRAM companies, there exists a voice that cautions against prematurely concluding that business has stabilized. Even so, among many Asian-based DRAM companies, there is unbridled optimism about today's DRAM market.

American-based companies might privately share this extreme optimism, but publicly they display "bridled optimism" on the DRAM outlook. Companies like Micron and Texas Instruments have to be especially careful during investor communications because of U.S. Securities and Exchange Commission requirements.

TI's Conference Call

Against this backdrop, Texas Instruments announced first quarter 1997 financial results during the middle of April and held a conference call shortly afterwards. The company's call echoed comments made by Micron during that company's conference call last month: DRAM market conditions have improved, including pricing, but DRAM market volatility requires continuing caution. The positives, however, outweigh the negatives. For example, TI mentioned positive DRAM news about computer customer strength, pricing, bookings, cost control, and related efficiencies. The bottom line—at least during investor conference calls for American-based DRAM companies—appears to be as follows: Maybe we cannot yet say the best is directly ahead, but it really seems that the worst has become history.

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Perspective

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Market Analysis

Dataquest's Tactical Memories Newsletter —Vol. II, No. 8

- *The Next-Generation Main Memory Interface Battle Heats Up*
- *SGS-Thomson Opens M5 Fab in Catania, Sicily*
- *DRAM Corner*
  - *- The "Truth" about DRAM Inventory*
  - *- What Precedes the 4:1 DRAM Price Crossover?*
  - *- When Will Micron Put Equipment into Its Lehi Fab?*

The Next-Generation Main Memory Interface Battle Heats Up

The top two next-generation main memory contenders, Rambus and SyncLink, both made announcements this week. Rambus announced two new licensees of its technology, Micron and Mitsubishi; a new name for its next-generation DRAM, Direct RDRAM; and a defined development partner list. Not to be outdone, Rambus' strongest competitor for the next-generation DRAM title, SyncLink, also made news this week. Siemens, a relatively new member of the SyncLink consortium, announced the development of the first SyncLink DRAM, SLDRAM.

Figure 1 shows DRAM manufacturers' production plans for all DRAM interface types.

DQ Take

Intel and the rest of the PC world are acutely aware of the importance of developing a next-generation DRAM that will break the bandwidth constraints of today's EDO DRAM and the emerging SDRAM. To bring attention to this need, Intel revealed in December its main memory road map, and the next-generation memory solution identified on this road map was a Rambus-based memory named nDRAM.

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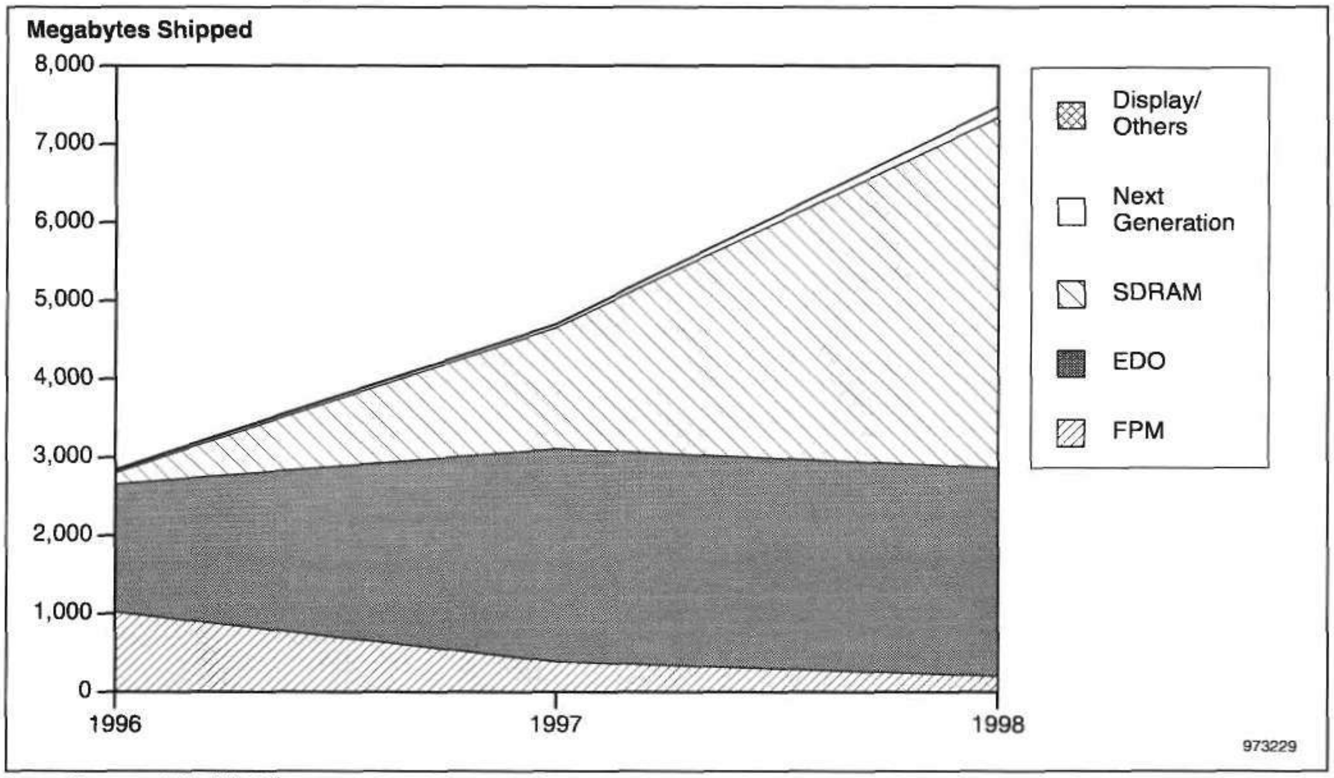
Figure 1
DRAM Production by Interface



Source: Dataquest (April 1997)

One would think Intel's announcement would end the debate about what the next-generation DRAM will be. However, the same day Dataquest was informed of Intel's intentions, Hitachi announced the development of Double Data Rate (DDR) SDRAM and stressed the need for an open standard, such as DDR SDRAM. Dataquest looks at DDR SDRAM as an evolutionary SDRAM improvement, very much like the improvement realized by extended data out (EDO) DRAM over fast page mode (FPM) DRAM. More important, Hitachi's announcement showed that the underlying concern of DRAM manufacturers was Rambus' proprietary nature and the fees it warrants. DRAM manufacturers were saying that if it isn't an open standard, they do not want it.

Rambus' latest announcement addresses some of the concerns that have been expressed since Intel's announcement in December.

- Each agreement is different, but the royalty rate from DRAM companies is capped at 2 percent in high volume and there are no fees for PC and system OEMs.
- Rambus is an "interface" company, and it controls all rights to Rambus interface technology. DRAM companies are open to differentiating their Rambus DRAM cores as long as they meet the interface specification laid out by Rambus.

- Intel has no Rambus ownership today, but Intel has a warrant for 1,000,000 shares (less than 5 percent of Rambus) that vests on high-volume production.
- All Rambus licensees participate in patent pooling related to the interface.

Dataquest finds it interesting that just as Hitachi cried for an open standard in December following a Rambus announcement, Siemens is now crying for an open standard following this month's Rambus announcement. Siemens is not a Rambus licensee, and it expressed the strong belief that an open standard solution is needed. The real challenge is developing a PC main memory that matches CPU data rates. Siemens believes that SLDRAM is a realistic solution and that, once a working part is developed, Intel will consider it. Siemens is working with MOSAID in developing SLDRAM.

Siemens will develop SLDRAM on a 0.25-micron process in a new Dresden, Germany, joint-venture fab of Siemens, IBM, and Toshiba. IBM, like Siemens, has yet to license Rambus technology. Toshiba is a Rambus licensee. A 0.25-micron process isn't required for SLDRAM, but addressing the time frame involved in a 0.25-micron process is a reasonable choice. Siemens plans on SLDRAM taping out in 1997, with first silicon in the first quarter of 1998.

It has taken the SyncLink consortium a long time to get a DRAM manufacturer to make a dedicated effort to developing SyncLink technology. Siemens' announcement changes this. Intel's road map certainly makes Rambus the favorite in this battle, but it looks like there will be a battle.

For reference, the data in Figure 1 shows DRAM manufacturers' production plans, in megabytes, for all DRAM interface types (drawn from Dataquest's *DRAM Supply/Demand Quarterly Statistics* report). This data shows that SyncLink and Rambus, both of which would appear in the category "Next Generation," are not expected to make serious inroads in the DRAM market between now and 1998.

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SGS-Thomson Opens M5 Fab in Catania, Sicily

The prime minister of Italy formally opened the SGS-Thomson M5 fab in Catania, Sicily, on Monday, April 14. The 200mm wafer plant will focus primarily on flash memory devices and will add around 4,000 wafers per week to the company's production capacity.

DQ Take

Nonvolatile memory is an area of strategic focus for SGS-Thomson, a sector in which the company is ranked in fourth position with 1996 revenue of $689 million. The company has achieved world market leadership in EEPROM, taking a 24 percent share of the market, and has a similar position in the declining EPROM market. The company's strategic goal is to be No. 1 in nonvolatile, and this implies growing its share of the flash market, an issue the new fab is designed to address. However, SGS-Thomson is not a major player in the flash market, holding a sixth place ranking, with a 3.3 percent share, behind Intel, Advanced Micro Devices, Fujitsu, and others. Can SGS-Thomson really expect to grow its share of this difficult sector? The new fab will presumably solve the capacity side of this problem, but marketing could be a more difficult issue. In the past, one of SGS-Thomson's strategies for gaining market share in these commodity markets has been through its pricing policy. However, in light of the recent decision by the European Union to abolish antidumping legislation on EPROMs and flash originating in Japan, this will now be a more difficult option.

The $400 million already spent or committed and the additional $300 million to be spent over the next 18 months demonstrates SGS-Thomson's commitment to this market and positions the company as a serious player. The technology can also be used in embedded form for automotive, cellular radio, and set-top box applications in which SGS-Thomson already holds a market-leading position with its application-specific standard products (ASSPs). These applications could offer a springboard for the company to penetrate these and other sectors with its flash technology.

As with all new fabs, the engineering precision on such a scale is impressive. The structure rests on 536 pillars, each 18 inches in diameter. Each pillar is buried 35 meters into the ground to achieve the required penetration into the base rock. The windows of the fab offer a clear view of the active volcano, Mount Etna, just a few miles away, with smoke rising constantly from its peak. Earthquakes have been another feature of the area. Yet the biggest problem for the vibration-resistant structure is the impact of the waves on the shore of the Mediterranean a short distance away. Such natural wonders at least divert the attention from the region's other natural hazard—the Mafia. It is to be hoped that this latter issue will play no part in the country's most prominent symbol of high-technology achievement.

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DRAM Corner

The "Truth" about DRAM Inventory

A conflicting set of hard-to-verify reports is circulating about the ever-elusive topic of DRAM inventory—especially today's 16Mb cash cow.

"Big Inventory" Rumors

Some DRAM suppliers are concerned that competitors recently accumulated a large inventory of 16Mb DRAM. This causes them concern about a second or third quarter 1997 flood of DRAM into the world markets. The "big inventory" speculation, however, started to diminish somewhat after March 31. Why? In part because that date marks the end of Japan's fiscal year. Late March would have been a prime time for these suppliers to "unload" any excess inventory so as to start the new fiscal year with a good balance sheet.

"Low Inventory" Reports

Now counterreports swirl of how low DRAM inventory has become—with worse news ahead for buyers. The term "16Mb allocation" is now uttered during some negotiations—with 4Mb end-of-life notices issuing.

Key suppliers now aim for inventory levels as low as just half a month's supply. Anything less than two month's inventory, however, appears manageable to them compared to the 10-month-plus inventory levels of 1996.

What Precedes the 4:1 DRAM Price Crossover? Answer: The 5:1 Crossover

The timing of the 4:1 DRAM price crossover to the 64Mb density commands great market visibility.

The 5:1 Price Crossover to 64Mb DRAM

Less noticed, however, is the so-called 5:1 crossover to 64Mb DRAM from 16Mb. The 5:1 price crossover ostensibly will serve as a trigger to system design engineers for designing in 64Mb DRAMs (in place of 16Mb parts). The theory is that 64Mb design in should occur at the time of the 5:1 crossover so as to mesh with the 4:1 quarter crossover that will occur several quarters later. Design in at the 5:1 crossover—and initial volume orders of 64Mb will be placed just when the 4:1 crossover occurs.

The 5:1 crossover, however, could present a conflicting picture later this year. Here's why.

The High Road to the 5:1 Crossover

Some major suppliers want the 64Mb price for key customers to stay above $50 for as long as possible. These suppliers also want to push the 16Mb price above $10—which would trigger a "high side" 5:1 crossover during the second half of 1997.

The Low Road to the 5:1 Crossover

Meanwhile, another set of suppliers might soon lower the 64Mb price below $40 for key customers. These suppliers aim at a 16Mb price of $8 or more—which would also trigger a "low side" 5:1 crossover in the second half of 1997.

Meanwhile, some DRAM users have indicated that they will wait for a 4.5:1 price crossover before they design in 64Mb devices. They likely remember the "prolonged" crossover from 4Mb to 16Mb devices of several years ago. Instead of perhaps prematuring locking in 64Mb-based designs—and then experiencing another excruciatingly slow move to the 4:1 crossover, they just wait a little longer. Their reasoning: Once pricing gets to the 4.5:1 ratio, 64Mb suppliers will not be able to stall 64Mb price declines.

Also, a lot of DRAM buyers are wondering why they are paying $60 to $80 for 64Mb DRAM when they hear these reports.

When Will Micron Put Equipment into Its Lehi Fab?

We heard this week that Micron Technology might start putting equipment into the Lehi, Utah, DRAM fab site during the second half of 1997. In last month's analyst's conference call, Micron said the plant would remain mothballed until the company became convinced that improved DRAM market conditions were not short term.Micron would neither confirm nor deny the report to Dataquest. This reminds us of lines from a Joseph Heller novel that go like this—"Gold [the lead character] learned that the CIA was involved in Angola. Gold learned this by reading in the newspaper that the CIA would 'neither confirm nor deny' its presence in Angola."

Micron is remaining cautious but likely evaluating what can be done if current DRAM market conditions prevail for several more months.

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Market Analysis

Dataquest's Tactical Memories Newsletter —Vol. II, No. 7

- *Earthquakes in Japan*
- *White Oak to Open Early*
- *NEC Wins U.S. Patent Rights for Hemispherical Grain Silicon*

Earthquakes in Japan

At least 23 people were injured as a strong earthquake jolted Japan's southern island of Kyushu on March 26, damaging buildings and disrupting train service. The quake measured 6.3 on the Richter scale and registered "upper 5" on the Japanese intensity scale of 7. Damages totaled an estimated ¥2.02 billion in ports and fishery facilities, roads and river embankments, forestry and farming. Figure 1 shows the locations of the earthquakes.

In the earthquake, at least 20 people were injured in Miyanojo and its vicinity, hit by falling objects outdoors or inside their homes, hurt by broken glass, or scalded by food being cooked, police said.

Five houses collapsed or were damaged in Kagoshima Prefecture, while there were 17 cases of landslides and damage to roads at four places. The earthquake also halted or delayed railway service, and airports temporarily closed their runways for damage inspection.

Two separate strong earthquakes measuring 5.1 to 5.5 on the open-ended Richter scale jolted three of Japan's four main islands early April 3, and at least several people were injured in the stronger quake after being struck by falling objects.

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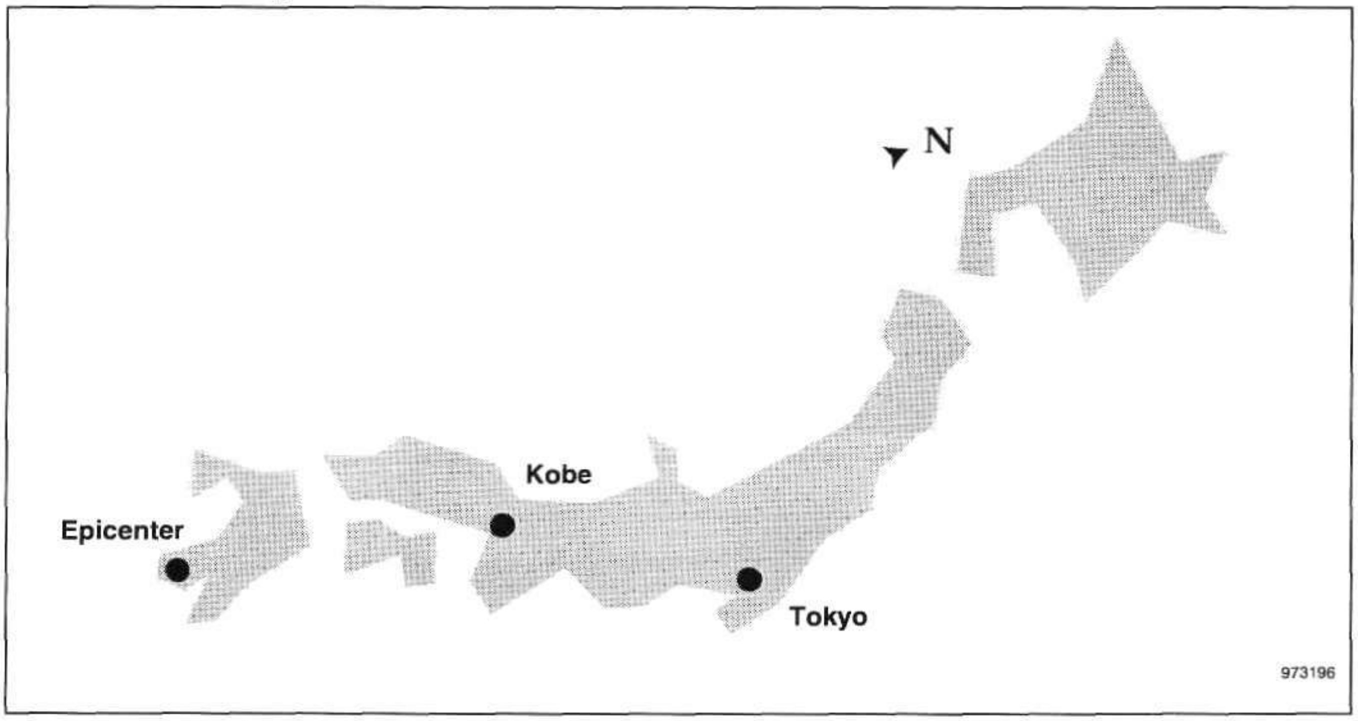
Figure 1
Location of Earthquakes



Source: Dataquest (April 1997)

The April 3 quakes caused landslides at 14 locations, damaged roads at three locations, and damaged five buildings. Some train service was temporarily suspended.

A fourth earthquake registering an estimated 4.7 on the Richter scale shook a broad area of Japan's southernmost main island of Kyushu early Friday, April 4. There were no immediate reports of injuries or damage.

After the first earthquake, Sony Corporation said that the company had temporarily suspended operations at a semiconductor plant after the March 26 earthquake. Operations at the company's Kokubu plant in Kyushu's Kagoshima Prefecture were suspended to check for damage to its facilities from the tremor. The plant's output includes integrated circuits and liquid crystal displays.

Several other Japanese high-tech companies that have plants in the region said they stopped production lines after the earthquake but had since resumed operations.

NEC Corporation said it stopped operations at its Kagoshima plant, which makes thin-film transistor LCDs, late on Wednesday but had resumed production, as there was no damage from the earthquake.

DQ Take

Dataquest's analysts in Japan have not heard of any serious impact on semiconductor wafer fabs in the area.

The Richter scale has been modified after the Kobe earthquake, and " five" in the current scale can be translated into "a little over four" in the former scale. Most fabs are set to stop operation automatically when the fabs are hit by "three and beyond" quakes in the former scale.

Companies that have fabs in the area are Sony, NEC, Matsushita, Oki, and Yamaha. All the companies say that there was no impact on the equipment at those fabs. We would assume that all these fabs must have stopped temporarily and resumed operation only after they finished checking thoroughly for damage. The companies say there should be minimal to no impact in terms of planned production output. Sony was the only exception, in that it suspended production at its Kokubu plant on March 27. We last heard that the plant was to have come back on line by the end of the week.

No spot market price increases because of the Japanese earthquake have yet been seen. A natural disaster, regardless of actual effect on DRAM production, is usually taken as a welcome reason to increase spot market prices. This is probably because of the recent big price increases fueled by reduction cutback rumors and European Union reference pricing.

Figure 2 shows the spot market price per megabyte.

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White Oak to Open Early

The Siemens-Motorola joint-venture 0.35-micron DRAM fab in Richmond, Virginia, White Oak Semiconductor, originally slated to begin producing silicon in mid-1998, is about a quarter ahead of its original schedule and should expect to take equipment deliveries starting in October for initial production of 64Mb DRAMs next spring.

The wafer fab was "topped out" during a ceremony on March 20, where the last 110-foot structural beam, signed by construction workers and 200 White Oak employees, was hoisted into place. Employees should begin moving into the site this summer.

DQ Take

The race to get to the 64Mb density ahead of the competition is on, and it's real. Should yields reach a level where the 64Mb device can start to displace the 16Mb DRAM earlier than expected, there could be a situation in which equipment sales remain higher than would otherwise be expected during a less-profitable period in the DRAM market.

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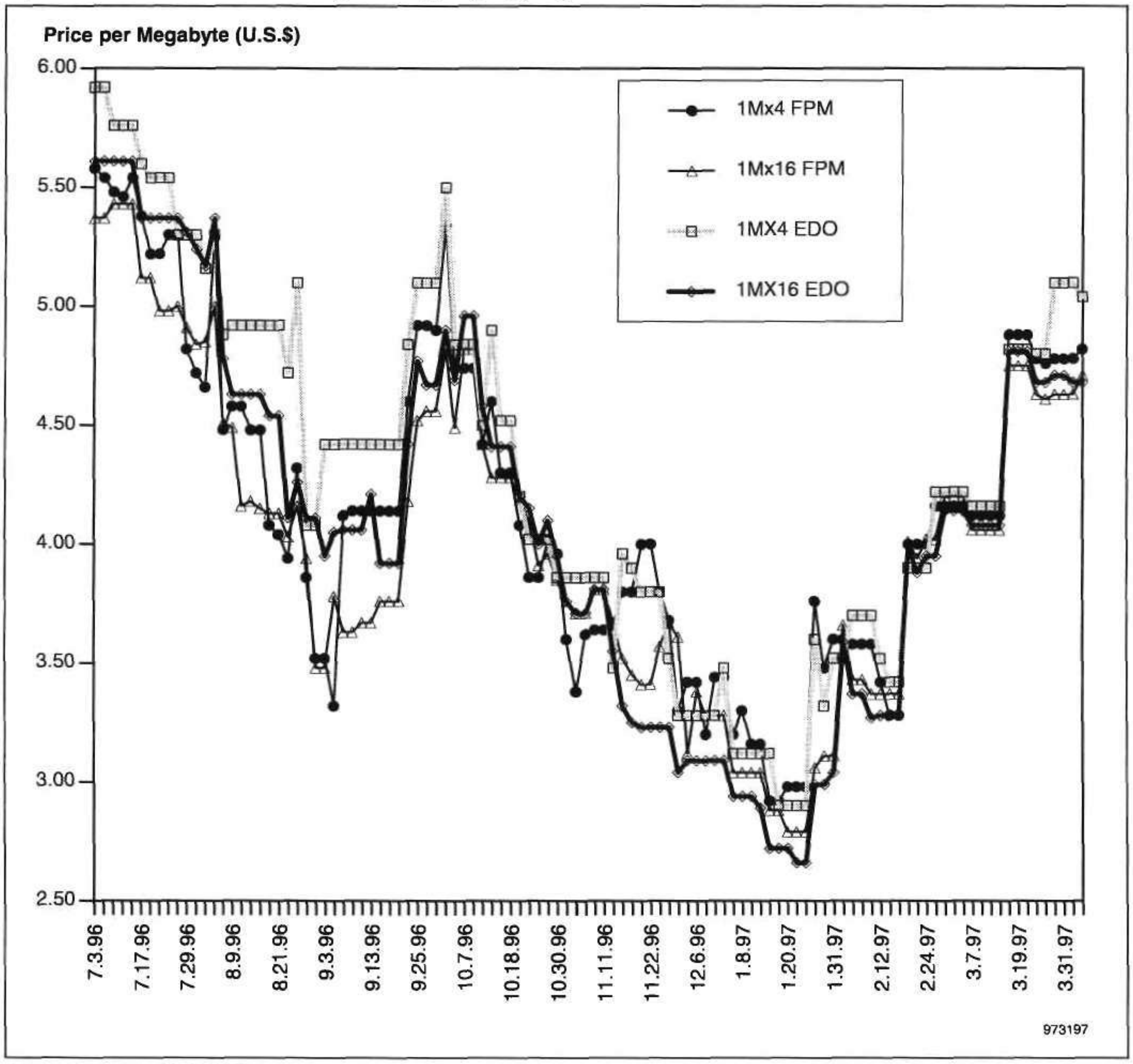
Figure 2
Spot Market DRAM Price per Megabyte, July 1996 to March 1997



Source: Dataquest (April 1997)

NEC Wins U.S. Patent Rights for Hemispherical Grain Silicon

NEC announced it has acquired patent rights in the United States for a hemispherical grain silicon (HSG) technology that makes it possible to enlarge the capacity of DRAM memory cells. NEC has also applied for a Japanese patent, which has not yet been granted.

DQ Take

NEC expects its HSG technology to improve its microchip-related balance of royalty payments, with an expected positive swing early next century. Today, HSG technology is used in research and development processes and is yet to cross over into a high-volume production process. It is unclear to Dataquest whether HSG technology will make this crossover.

Dataquest believes the only company using a technology that accomplishes the same goal, to physically enhance the surface area of a certain size polysilicon electrode, in high-volume DRAM production is Micron Technology. However, Dataquest does not believe that the Micron process is HSG technology.

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Correction

After our story on SDRAM ran in Volume 2, Number 4, we got a call from Hyundai pointing out that we had missed mentioning that company's aggressive move into SDRAMs. We had failed to name Hyundai along with the three leading vendors of SDRAM. By the statistics collected when we surveyed vendors for our most recent DRAM Supply/Demand Quarterly Report, Hyundai indicated that it had shipped about 5 percent of the world's 16Mb SDRAMs last quarter, placing it behind NEC, Hitachi, and Samsung, each of which had more than 25 percent of the market. We apologize for not having mentioned Hyundai's efforts in the SDRAM market.

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Perspective

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Market Analysis

Flash Market Growth Fueled by New Applications

Abstract: *The flash memory market will be very stormy for the next few years. Its size and growth make it attractive for new entrants, and targets for them are becoming clearer. More competitors, new technologies, and emerging markets will make success challenging but lucrative.*
By Bruce Bonner

Flash Market Trends

Larger, More Mature

The 1996 flash memory market was the third-largest memory market in history and the largest nonvolatile one. Dataquest's forecast for 1996 was $2.5 billion, and preliminary estimates indicate actual shipments to be $2.8 billion. Furthermore, the number of companies garnering over $100 million in flash sales expanded from four in 1995 to six in 1996, and those exceeding $50 million went from six to 10 companies. All this indicates that the flash memory market is becoming a force to be reckoned with, after years of hype predicting just that. It has become a "real" market, not just a niche.

Overall market dynamics and growth mechanisms are becoming more mature, like other, older, memory technologies, such as DRAM, SRAM, and EPROM. One indication of this is a developing second-tier supplier base that focuses on volume production instead of market creation and expansion. Another is that supply, demand, and capacity are starting to determine prices instead of sole-source vendors dictating them.

Finally, market growth is being seen from both key applications and overall usage. The first requirement for market development is a "killer app" to consume large amount of the product/technology and kick it off; for flash,

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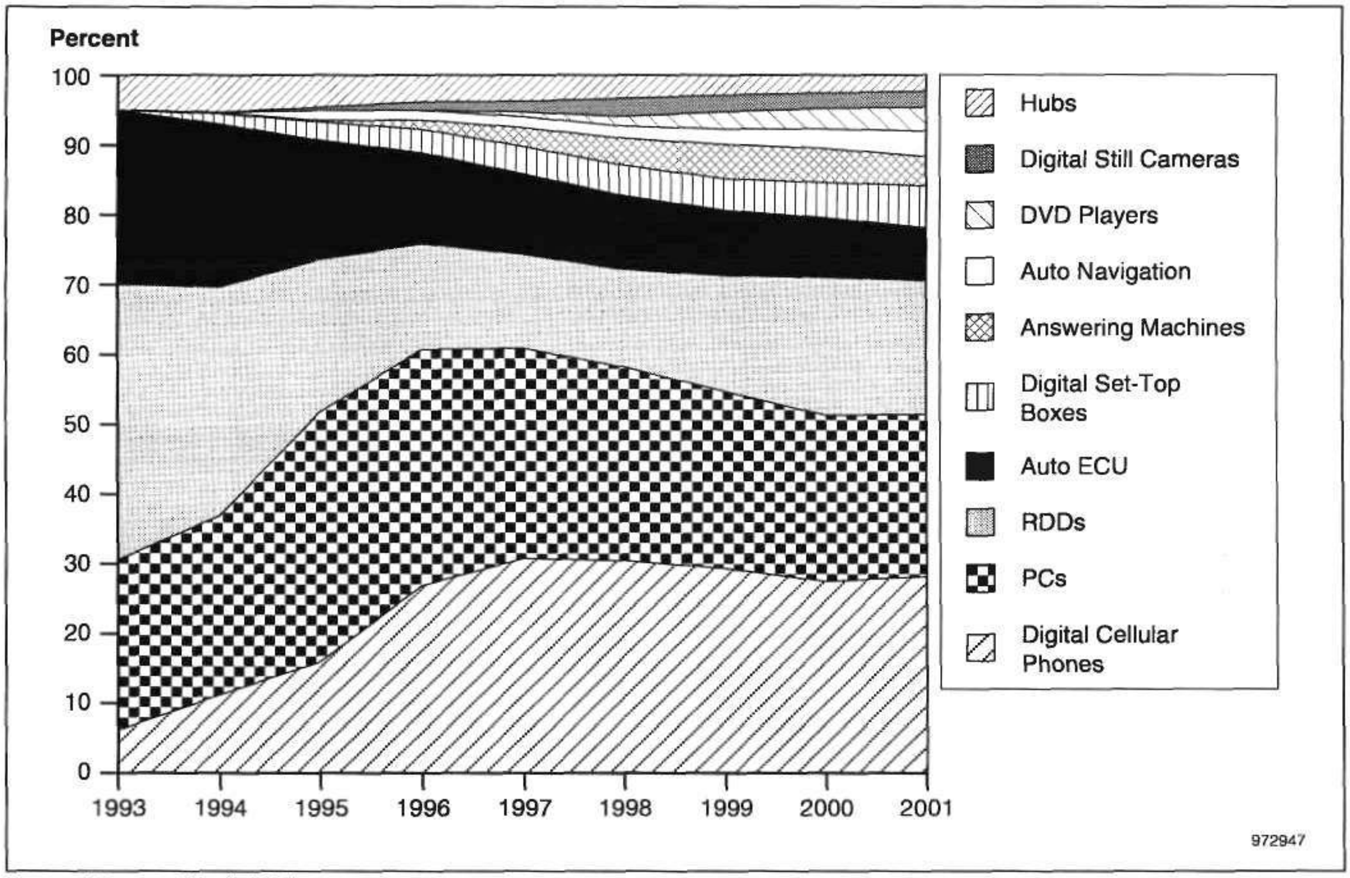
this has been the digital cellular telephone. The next stage is for other uses to come to the fore and broaden the customer base to give it sustainable energy, even if the initial sponsor stumbles. But what are these applications that are driving the future of the flash market?

Key Markets Coming into Focus

Dominant applications for flash are beginning to emerge from the mist. As seen in Figure 1, they are wireless telecommunications handsets, internetworking infrastructure, PC BIOS, rigid disk drives, and automotive engine control units. That is the good news. The bad news is that they all have very different user wants and needs, so one basic chip design cannot be used for all of them (more on that later).

Figure 1
Top 10 Unit Applications



Source: Dataquest (April 1997)

Each of these is large enough to justify individual investment for unique designs and technology, because they will grow to an average of $1 billion each by the year 2000. Also, unlike the past growth of flash, which has come at the expense of EPROM sales, future expansion will be in totally new markets that do more than swap sales in one nonvolatile memory product line for another.

Dataquest expects the investments in flash technology to be aimed in three distinct directions. The first is low-voltage technology for battery-powered microcode storage. The second variation will be mass storage optimized for lower cost per bit and higher densities. The remainder will be a more standardized "generic" type of flash that has little technical differentiation and lower prices. New, hungry entrants will search out the potentially explosive applications and give the designers the products they want, not just need.

More Competitors

A very hard fact of high-tech life is that the development and production costs for semiconductor products are very high. Small markets can only sustain a small number of suppliers that are able to stay in business with the profits necessary to continue for the long term. But as that market grows, it creates space, and opportunities, for additional companies. Flash is such a case.

The user base for flash to date has been very broad and has lacked overlapping requirements that bring about common device specifications that could drive economies of scale. Instead, the response has been proprietary products developed by pioneers that make design-wins, profit, and market share more secure.

Opportunities are available for new players that have been unaddressed by the existing "full line card" vendors, but these can be taken advantage of only by new, creative thinking.

More Technologies

New entrants must "bring something to the table" to be considered by big buyers. This is especially true in the flash arena, because the incumbents are world-class semiconductor manufacturers like Intel Corporation and Advanced Micro Devices Inc. There are two solutions to this problem: give customers either a better price or a better product to motivate them to change. Because basic technology approaches dictate functionality, even if practiced by different companies, a basic strategy for capturing a key account is to use a better technical implementation for that specific application. This could be focused to give a better cost or performance.

Using this strategy, new entrants are causing flash technology battles, with different solutions to the same problem, at key customers. The end to this confusing situation comes with de facto standards that are created by shipping the most (not necessarily the best) product. This competition benefits the users by furnishing better products that are a better value.

Stormy Weather

What this paints is a very exciting picture for those in the flash memory market. Its size and growth make it attractive for new entrants. Targets are becoming clearer. More competitors are vying for customers' attention, using new technologies that either propel the industry forward or just confuse the issue, depending on point of view. All of these make selecting the best business and technical strategies difficult but not impossible, as will be explained later.

Technical Trends

Code or Data?

The most basic segmentation for the flash market is dividing it into "code" or "data" halves. The primary model for code storage is executable software for a microcontroller stored in a flash chip and subsequently executed directly from it at the processor clock frequency. Data storage consists of information stored (written) in the flash chip but not executed at speed. A variation of data storage is used for remembering a small number of critical program parameters, such as user setup preferences, to which the operating software refers for decisions. Systems without flash often use an electrically erasable programmable ROM (EEPROM) for this function, but having a flash chip in the system allows the designer to remove a redundant chip if he or she wishes.

Low Voltage?

Another flash market segmentation is operating voltage. Battery-operated handheld equipment, such as digital cellular telephones, increases battery life by reducing the supply voltage internally, which is usually driven by logic components in the design. But the flash chip needs to be compatible with them, meaning that it needs to be low voltage, too. In the past, the issue of supplying a higher voltage for programming and erase (V_{pp}) versus using just one supply voltage was bitterly fought, but newer designs can assume that only a single voltage is needed. Some vendors give the user the option of using a higher V_{pp} voltage, too, which speeds production line programming considerably. This is the Intel Smart Voltage approach. Another strategy is to operate the flash device at a higher supply voltage, say, 2.7V, but make it compatible with a 1.8V system bus.

Code Store General Technical Trends

Most (about 90 percent) of the current flash market is classified as code storage applications. The system capacity is controlled by selecting the proper density of flash chip, where density increases in multiples of two—different from DRAM, which has density multiples of four. Code storage applications generally value read speed most. The next most important specification is how the erase blocks are organized, with the "boot block" style the most popular.

A current key issue for code store parts is low-voltage operation for handheld electronic devices, such as digital cellular phones.

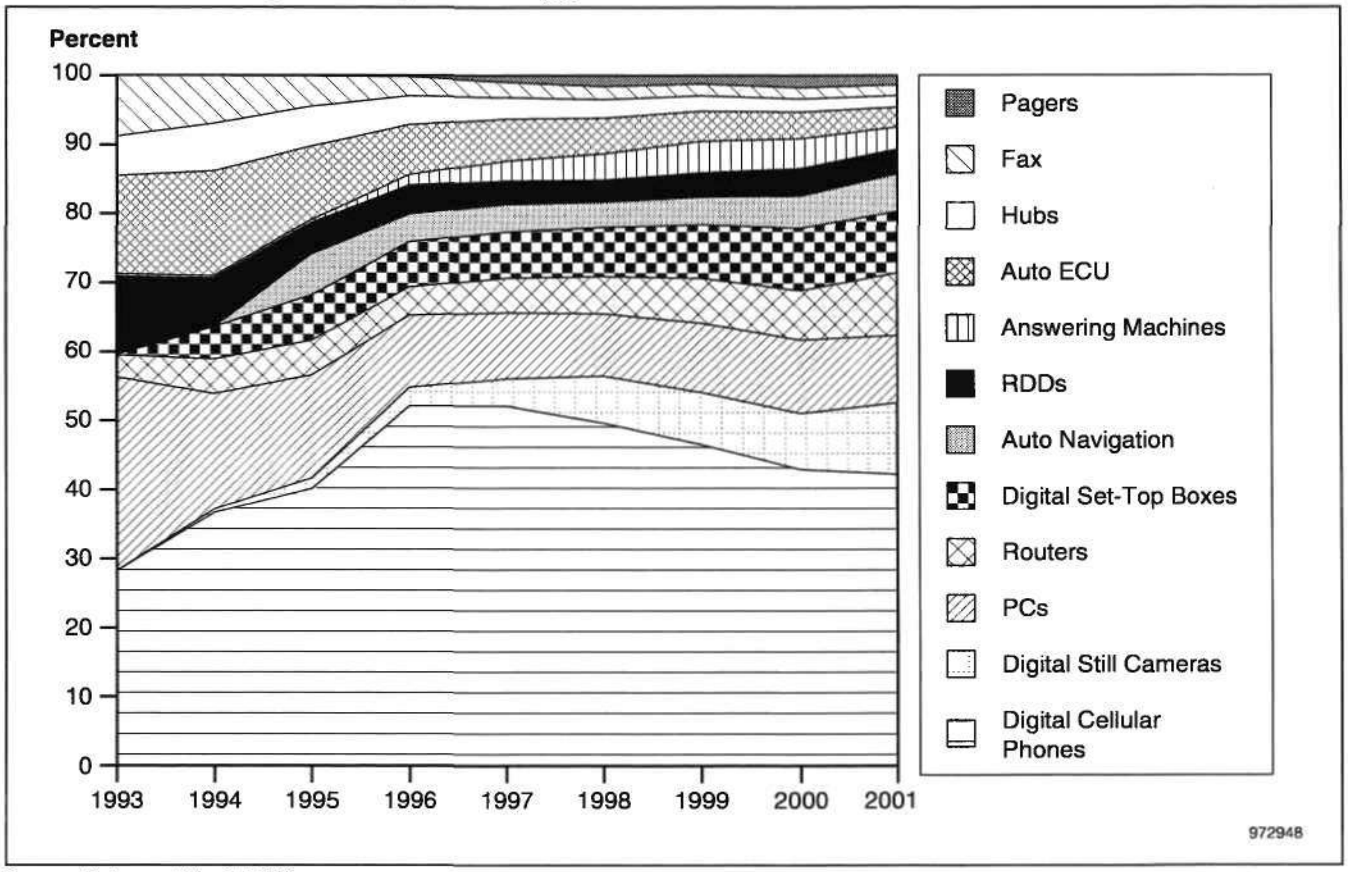
Data Store General Technical Trends

System capacity for data storage flash applications is modulated by adjusting the number of flash chips, which is how DRAM is frequently used. The particular chip density selected is usually the one with the lowest price per bit. And guess what? The most important current issue for data chips is reducing price per bit. Low price per bit allows either lower absolute price for a constant density or more bits for a constant price. Erase blocking needs to be symmetrical to facilitate data manipulation or disk drive emulation.

Typically, other specifications of concern are effective write speed and, in portables, low voltage and removability.

Figure 2 shows the top 12 bit applications.

Figure 2
Relative Percentages of Top 12 Bit Applications over Time



Source: Dataquest (April 1997)

Largest Flash Markets

Current

The following is a listing of the largest markets for flash, by revenue:

- PC BIOS—Low-density data storage
- Digital cellular phones—Code, some parameter storage
- Internetworking—Data storage
- Rigid disk drives—High-density code storage
- Automotive—Code storage

All of these are existing markets that already see a need for flash memory and have the budget to pay for it. They also offer low risk and high run rates.

Future

The following are the markets Dataquest believes will be the future drivers of flash market growth:

- NetPC, WebTV, and set-top boxes—Data storage
- Digital cordless phones—Code, some parameter storage
- Digital photo and audio—High-density data storage
- Personal digital assistants (PDAs) and handheld PCs—Data storage
- Unknown code and data storage applications enabled by lower-cost, lower-voltage flash devices

Compared with current large flash markets, these are just beginning their climb. And, to be honest, probably some of them will be false starts, which may be the case with NetPC/WebTV products.

Application Trends and Requirements

Digital Cellular Phones and Cordless Phones

Flash is an enabling technology for digital cellular telephones, such as GSM types. To date, it has mainly been used as an updatable read-only memory (an insurance policy for code and network changes), but newer models are also moving the temporary data storage from EEPROMs to the flash chip.

Low-voltage operation is a key issue because the logic components in the handsets are considerably advanced, in some cases getting down to 0.9V! Flash is the slow boat in this convoy. AMD's recent 2.2V 8Mb announcement is an indication of the intensity of this battle.

Another interesting aspect of the AMD 2.2V product is what AMD calls "zero power." This is an automatic power down to the "sleep" mode when the device is not being accessed, which takes only nanoamperes of supply current. This addressed another concern of digital cellular phone designers: low energy usage. Instantaneous power consumption does not matter per se. What matters is *energy*, and energy equals power times time. To say it another way, what matters is the "area under the curve." This is an issue for flash because the physics of operating a flash chip do not change just because the operating voltage goes down. So many electrons on the floating gate are still needed to program a cell, and the energy required to do that stays constant no matter what the supply voltage is. This is a prime area for innovation for different technology approaches, such as DiNOR. New thinking is probably required for substantial energy usage reductions.

As discussed previously in the technical trends section, cellular phone use flash for code storage, but the handsets also need to store small amounts of data during operation. This need is being filled with EEPROMs, sometimes with multiple EEPROMs in a single unit. The obstacle to moving this auxiliary storage to the flash chip is that flash is not a direct overwrite technology like EEPROM is, and the erase block where the data is located must sometimes be used to reset the information. Currently, an erase function in a flash chip puts it offline, not allowing it to continue executing code in parallel, a need for real-time operation. Writing data also has the same issue. This is a problem.

One solution to this problem is called "read while write" (RWW). In this, the flash device is designed with separate erase blocks and related circuitry for separate sections of the flash memory array. This allows simultaneous reading of program information while a write or erase operation is occurring in a different part of the chip. Another solution is putting a small E^2 section on a larger flash chip, giving an integrated solution to the same problem. A third approach is "software read while write," where a mini-OS in the phone manages the read/write transactions to the flash chip. Phone design engineers prefer the "hardware" RWW approach, and it seems to be gaining popularity in the market.

A final trend in the wireless phone industry is the constant push to make the electronics in them as physically small as possible. For flash, this will vector off in two directions: either including flash in another system chip, such as the digital signal processor (DSP), or using advanced packaging techniques to shrink the footprint the chip uses on the printed circuit board (PCB). Embedding flash (or any memory type, for that matter) is an important trend in the consumer electronics industry, and it will be used when the amount of memory is small enough not to raise the cost of the one-chip solution over the cost of a two-chip one. Because the code size in these products is currently 4Mb to 8Mb, this merging of functions is not economical yet, so a physical approach is more appealing.

An attractive way to shrink the flash package is with chip-scale packaging (CSP) technology. Most of these are variations of a ball grid array (BGA) method of electrically and mechanically attaching the device to the PCB. Another is to place a memory die directly on the PCB and attach by the chip on board (COB) method. Although this is theoretically possible, COB has many hurdles to overcome for high-volume supply and usage, most of which are fixed by CSP. Dataquest expects chip-scale packaging to win in the digital wireless flash market.

Networking

Networking is the only large-scale data storage flash application to date. Consumption is being driven by the astounding growth of the Internet, and the resulting success of Cisco Systems Inc., 3Com Corporation, and Bay Networks Inc. The premier example of this is the high-end Internet routers, which use 10MB to 20MB in *each system*. Although the unit volume is modest compared with some consumer applications, the high density and the resulting high sales prices for the flash chips make this a short-term gold mine. Hubs and switches also use a lot of flash bits, but with fewer megabytes per system.

The technology of these systems is that of high-end PC systems, either because they *are* PCs or because they are built with similar hardware. This means they are "plugged into the wall"; that is, they have no demanding power budgets and therefore do not want to pay any premium for low-voltage-enabled memories. Another similarity to a PC lies in the way flash is used; it is downloaded to DRAM for execution, so access speed is of no concern.

But, also like PC flash, price is a central concern of OEM buyers. Specifically, it is low price per bit, also known as dollars per megabyte, that lures these buyers. This is a fixed-capacity application, and reducing dollars per megabyte lowers the purchaser's cost for that capacity. The flash technology implications of this will be discussed later in the report. Another similarity to the PC, or to the DRAM used in it, lies in the use of installable modules with multiple flash chips. Again, the necessary capacity is fixed for a specific machine, but the number of flash chips used to make up that amount is not. As with DRAM, one can use the density with the lowest cost per bit and then assemble the parts on a single in-line memory module (SIMM), double in-line memory module (DIMM), or PCMCIA card for use in a particular installation. In theory, a rigid disk drive could be used, but because up time is of paramount important for Internet hardware, flash is the preferred medium because of its high reliability and fast read performance.

PC BIOS

The PC BIOS is a quirky data application for flash. It is considered data because the contents of the flash chip are downloaded to DRAM for execution, but it is very low density compared to other data applications, so it tends to have more in common with lower-density code store devices. This would mean that the peripheral circuitry around the memory array makes up a larger portion of the die size, which makes price per bit increase. It also might mean that the wafers should be built with a process that is optimized more for logic than for memory.

The density for PC BIOS is for a Pentium PC and 2Mb for a Pentium Pro system. Dataquest expects the BIOS density to increase faster than it has in the past because the traditional 1Mb limit has been broken; we also expect that more capacity can be added in the future for the same cost because of Moore's law-dictated technology advances.

The key specification, if it can be called that, for BIOS flash is price. Any component in a PC has incredible price pressure on it, both from a competitive and budget standpoint, and flash is no exception. The general price for a 1Mb flash chip is $3.50, and Dataquest expects this price point will be honored for 2Mb chips when the BIOS density sweet spot increases to that. No other specification is allowed to increase the cost above this point, except for low-volume models that are somehow unique, such as ruggedized notebooks. Also note that most flash BIOS parts are programmed only once, and that is when the part is prepared for operation in the printed circuit board assembly factory. After that, it is only an "insurance policy," so the flash benefit of reprogrammability is not used much by users.

NetPC, WebTV, and Digital Network Set-Top Boxes

This application uses flash memory as an updatable code storage mechanism where all or part of the operating firmware is stored. These applications like the updatability of flash for many of the same reasons as the networking applications do. The attached network can change, the user setup can change, and, of course, the software has a bug in it. Or maybe the user just likes the secure feeling of having the latest (daily?) version of Netscape. And to be clear, the "set-top" boxes of interest to flash here are the ones either linked to a digital satellite dish or a digital cable system.

Current versions mostly use flash for direct execute code storage, and some sort of RAM for temporary data storage. If this information disappears when the plug is pulled out, there is no issue currently. However, in the future, the user may have a small amount of what looks like a hard disk drive but is a solid-state flash drive, instead.

This application is potentially a huge opportunity for flash if the market takes off and flash stays in the product instead of being replaced by mask ROM (MROM). Dataquest is somewhat skeptical about the NetPC and WebTV but will continue to monitor this area closely for potential wild success.

Digital Photo and Audio

Imaging

Digital photography is growing very rapidly, about 100 percent a year, with 1997 unit sales estimated to be 1.9 million units. The product is used to capture images in a native electronic format for use in desktop publishing, presentations, and Web publishing. This positions it squarely as a PC peripheral, as opposed to a replacement for traditional silver halide film. But this is the wild card aspect of this technology; *if* it does start to be used as a better camera, in the way cellular phones have been used to supplement wired telephones, this could be an incredible growth market. Current implementations tend to use 2MB of flash for about 20 to 24 images. This application is limited by both the cost of higher-resolution charge-coupled devices (CCDs) for image sensing and the cost of flash. Dataquest believes that the flash sweet spot for digital photography will be the capacity (density) of the lowest-cost-per-bit flash memory. Samsung is now shipping a 32Mb (4MB) NAND flash chip and is starting to sell a 64Mb (8MB) device. Because of the rapid advances being made in flash memory technology, such as the use of multilevel cell (MLC), Dataquest believes that flash will not be a limiting factor but that the technology will be used when it is available for those users who need the extra capacity and are willing to pay a premium for it.

A problem for the market today is the lack of a small form-factor flash card. There are three competing standards:

- Miniature Card—Intel/AMD/Fujitsu/Sharp
- CompactFlash—SanDisk
- Solid-State Floppy Disk Card (SSFDC)—Toshiba/Samsung

Right now, CompactFlash seems to be winning, but because of the changing character of digital photography and the small number of both OEMs and design-wins, it is too early to call a winner. The red flag here is that this problem *has* already hurt this fledgling industry because camera manufacturers have decided in some cases not to include any type of removable media or have chosen different media than their competitors. This is delaying the emergence of a standardized digital film market. We hope this will be sorted out quickly.

Audio Storage

From many perspectives, audio flash storage is a subset of imaging, with many technical issues in common. A need for lower price per bit is driven by the appetite for increasing capacity (more bits) but is coupled with a need to keep the total cost of that memory within a budget. High performance is *not* needed, in general, because the device is not connected to a processor as a code storage means for instantaneous execution. But there is one important difference: this application requires much less flash capacity than visual storage does. This is a problem because the primary strategy for lowering cost per bit is to make the largest chip possible. One can do a "chop" of a high-density chip to get a smaller one, but array efficiency suffers, increasing per-bit price. Another solution is via system-level integration, where a complete audio storage system, including both signal processing and storage, is in a single chip. In this product, the flash is moving toward a multilevel-cell style that directly stores the sound (usually a voice) instead of doing an analog-to-digital conversion and compression. The issues that will be resolved in the future concern whether the density necessary is large enough to justify a separate flash IC or if the storage needs to be removable.

Handheld PCs and PDAs

Bonner's law of solid-state storage: "If people *can* use a hard disk drive for a specific application, they *will*."

Someone constructing a miniature desktop PC will want to use a miniature disk drive to remain true to the desktop PC functional model. If a new functional model is being made (probably with the feared "paradigm shift"), flash has a chance of being used. But other semiconductor memories, such as battery-backed-up SRAM, can be used instead of flash. All this is made more tenuous by the large number of proprietary designs in the personal organizer market. Currently, this market is attractive to flash vendors because of its familiarity, but the market size is small and the risk is high.

Automotive

The automotive flash market is flat, with any increase in unit volume offset by expected normal price declines. That said, it is a $100 million-plus annual market than needs to be spoken to. The current high-end engine control unit (ECU) market is making the transition to a 4Mb density, in general, with an increase to 8Mb sometime after the year 2000.

From a technical perspective, the most demanding aspects of this segment are the need for a wide operating temperature range (from -40°C to 125°C) and absolutely top quality. Auto OEMs are requesting a QS-9000 quality certification by semiconductor suppliers, which are resisting it. Future trends are for high-speed operation (yes, at low and high temperature) to meld with the switch to RISC processors after the year 2000. Leading OEMs are also requesting known good die programs or CSP-packaged product to facilitate product miniaturization. Finally, because of government transportation and safety regulations and long product development cycles in this segment, flash products, whatever they are, need to be supported directly for about 10 years, making this somewhat incompatible with the PC cycles that are now driving the semiconductor industry.

Dataquest Perspective

If the next five years for the flash memory industry are like the past years, and Dataquest thinks they will be, the ancient curse of "may you live an interesting life" will be in full force. The industry will grow not only in size, but also in major segments. The competition for customers and markets will be fierce, with new companies putting their lives on the line with new product and technology concepts. These enhanced offerings will in turn enable a revolution in both the consumer and commercial products using them, producing success for both parties.

These and other topics are addressed in a more quantitative manner in Dataquest's Focus Report *Flash Memory Applications* (MMRY-WW-FR-9701, April 1997).

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Perspective

Memories Worldwide

Market Analysis

Dataquest's Tactical Memories Newsletter —Vol. II, No. 6

- *Is Bit Consumption Heating Up?*
- *EU Announces Phased Reintroduction of DRAM Antidumping Measures*
- *TSMC and SST Sign Licensing Agreement to Jointly Pursue Embedded Flash Applications*
- *Micron Technology's Earnings Conference Call*

Is Bit Consumption Heating Up?

Dataquest's Memories Worldwide analysts have been confronted with the chart in Figure 1, which has been used by many to show that bit consumption is skyrocketing in response to the price falls that have happened over the past 15 months. Although the chart appears to be a compelling argument, showing a big jump from a steady 1994-to-1995 growth into a much sharper growth in 1996, we find that this trend can be debunked, and we find little reason to believe that there has been any sizable increase of bit shipments because of all the recent price reductions.

If the same data is plotted on a logarithmic scale, a scale in which a straight line indicates steady growth, we see that the growth in 1996 was nearly exactly the same as the growth in every prior year since the beginning of 1991, when World Semiconductor Trade Statistics first started to track DRAMs by density. We have even added a line showing the growth trend with all the bumps removed, just to show how straight the line really is (see Figure 2). This growth continued, starting during the price falls of 1991, through the period of flat pricing from mid-1992, through the end of 1995, and unwaveringly through 1996, even while the price per megabyte fell by 75 percent.

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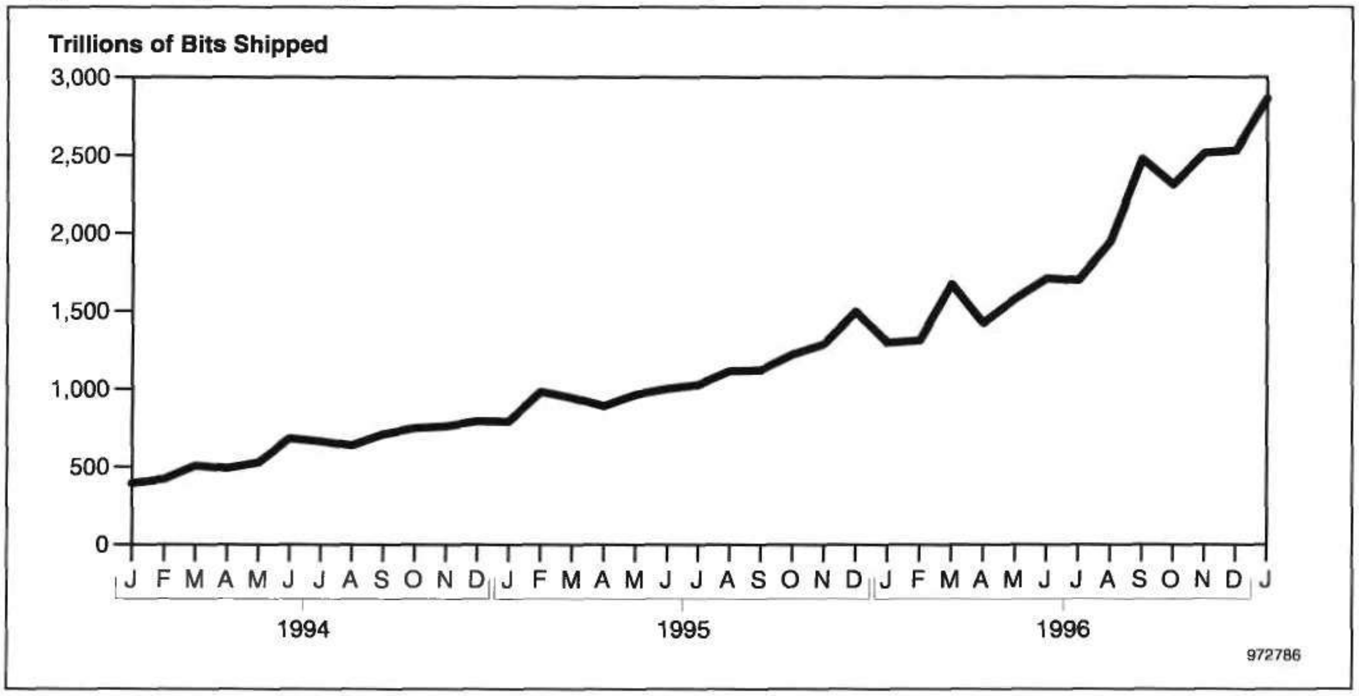
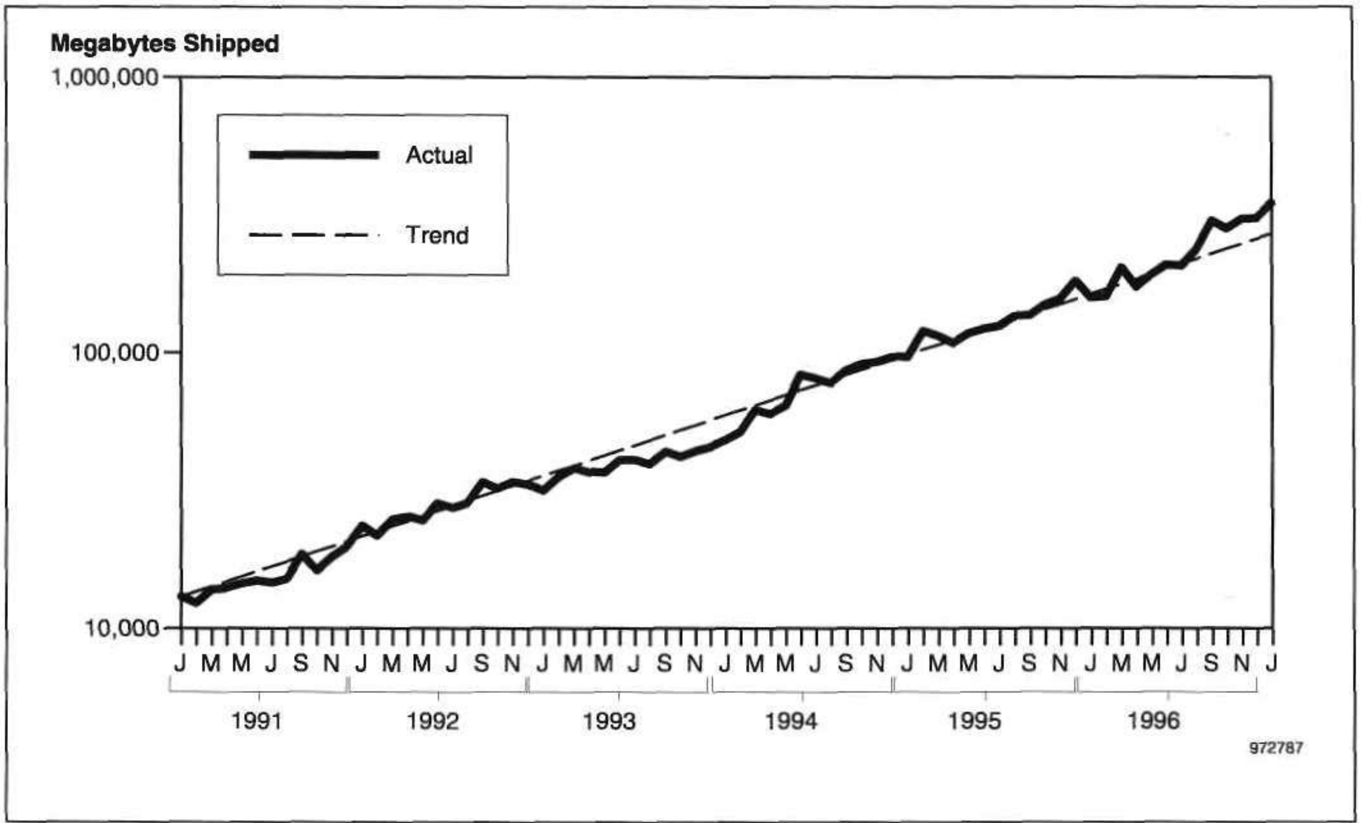
(For Cross-Technology, file in the Semiconductor Devices and User Issues binder)

Figure 1
Apparent Skyrocketing Bit Demand of 1996



Source: Dataquest (March 1997)

Figure 2
Logarithmic Chart of WSTS Megabyte Shipments, January 1991 to January 1997



Source: Dataquest (March 1997)

In other words, there has been no big response in bit consumption to the big decrease in prices, and there is no reason for us to expect a change in this trend in the future.

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EU Announces Phased Reintroduction of DRAM Antidumping Measures

The European Union (EU) announced on Monday, March 10, 1997, that reference pricing on DRAM originating from Japan and Korea would be phased back in. This decision follows a 21-month suspension of the DRAM antidumping measures introduced in January 1990. The interim period during which reference pricing is to be reintroduced begins on April 1 and runs until June 30. This means that no minimum price will be in force during March, but from July 1 full reference pricing will be in place. During April, May, and June, an increasing percentage of the full reference price will be applied. The existing arrangement for calculating individual companies' reference prices is to remain, which means that Japanese vendors will have blanket weighted-average reference prices while Korean vendors will have individual ones. Also, Japanese vendors that have a cost structure lower than the average minimum price will be allowed to sell below that level during the interim period.

DQ Take

In what appears to be a classic "fudge," the EU has sidestepped the DRAM antidumping issue by announcing what is, in effect, a moratorium on the reintroduction of reference pricing. Citing a desire not to disrupt the European DRAM market, the EU has attempted to please everyone while succeeding in pleasing no one. In what is called a "flexible approach," reference pricing will be brought back "in a gradual manner" in order to minimize "disruptive effects." In other words, the EU has been forced, by local DRAM producers on one hand and by PC producers on the other, into a compromise. This compromise may well have the desired effect—that is, no effect.

Dataquest understands that the 16Mb chip will have a reference price of about $9 imposed from July 1. Recent unconfirmed action to "regulate" production, taken first by the Korean vendors but followed quickly by the Japanese, appears to have restricted supply sufficiently to force DRAM prices up by as much as 50 percent on the spot market. This has resulted in a rise in contract pricing to about $9 for the 16Mb device. By the time those unaffected by the EU antidumping measures, principally the Taiwanese, have ramped production volumes to take advantage of any opportunity to grab market share, the leading DRAM vendors will have moved the market to the 64Mb density and synchronous technology devices that have relatively high average selling prices, and any perceived need for antidumping measures will have disappeared.

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TSMC and SST Sign Licensing Agreement to Jointly Pursue Embedded Flash Applications

Silicon Storage Technology Inc. and Taiwan Semiconductor Mfg. Co. have signed a technology licensing agreement covering the design, manufacture, and distribution of embedded flash memory products based on SST's SuperFlash technology. Under the licensing agreement, SST has granted TSMC a license to use SST's SuperFlash technology to provide customers access to embedded flash applications.

DQ Take

More and more electronic applications are memory hungry. The need to drive down chip count to reduce costs, save space, and limit weight has coupled with benefits such as reduced power consumption and improved system quality and reliability. The fundamental markets driving embedded applications actually remain strong. From an applications point of view, embedded flash can naturally be integrated with the microcontroller, digital signal processor (DSP), or application-specific IC (ASIC) for use in such applications as analog storage devices, smart card ICs, and programmable logic devices. Chips with embedded flash memory can be incorporated into a wide range of computer, communications, and consumer products.

SST's SuperFlash technology uses a thick-oxide process with fewer manufacturing steps that results in higher yields and offers significant cost benefits for embedded applications. The two companies are developing a proprietary process to allow significant amounts of embedded flash to be used without the die size penalty of traditional two-transistor thin-oxide cell embedded EEPROM flash technology. The licensing agreement covers process technologies with 0.5-micron, 0.35-micron, and smaller geometries. TSMC is planning the launch of 0.25-micron logic, embedded DRAM, SRAM, and flash processes in the fourth quarter of 1997. TSMC has affirmed its commitment to providing its customers with early access to advanced technology.

The licensing agreement has granted TSMC a license to use SST's SuperFlash technology to make embedded flash applications available to its customers. This embedded flash process will enable the customers to design application-specific standard products that integrate the appropriate amount of memory at the speed required. Dataquest expects that TSMC will provide a final solution to volume production in the vast array of applications with embedded SuperFlash technology.

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Micron Technology's Earnings Conference Call

Micron Technology Inc. reported net income of $143 million on net sales of $876 million for the second quarter of fiscal year 1997, ended February 27. Although financial results declined versus the same quarter one year ago, Micron's sequential quarterly performance signals continuing recovery for the Boise, Idaho-based company. For example, operating income rose to $77 million versus $41 million for the first quarter of fiscal 1997—and nearly $300 million for second quarter 1996. (Micron's net income for the quarter benefited from a $200 million-plus gain from the sale of subsidiary stock, so net income comparisons are less useful.)

The following culls key tidbits from the analyst conference call and the press release:

- Gross margin on memory products rose for second quarter 1997 to 32 percent versus 24 percent for first quarter 1997; this margin was more than 60 percent for second quarter 1996.
- Second quarter 1997 DRAM bit growth rates were:
  - 300 percent growth versus second quarter 1996
  - 55 percent growth versus first quarter 1997
- The tier one contract price of 16Mb DRAM has increased to about $7 to $7.50, versus the range of $6.40 to $7.00 of not so long ago.
- Micron's spot 16Mb price was less than $6 and is now mid-$9.00.
- Micron's thrust remains 16Mb extended data out (EDO) technology, but the company will monitor summer 1997 chipset announcements in case synchronous SDRAM (SDRAM) demand accelerates by the end of this calendar year.

DQ Take

Micron revealed during the call that it will negotiate for an increase in the tier one contract price of 16Mb DRAM provided that the spot price remains unchanged. The company believes it will be able to increase the tier one price above $8 and perhaps above $9. Micron's effort will start within several weeks. Longer lead times also fit into the equation.

This scenario is familiar. During the 1994-to-1995 heyday of the DRAM shortage, Micron would typically lead the market in terms of 4Mb DRAM price increases. Most suppliers would wait until Micron had sought price hikes from major buyers. If Micron got them, other suppliers would then negotiate for higher pricing. Micron would also typically be first to announce spot market price increases.

The DRAM mood varies somewhat depending on world region. Europe's center of attention has become the impact of reference pricing; any government involvement translates into increased market uncertainty. American-based suppliers like Micron and Texas Instruments remain ever concerned about unexpected weakening of demand, but DRAM business conditions continue to recover. The mood varies in Japan because suppliers are at different stages of recovery. The global concern now centers on the Korean-based suppliers, which have at least supplemented, if not replaced, Taiwanese suppliers as the 1997 wild card.

Micron's next conference call should be sometime during June. By then, the market will know whether Micron won higher pricing from contract customers—or not—and will know its competitors' response.

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Dataquest's Tactical Memories Newsletter
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Perspective

Memories Worldwide

Market Analysis

Dataquest's Tactical Memories Newsletter —Vol. II, No. 5

- *Spot Pricing Continues Its Climb*
- *Siemens Eyes the Flash Market—Who Doesn't?*
- *Atmel and SST Disclose Lower First Quarter 1997 Expectations*

Spot Pricing Continues Its Climb

Table 1 shows DRAM price ranges as seen by Dataquest during the week ending March 7, 1997. Figure 1 shows DRAM pricing trends.

DQ Take

Although there has been little increase in price from last week, the overall upturn that began about a month ago has been fairly significant. Table 2 illustrates the price increase from the beginning of February to now.

Clearly, product availability reductions in this channel have had a dramatic effect on spot market trading prices. This percentage increase from the January 31 price to the March 7 price has been between 36.7 percent and 45.8 percent, depending on the device. By anyone's scales, these are large increases.

Table 1
Spot Prices for Week Ending March 7, 1997 (Dollars)

	FPM	EDO
1Mbx4	1.95-2.10	1.95-2.10
1Mbx16	7.90-8.20	7.80-8.20

Source: Dataquest (March 1997)

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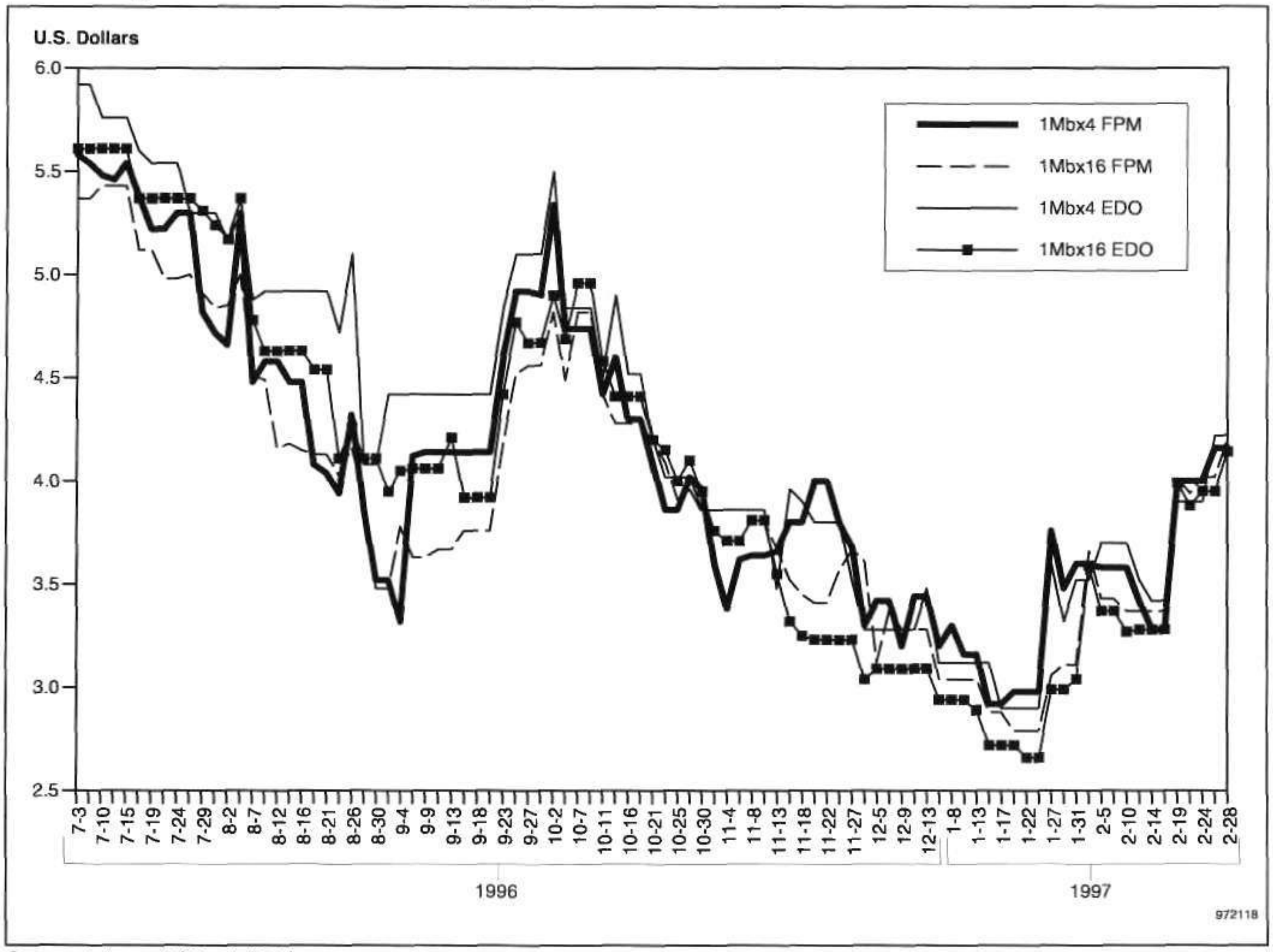
Figure 1
DRAM Spot Market Price per Megabyte Trends



Source: Dataquest (March 1997)

Table 2
Spot Market Price Comparisons (Dollars)

	January 31, 1997	March 7, 1997	Change ($)	Change (%)
1Mbx4 FPM Low	1.40	1.95	0.55	39.3
1Mbx4 FPM High	1.50	2.10	0.60	40.0
1Mbx16 FPM Low	5.50	7.90	2.40	43.6
1Mbx16 FPM High	6.00	8.20	2.20	36.7
1Mbx4 EDO Low	1.40	1.95	0.55	39.3
1Mbx4 EDO High	1.50	2.10	0.60	40.0
1Mbx16 EDO Low	5.35	7.80	2.45	45.8
1Mbx16 EDO High	5.65	8.20	2.55	45.1

Source: Dataquest (March 1997)

Although all increases were large in nature, the three greatest percentage increases have been on 16Mb devices—fast page mode (FPM) low, extended data out (EDO) high, and EDO low. All of these increased by over 43 percent This is due in part to the apparent oversupply of 16Mb chips in the early part of the year, which had driven the commodity prices on the spot market down. Now, as the 16Mb are in short supply on the spot market, the prices have shot up.

Also, at the end of January, 16Mb FPM product commanded a price premium over FPM product. This premium was at the minimum and maximum trading points on the range. Now, however, the situation is different. Although the minimum trade value for EDO 1Mbx16 is $0.10 lower than its equivalent FPM device, there is price parity at the high point. This would indicate equal availability constraints for both technology types.

4Mb devices are fairly self-explanatory. In January, there was price parity between FPM and EDO mode on the 60ns 5V SOJ product tracked by Dataquest. Similarly, at the end of the first week in March, both traded in identical price ranges. Thus, both 4Mb devices went from equal oversupply to equal limited availability in the spot market. Thus, it is fair to deduce that there has been a serious shift in availability in the spot market distribution channel.

However, I feel it important to emphasize that although supply would appear to be drying up in the spot market, this should not be heralded as the arrival of allocation for contract buyers. Far from it. Simply put, the spot market has ceased to become a depository for excess DRAM. DRAM suppliers still have enough capacity to cope with the requirements of their OEM customers.

Evelyn Cronin, Semiconductor Supply and Pricing Worldwide, evelyn.cronin@dataquest.com

Siemens Eyes the Flash Market—Who Doesn't?

In a recent interview, Dr. Ulrich Schumacher, the new president of Siemens Semiconductor, suggested that Siemens was actively looking for a partner to get into the flash market, especially if DRAM average selling prices (ASPs) in Europe rise as a result of a reintroduction of reference pricing on March 10. Because every other DRAM vendor has come out with a similar statement over the past year, is this just another flash in the pan?

DQ Take

What is strange about this statement by Siemens is that it links a move into flash with an increase in DRAM ASPs. Usually, DRAM vendors look toward other products, such as flash or application-specific ICs (ASICs), as potential saviors when the DRAM market has crashed. Siemens is not a typical DRAM vendor, however, because it does benefit from a wide product portfolio. The implication must be, therefore, that Siemens requires revenue from DRAM to fund flash development and manufacturing. Schumacher admits that flash technology would have to be bought in, although he is coy about naming potential partners. SGS-Thomson is the only semiconductor vendor currently manufacturing flash in Europe, although Intel is in the process of building a flash fab in Israel. Local European production would enable the flash vendors to avoid import duties and give them access to important European markets, so there may well be other leading flash vendors looking for a credible partner in Europe. Siemens fits the bill in the credibility stakes: solid engineering expertise, leading-edge process capability, and a knowledge of the main flash application markets of telecommunications and automotive are all qualifications that Siemens can boast. Developing flash as a product line in its own right would complement Siemens' capability in logic and microcontrollers, where it is already embedding flash, and in smart cards, were a move from EEPROM to flash memory to take place.

By Richard Gordon, richard.gordon@dqeurope.com

Atmel and SST Disclose Lower First Quarter 1997 Expectations

Both Atmel Corporation and Silicon Storage Technology issued press releases warning investors that they will not meet expectations for the first quarter of 1997. Silicon Storage expects its operating results for the first quarter ending March 31 to fall below fourth quarter net income of $700,000, or $0.03 cents a share, and revenue of $23.5 million. In a press release of Friday, March 7, Silicon Storage said it does not expect to meet its order, revenue, and profitability goals for the first quarter because of lower-than-expected shipment rates and steep market-driven declines in selling prices during the first quarter. Silicon Storage said it also expects lower net revenue and reduced gross margins and expects this trend to continue during the first half of 1997.

Atmel said revenue for the quarter will be down as much as 10 percent from fourth quarter levels, citing pricing pressure in EPROMs and delays in qualification of new flash memory products. The company also said the recent strength of the dollar has hampered results.

DQ Take

Although they appear similar, different things are happening at Atmel and Silicon Storage. In Atmel's case, the transition to flash memory from EEPROM has proved to be more difficult than expected. In its press release, the company said it was having difficulty shipping qualification samples to key customers. Qualification samples are low-volume requirements that do not tax a factory's capacity, only its ability make them right. To date, most of what Atmel calls flash has been lower-density parts with EEPROM internals. They work like flash on the outside but have a higher cost structure than true flash because of a two-transistor E^2 cell instead of flash's one-transistor arrangement. The new "49" series single-transistor-cell flash parts seem to be coming up slowly. Dataquest predicts that Atmel will solve its technical problems because of its history in E^2, just not as fast as it hoped.

Silicon Storage, on the other hand, seems just to be having business issues. The prices for lower-density flash have been decreasing especially fast, and that is Silicon Storage's forte. So it all sounds reasonable. But one disparate piece of information is that flash pricing actually rose in January, according to Dataquest! Figure 2 shows that January 1997 broke a year of flash price erosion. We expect that 1Mb pricing (not shown) was flat, instead of up. The issue seems to be more that there is increasing competition from Taiwan companies like Macronix that are taking away some of Silicon Storage's business.

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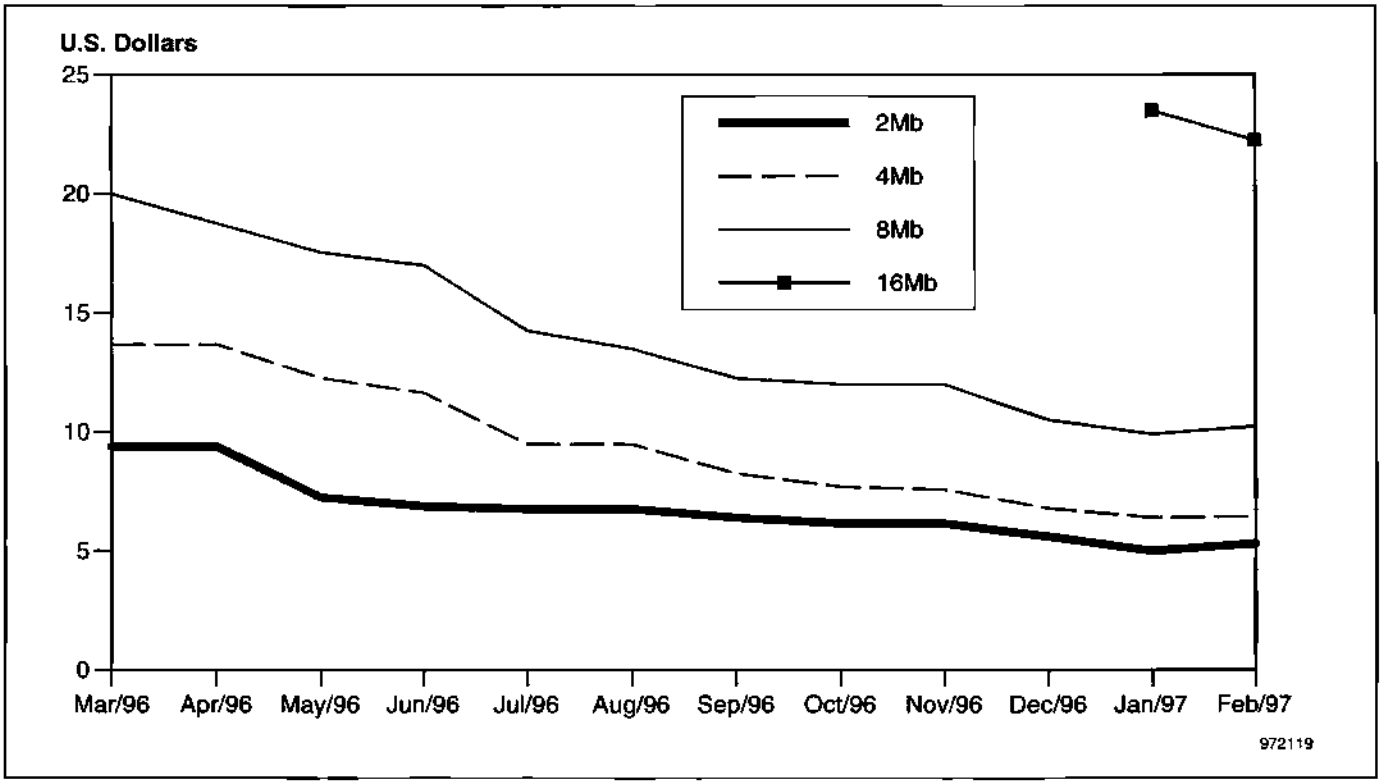
Figure 2
Flash U.S. 10,000-Unit Contract Pricing



Source: Dataquest (March 1997)

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Dataquest's Tactical Memories Newsletter
251 River Oaks Parkway, San Jose, California 95134

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Market Analysis

Dataquest's Tactical Memories Newsletter —Vol. II, No. 4

- *The Impending SDRAM Shortage*
- *Korean DRAM Makers: What 30 Percent Would Really Mean*

The Impending SDRAM Shortage

Dataquest has been spending time with clients, warning them of an impending synchronous DRAM shortage. This article will provide a brief explanation about why we anticipate this shortage and will explain what we believe our clients need to do to prevent this shortage from hurting them in the long run.

DRAM Manufacturers' Plans: Gradual SDRAM Phase-In

Figure 1 shows data taken from Dataquest's *DRAM Supply/Demand Quarterly Statistics* report. To produce this report, Dataquest performs quarterly surveys with all major DRAM manufacturers and asks for projected production figures by density, organization (x4, x16, and so on), and by input/output (I/O) type. In order to be able to present all densities on the same chart, we have presented production plans for all companies combined, in megabytes by I/O type. The curve shows a dramatic change from fast page mode (FPM) in 1996, followed by the anticipation of a far more gradual change toward SDRAM occurring in 1997 and 1998. The extended data out (EDO) changeover was largely driven by the PC market, which accounts for two-thirds to three-quarters of the total DRAM market.

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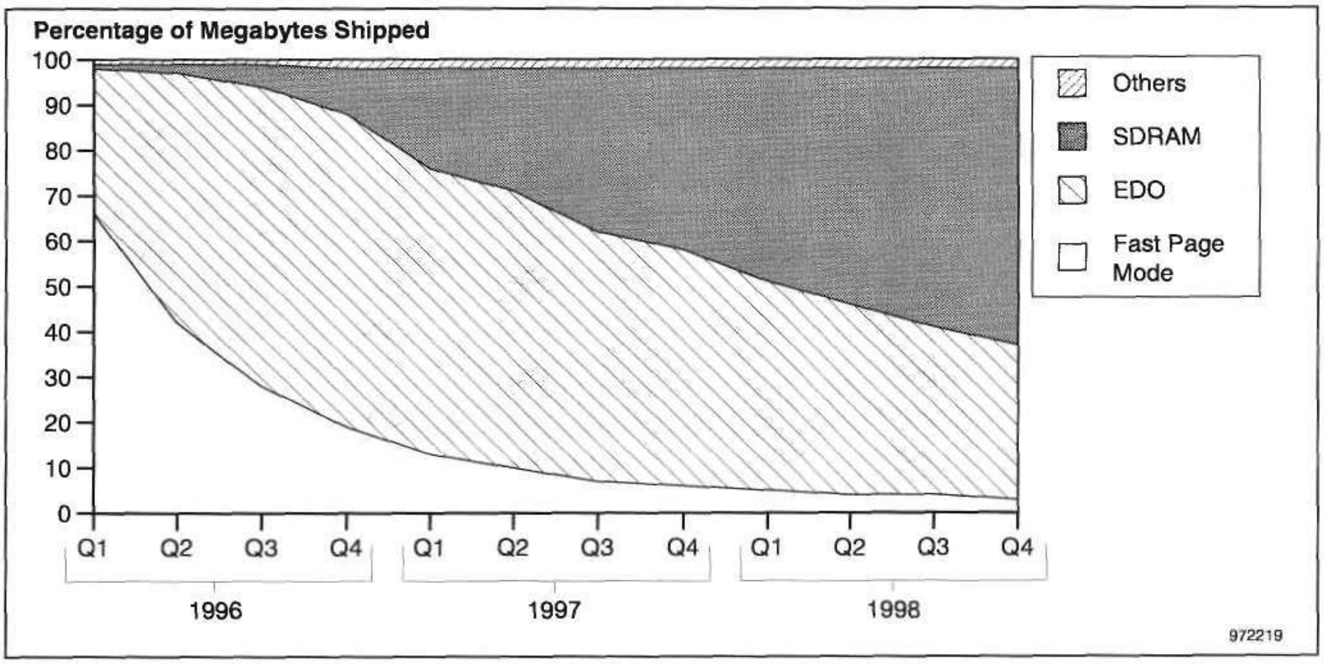
Figure 1
Manufacturers' DRAM Megabyte Shipment Plans by I/O Type



Source: Dataquest (February 1997)

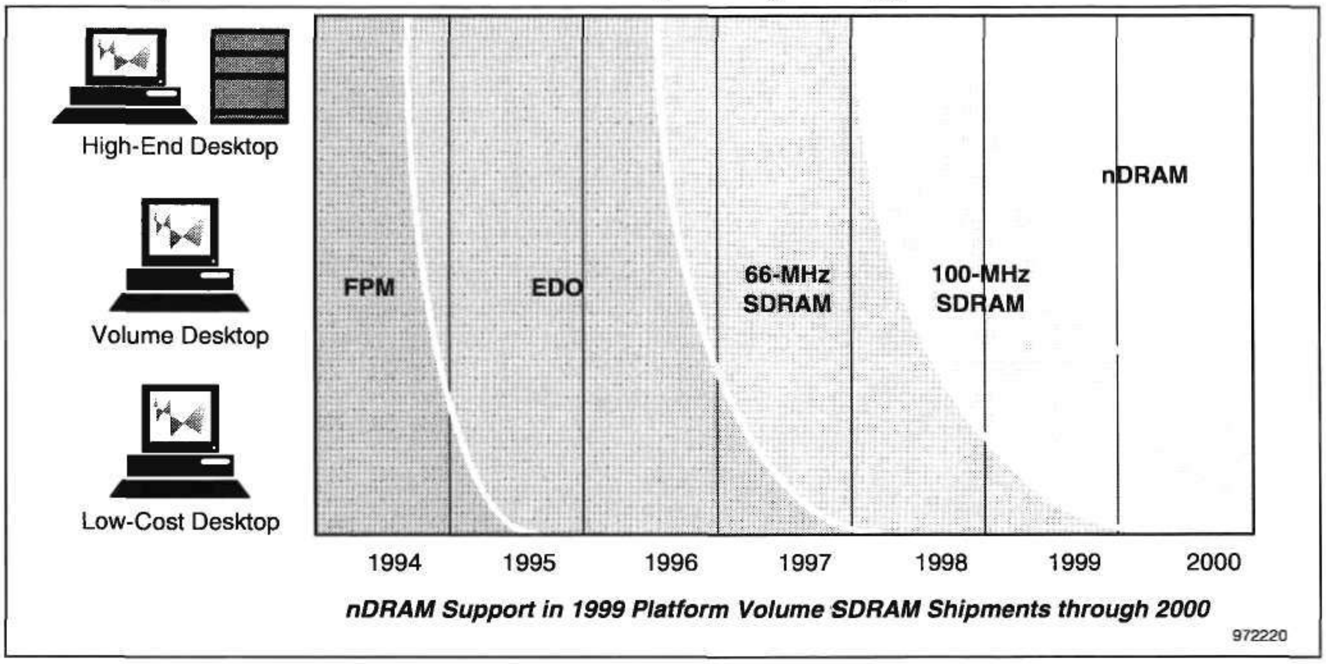
Intel's Plans: Swift and Complete Change

Last December, Intel unveiled its plans for DRAM usage by PC type. This chart was a part of the announcement package Intel shared with analysts when it announced its intentions to use a version of the Rambus interface for PC main memories in 1999.

The first thing that struck us when Dataquest saw this presentation was that the chart showed that high-end desktops and volume desktop computers had already migrated to the SDRAM, and the only platform that had *not* already migrated was the low-cost desktop system! Although such an event, had it actually happened, would have had to escape the attention of both sellers and purchasers of the DRAMs themselves, Dataquest actually took the disclosure to mean that the change was viewed by Intel as so imminent that it was unimportant to try to fix it to a precise time within the current period.

The FPM-to-EDO changeover appears to be in order with actual happenings in the market as shown in the 1996 data in Figure 1. Figure 2 shows Intel's expectations for PC DRAM consumption. What is impressive is that Intel appears to expect the SDRAM changeover to occur with the same rapid velocity as the EDO changeover last year.

Figure 2
Intel's Expectations for PC DRAM Consumption by I/O Type



Source: Intel Corporation

DQ Take

It doesn't take much comparison between the two figures to see that there is going to be a sudden change from EDO to SDRAM that will catch many DRAM manufacturers by surprise. Although we will not go into a lot of detail here about the timing of the change (we will leave that to a more detailed Perspective), we will warn that there are steps that must be taken by DRAM manufacturers to protect their market share and by DRAM purchasers to assure their sources of supply.

For our clients who are DRAM manufacturers, Dataquest warns that the SDRAM changeover will bring the same problems as did the EDO changeover last year, but with more gravity. Any inventory of EDO you are left holding will be used as a negotiating chip against you when taking orders for SDRAMs. Do not expect a price premium for SDRAMs, however; realize that the more aggressively you move production away from EDO and toward SDRAM, the more likely your company will be to maintain or even increase its share of the 1997 DRAM market.

Those clients who purchase DRAMs should assure themselves that they are in a strong position with those companies that are proven providers of SDRAMs. This is a short list that includes Samsung, NEC, Hitachi, and Toshiba but tends to drop off after these four. Intel has already made such a move by investing in Samsung's new Austin, Texas, 64Mb DRAM wafer fabrication plant. Although the 64Mb density may not be the one Intel initially uses, the company has strengthened its position against competing buyers of Samsung's SDRAMs of all densities.

Finally, our financial clients might want to review their expectations for DRAM manufacturers in light of the market share gain or loss that will be caused by the company's particular strength in the SDRAM market.

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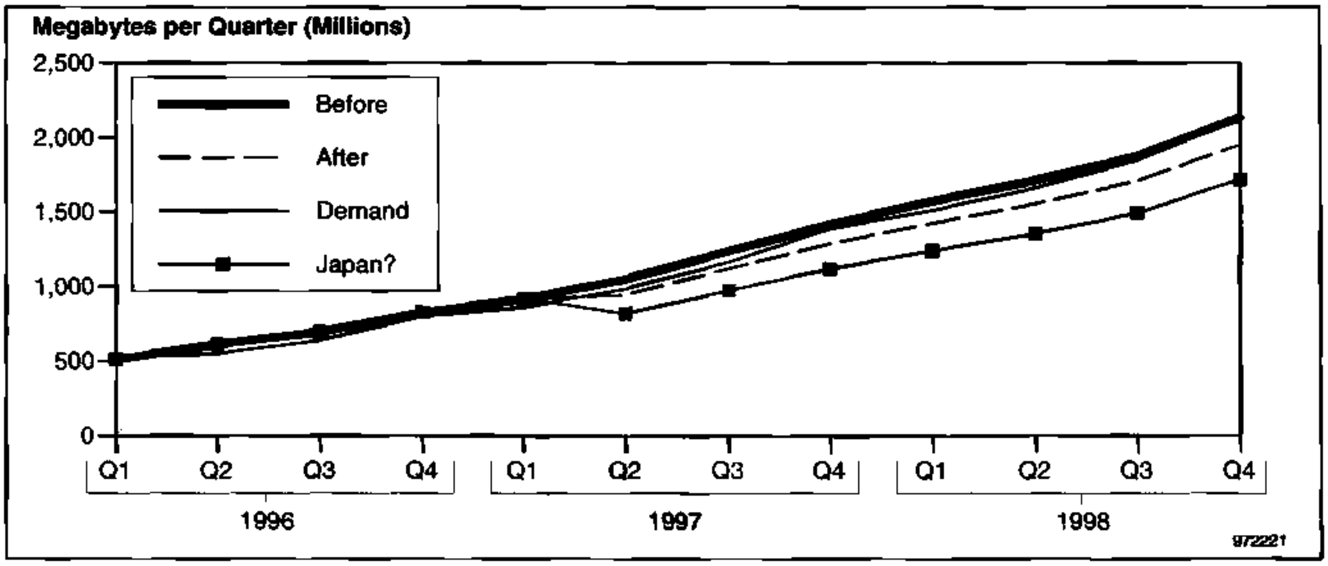
Korean DRAM Makers: What 30 Percent Would Really Mean

With the passage of time, Dataquest has seen little occur to shed any more light on the rumors that the Korean government is involved in the cutbacks now being discussed openly by Korean DRAM manufacturers. Some points of interest emerge:

- Samsung has told some that it will perform a 30 percent reduction in wafer starts but expects that to be compensated for by a new die shrink.
- Nearly all DRAM module manufacturers say that, since the announcement, their contract prices have risen from 10 percent to 20 percent.
- MicronTecknology Inc.'s president, Steve Appleton, said in an analysts' conference on February 24 that Micron's DRAM average selling prices (ASPs) had risen 50 percent in the past few weeks.

Figure 3 has been derived from data in Dataquest's *DRAM Supply/Demand Quarterly Statistics* to show the effect of a 30 percent across-the-board Korean production decrease on our supply/demand estimates starting in the second quarter of this year. The lines show demand, the production plans shared with Dataquest during our last survey in November, and the supply figure if all Korean manufacturers cut their total megabyte production by precisely 30 percent. The oversupply that Dataquest projects to last until the fourth quarter of 1998 suddenly changes to an undersupply starting next quarter.

Figure 3
DRAM Supply and Demand before and after Korean and Possible Japanese Cutbacks



Source: Dataquest (February 1997)

Korean manufacturers have shared with us their hopes that Japanese manufacturers would follow suit and have asked what would happen if all Japanese manufacturers were also to cut their production by 30 percent. This is shown on the line at the bottom, which cuts the production of all Japanese and all Korean DRAM manufacturers by 30 percent. This results in an undersupply of around 16 percent, which is high in comparison to much of the undersupply historically measured by Dataquest, so it is extremely unlikely for us to expect such an event to occur.

DQ Take

We still have questions about the instigator of the cutbacks and the rationale behind a cutback rather than the setting of a price floor. However, there is no denying that the desired effect is taking place (although we are *extremely* doubtful about Micron's 50 percent figure). Little things add credibility to the story of the government edict, such as the fact that Samsung's statements appear to show that the company is abiding by the letter of some law, by cutting wafer starts, but not by the spirit of the law, by cutting production. Samsung and others are also trying to reroute production to the 64Mb density, an effort that could have the net effect of increasing bit shipments dramatically. The DRAM market is a market for bits, and bit growth moves along at a relatively solid pace, so the cutback would also be thwarted by this move.

Since we are still admittedly in the dark, we will keep our clients posted about any new happenings we hear of.

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Dataquest's Tactical Memories Newsletter

- *Korean DRAM Makers: Rumors and Facts*
- *Spot Market DRAM Pricing*

Korean DRAM Makers: Rumors and Facts

For the past two weeks rumors have been flying fast and furious about Korean DRAM manufacturers. The *Wall Street Journal*, Reuters, and certain electronic newsletters have covered the rumors but to date have carried little from the companies the rumors are about. With the exception of Samsung, none of the three companies in Korea—Samsung, Hyundai, and LG Semicon—has made any statement to clarify what is actually happening. This issue will be devoted to these rumors and the facts that Dataquest has been able to uncover so far to support or refute what these rumors contend. Spot prices have responded mildly to the rumors (see Figure 1), and Dataquest analyst Evelyn Cronin will mention her observations on the spot and contract market later in this issue.

Rumor 1: Korean Government Forces Production Cutbacks

The first rumor contends that the Korean government has commanded DRAM manufacturers to reduce their production of DRAMs by anywhere from 30 percent to 40 percent to help stabilize the market and try to raise prices. The rumor states that this was issued as an edict, with no choices left to the manufacturers but to follow orders.

Certain regional representatives of some of these companies have unofficially confirmed that this is happening but claim that there will not be official releases about this.

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In Japan, the Nikkei newspapers had an article last week on this topic. The article stated as fact two glaring errors:

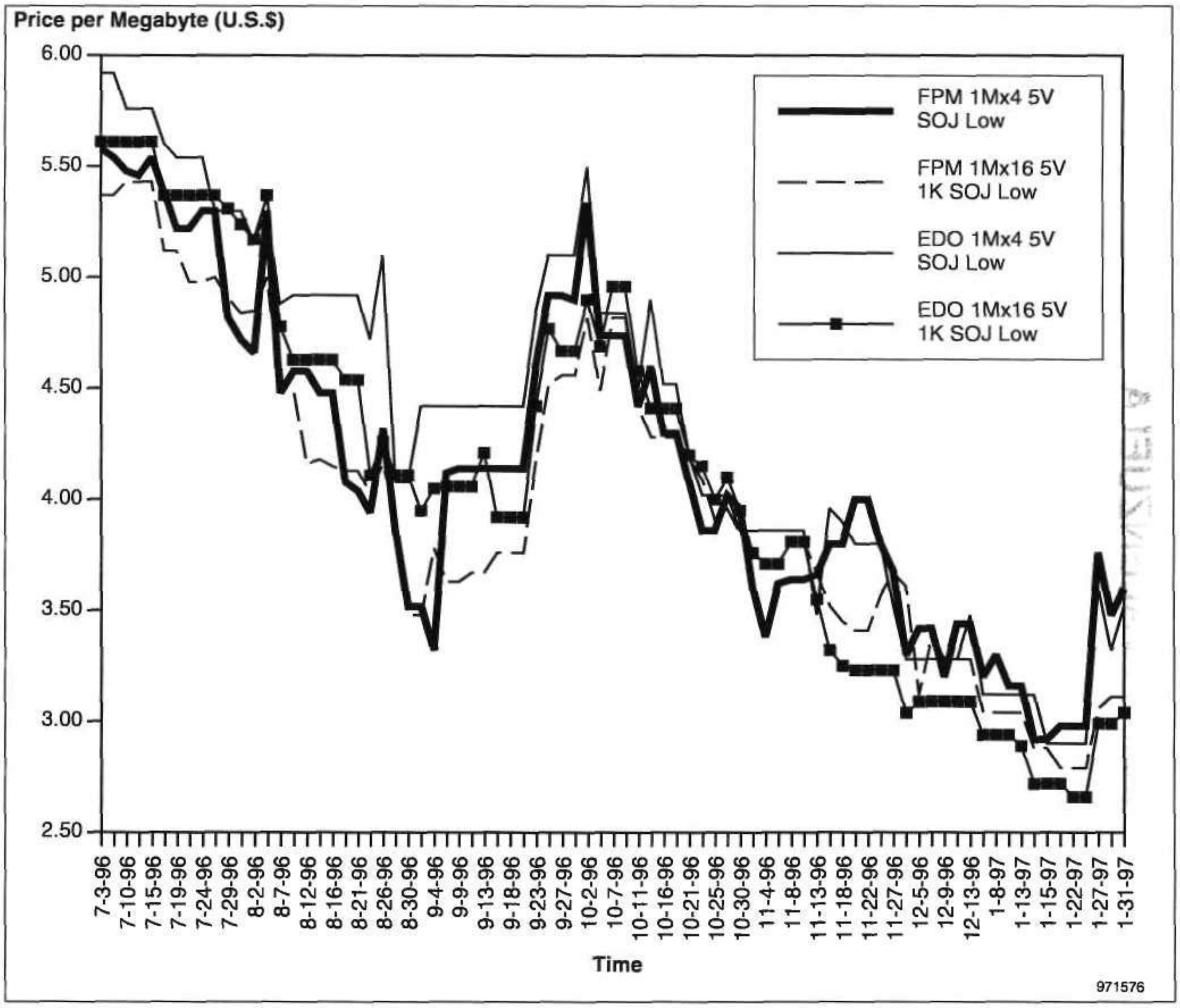
- LG Semicon's production of 16Mb DRAMs is 9 million units per month, and the company plans to cut this by 30 percent.
- Korean companies started shipping 16Mb DRAMs only in 1996.

Just to reflect the confusion in the market, we hear that another journal in Nikkei group denied the rumor of Korean government intervention later the same day.

DQ Take

The only trouble with this rumor is that it makes no sense. In 1995, DRAMs accounted for nearly 10 percent of Korea's exports. Because Korea is an export economy, it would be pretty bad if the government were to issue an

Figure 1
DRAM Spot-Market Price per Megabyte Trends



Source: Dataquest (February 1997)

edict to Korean manufacturers to give away market share. Further, analysts in Dataquest's Korean office assure us that, from their understanding of the industry and its relationship with the Korean government, the Korean government has no authority to force production cutbacks.

Dataquest has found that the headquarters of Korean companies, all three of which were visited by Dataquest analysts last week, appear not to be doing much to share their plans with their regional offices. When we asked about their position, spokespersons at two of the companies' headquarters said that the three companies "independently" decided to take steps to increase prices through production cutbacks. Their stress on the word "independently" gave us the impression that this word was carefully selected to assure that there was no suspicion that illicit activities might be taking place. The regional offices, in a vacuum of information, find themselves listening to the same rumors that we are hearing at Dataquest.

In Japan, where nearly 50 percent of the world's DRAMs are made, some companies are having meetings to evaluate the situation and make decisions about their own plan of action.

Our impression is that Japanese companies will be wary of following the Korean companies' example.

Module companies in Japan initially seem to be welcoming the move, because module prices in Japan (which have been higher than in other regions) had started to come down quickly; only at the end of the week of January 20 did module prices start to creep back up. Their joy may not last long, being forced to live on thin margins. Wafer companies are just too careful to expect anything. They know there will be a time lag until any wafer requirement reductions would hit them.

All in all, the Japanese audience is just behaving typically—no applause, no booing.

Rumor 2: Vendors to Stop Shipments until Prices Rise 25 Percent

Another rumor asserts that DRAM cannot be bought from any of the three Korean vendors in Europe, and possibly throughout the world. They are said to be waiting for a 25 percent hike in average selling prices. The rumor further states that this week there are going to be announcements from each of the individual Korean companies about a 40 percent cut in production. Also, according to the rumor, the Korean companies' announcements are expected to be followed by similar announcements from Japanese companies, the first of which are predicted to be NEC, Oki, and Toshiba.

DQ Take

There could be a very long wait for prices to rise 25 percent. It is not unusual for DRAM prices to be based on cost, and this fact, on top of today's large oversupply, rules out any price hike of that magnitude.

Discussions with Japanese DRAM manufacturers indicate that there is at present no plan to copy any such announcement that might be made.

Dataquest does believe that the rumors are indicative of an effort to halt continued price slides, especially because those price slides appear to have taken DRAM prices below variable cost for certain manufacturers. Below, we will reveal some of the statements made to us by Korean manufacturers that lend support to the belief that these companies are being forced into production cutbacks, not by their government, but by some bold decisions not to take business at unprofitable prices.

Some Facts: Vendors Regulate Shipments after No-Bidding Orders

In a press announcement, the only one of the three Korean DRAM manufacturers, Samsung, claimed that it has been adjusting 16Mb DRAM production ever since the third quarter of last year. It is important to note that the company used the term "regulate," meaning minor changes in production, not the 30 to 40 percent production cutbacks suggested by the rumors. If this minor change could have influenced prices, then price increases should have happened as far back as the third quarter of 1996.

LG Semicon has told us that it plans to focus on and emphasize DRAM support at OEMs, possibly resulting in the company's de-emphasizing business through the reseller channels. LG Semicon claims not to be planning to "shut down capacity," but rather to streamline its channel strategy.

By now, Samsung's strategy of holding back production after no-bidding orders seems to have been adopted by all three Korean manufacturers in an effort to keep the 16Mb DRAM price strong for the time being. Some in Korea believe that stable prices will continue for three to six months, but if Japanese DRAM manufacturers join the cutback, price firming will extend much longer. Some Samsung executives expect follow-on reductions to keep pricing stable until the end of this year.

In reality, when observing the demand and supply relationships of the 16Mb DRAM, the real oversupply is not all that big. Shipment reductions may be one of the best solutions to escape from a general semiconductor recession.

So What Does All of This Mean?

Most of all, Dataquest anticipates that prices will not recover much, but that the big difference between abysmal spot market prices and more rational contract prices will dry up. Contract prices are in line with production costs, being near the level of $5.00 per megabyte, while the spot market dipped below $3.00. As the market stabilizes, spot market prices should rise to, and oscillate around, contract prices, as they do in any stable market. Ever since the end of 1995, spot market prices have stayed significantly below contract prices.

After the stabilization occurs, we anticipate that contract prices will stay in their historical price decline of 28 percent per year. This is a trend that Dataquest has been measuring since 1974, and our statistics indicate that today's contract prices have met the curve, rather than sinking below it.

Some financial analysts appear to be using this story to push up some stock valuations. They are looking for any signs—genuine or not—of DRAM price stabilization.

If announcements are made about the plans of the DRAM manufacturers, then this should be interpreted as an "influence" situation, not a "control/power" one. In the U.S. airline industry, leading companies publicly announce price moves and hope their competition will agree and follow. The DRAM companies involved in this move are positioning themselves as "leaders," and the others will end up being the "followers." Because all the DRAM manufacturers agree that prices are too low, such a plan should have a good chance of working. It appears to be more than a coincidence that Korean manufacturers are giving a signal indicating an intent to reduce their own capital spending right in the middle of Japanese companies' fiscal year budgeting process for their April 1 capital spending plans.

Also, we should be aware of the migration from extended data out (EDO) to synchronous DRAMs (SDRAMs), from 5V to 3.3V, and from single in-line memory modules (SIMMs) to dual in-line memory modules (DIMMs), which will start in volume in the second half of this year. Reduced availability of EDO 16Mb DRAMs may well help speed up this migration for midrange and high-end PCs. DRAM pricing could be just one of many issues that PC companies will have to deal with in this turbulent year.

A conclusion can be reached that the Korean companies are finally admitting that they have serious profitability issues in DRAM, to the point of trying to stop the bleeding. The cracks in the "invest for the future market share" strategy are showing. The only question that remains is what the manifestation of the solution will be. Build inventory again? Continue to reduce wafer starts? Cut capital spending again? Mothball fabs? All the above?

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Spot Market DRAM Pricing

Figure 1 showed the latest pricing from the spot market in the United States. There is a definite price increase, largely as expected and fueled by the Korean suppliers' planned DRAM cutbacks (be they rumor or fact).

Brokers say that they haven't seen any Hyundai and LG Semicon parts "for a while" but that they had "some" Samsung parts recently. The lack of Hyundai and LG Semicon parts is significant to the brokers because they claim to have traded more of these suppliers' DRAMs than any others last year. OEMs say that they are still receiving regular deliveries. This concurs with a statement made by LG Semicon that it is grooming its account base away from resellers and toward OEMs.

Just to put the spot market price rise in context for everyone: Recently, spot market pricing levels were about the same as they were in mid-November 1996. Translated, this means: 1Mbx4 at $1.88 to $2.00 and 1Mbx16 at $6.00 to $6.50 (for both FPM and EDO). These will probably increase daily.

Please note, however, that the price increase has been minimal so far. Spot market availability remains good on standard DRAM (SDRAM and 64Mb are more difficult to obtain, obviously), so brokers were unable to jack the prices up too much. Significantly, though, Korean product is almost nonexistent. Volume DRAM trading is now on Japanese and American product.

The DRAM production cutback could stabilize the market a lot more (at least short term). Price per megabyte had been under $3 in early January, which is not healthy for any company, regardless of its production costs and cash reserves.

Time will tell how things pan out.

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- *WSTS Price per Megabyte Falls Again*
- *Silicon Magic/Oki Embedded DRAM Graphics Chip Announced*
- *Flash Memory Storage Cards for Consumer Products Debut at CES*
- *DRAM Spot Market Update*

WSTS Price per Megabyte Falls Again

After a tiny rise in October's price per megabyte, the World Semiconductor Trade Statistics (WSTS) figures just released once again show that the price for a megabyte of DRAM has fallen, this time all the way down to $5.03 (see Figure 1). Despite this, we have seen little indication of a response in the form of increased bit consumption. This inelasticity translates to a relatively steady bit growth over the same period (see Figure 2), no matter whether the price per megabyte is flat, as it was from 1992 through 1995, or if it is dropping precipitously. Figure 2 overlays actual megabyte consumption over a trend line showing the average growth, on a logarithmic scale. The actual data's deviation from the projection of average growth is slight.

DQ Take

Dataquest regards the general softening of the price fall as an indication that we are about to enter a period of stable decline, where prices will follow their more typical 28 percent per year reduction. At the beginning of the year, Dataquest anticipated that lower prices would cause increased demand, something of a balancing act. Recent decreases in our memory forecast are because of the overwhelming lack of market response to 1996's bargain DRAM prices. The DRAM market appears to have little, if any, elasticity.

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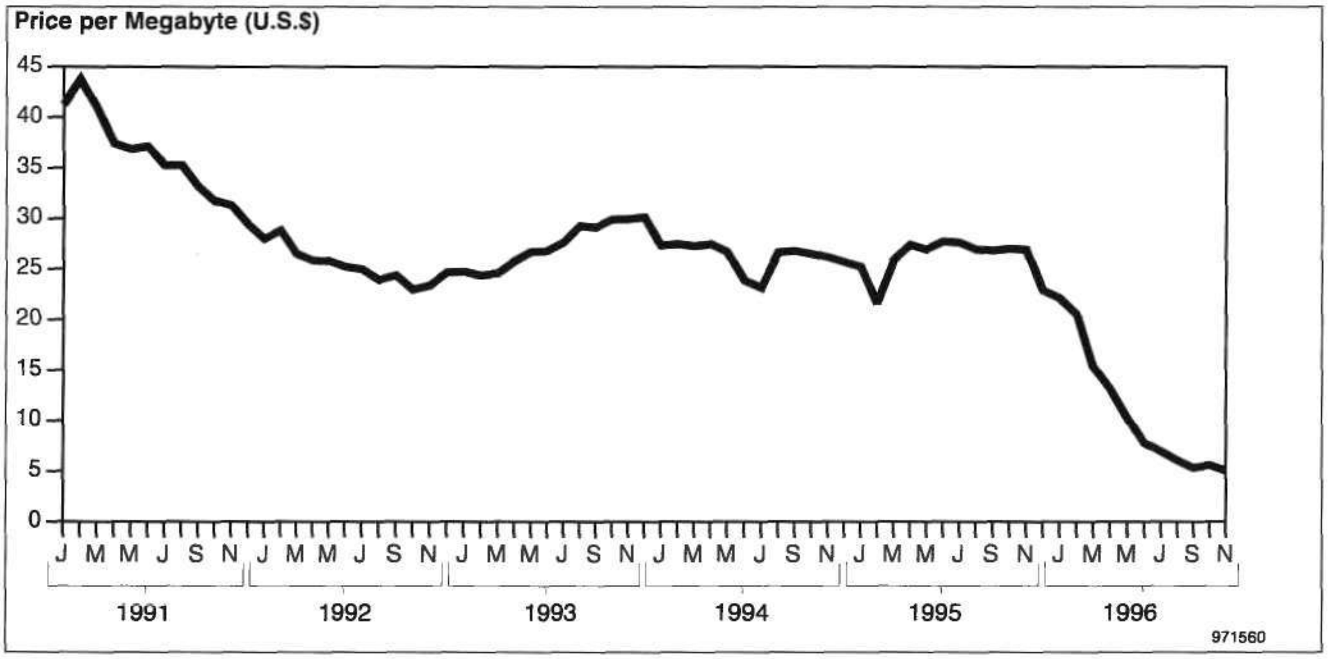
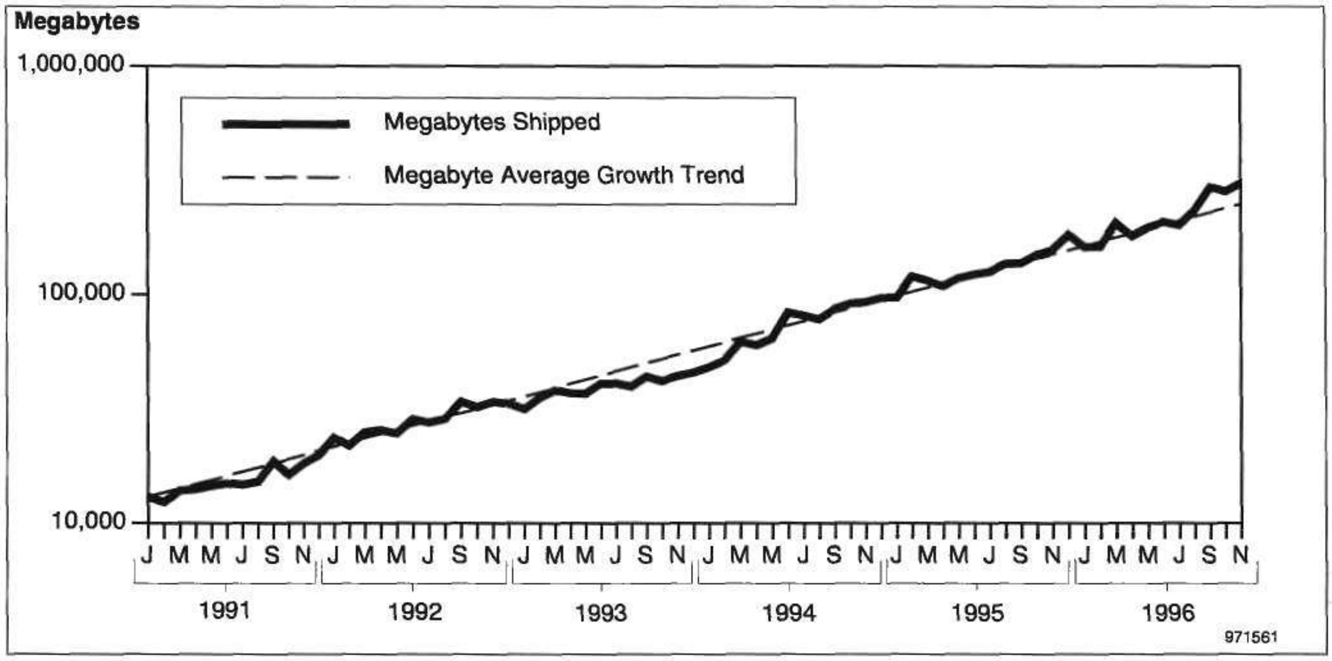
Figure 1
Price per Megabyte for DRAMs, January 1991 to November 1996



Source: WSTS, Dataquest (January 1997)

Figure 2
DRAM Megabyte Consumption versus Projected Average, January 1991 to November 1996



Source: WSTS, Dataquest (January 1997)

Silicon Magic/Oki Embedded DRAM Graphics Chip Announced

Silicon Magic and Oki Semiconductor announced both companies' versions of the first embedded DRAM product to be produced under the companies' joint technology development agreement. The MAGIC F/X 256 and MSM7680 embedded DRAM chip accelerates video and graphics performance and features built-in hardware MPEG-1 video, audio decode, video capture port, and business audio. The product is designed for high-performance 2-D and 3-D multimedia applications requiring high bandwidth, including Internet or intranet applications, desktop videoconferencing, and digital kiosks, and is supported with a range of software drivers.

10 Mb (1.25MB) of embedded SDRAM is coupled to a graphics processor via a 256-bit internal bus. An expansion bus allows an additional 1MB of memory to be connected to the system.

The Silicon Magic MAGIC F/X 256 and the Oki MSM7680 will be available from their respective companies in the first quarter of 1997. Evaluation boards are available to qualified manufacturers.

DQ Take

It is a little confusing to us to be watching two companies that are both pioneers in the embedded DRAM market for graphics controllers, both having names that include the word "Magic." NeoMagic has been successfully shipping its embedded DRAM graphics controller to notebook PC manufacturers for about a year now. The product's claim to fame is its small size and low power consumption in comparison with a two-chip DRAM/controller combination. Silicon Magic is focusing on high performance for the desktop, while offering the other benefits mentioned earlier.

But this is really about embedded DRAM technology, a technology that Silicon Magic says will benefit disk drive caching, audio controllers, frame buffer memories for graphics applications, network switching, and many other applications. This is the company's mission. True, many systems do not need all the DRAM provided by a 16Mb IC, and this is a good reason to look to integrate a smaller DRAM with some relevant logic. Dataquest will be probing this market in a report from the Memories Worldwide program later this year.

By Jim Handy, Memories Worldwide, jhandy@dataquest.com

Flash Memory Storage Cards for Consumer Products Debut at CES

Digital still cameras, as well as digital audio recorders, advanced pagers, cellular phones, personal digital assistants (PDAs), and handheld computers using flash memory were all present at this year's winter Consumer Electronics Show (CES). This year's CES was a coming out party of sorts for flash storage as an enabling component of digital consumer products. The Miniature Card Implementers Forum (MCIF), Toshiba supporting

SmartMedia, also known as the Solid-State Floppy Disk Card (SSFDC), and a number of vendors showcasing digital still cameras with CompactFlash all were present and willing to share compelling arguments for their technology.

DQ Take

Although considerable attention was paid to consumer products using flash memory storage cards at this year's CES, there still isn't a clear cut leader in this interface battle. SanDisk's CompactFlash, Intel and Advanced Micro Devices' Miniature Cards, and Toshiba and Samsung's SmartMedia all were present in different ways.

Dataquest analysts counted two digital still cameras using CompactFlash. SanDisk, however, wasn't present at CES to champion CompactFlash's merits. Two digital still cameras using SmartMedia were also present. Toshiba, unlike SanDisk, was on hand as a SmartMedia advocate. Miniature Card technology was present in only one digital still camera, but it enjoyed the widest reach in other products. In addition to the one camera, Miniature Card technology was present in Cherry Electrical Product's Universal Serial Bus-enabled keyboard, which has a miniature card reader built in (by the numeric keypads), and Philips' Velo handheld PC. The Velo has provision for inserting two miniature cards, one for expanding DRAM and the other for upgrading the Velo 1 operating system.

In addition to having the widest reach, the Miniature Card supporters, the MCIF, were also easy to find. The MCIF, which was formed in early 1995, now has more than 50 members, including such semiconductor companies as Intel, Advanced Micro Devices, Sharp, Mitsubishi, Samsung, and Hyundai, and system companies like Konica, Sony, Nokia, and Olympus. The Miniature Card is a small form-factor memory card standard that can be used for flash, DRAM, or ROM storage.

This interface battle is only starting and, from the consumer products already available, it looks as though it will be interesting.

By George Iwanyc, Memories Worldwide, giwanyc@dataquest.com

DRAM Spot Market Price Update

Table 1 summarizes the spot market trends for the past week as seen by Dataquest.

Table 1
Spot Market Pricing (Dollars)

	FPM	EDO
1Mbx4	1.40-1.50	1.40-1.50
1Mbx16	5.50-6.00	5.35-5.65

Source: Dataquest (January 1997)

DQ Take

And you thought prices might stabilize! Wrong. Another volatile week has just concluded in the spot market. Oversupply, eroding price points, and trading are all issues that continue to play on the minds of spot market watchers.

This week, pricing is down across the board. While extended data out (EDO) product is generally lower priced, fast page mode (FPM) is coming down. On the 1Mbx4 devices, this week has seen price parity between the two technologies at 60ns. For 1Mbx16-60ns devices, however, EDO is moving into the mid-$5 price range. The FPM versions of this device are down but are still slightly more expensive.

Looking to other chips, the 4Mbx4 chip (both FPM and EDO) is down again but is still up to $1 more expensive than the 1Mbx16. The most interesting emergence is the continued price premium for 2Mbx8 chips. Although these chips have come down from last week, they still trade around $7. A major point for 2Mbx8 chip, though, is whether the higher price is driven by general lack of supply or overall lack of demand.

In single in-line memory modules (SIMMs), the 4MB nonparity SIMM is now under $14 across the board. By contrast, pricing on the 8MBx32 is more stable—these remain in about the same ranges as last week. Again the 16MB nonparity SIMM is falling in price and is now officially under $60 across the board. However, this is still more than twice the price of two 8MB SIMMs.

From a trading view, little has changed since last week's hesitant beginnings. It is still too early in 1997, though, to try to see if this low-volume trading will be maintained all year. One thing that has been reinforced from September 1996 to now is that rock-bottom prices on the spot market do not necessarily translate into buying frenzies among OEM customers.

By Evelyn Cronin, Semiconductor Supply and Pricing Worldwide, ecronin@dataquest.com

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Dataquest's Tactical Memories Newsletter
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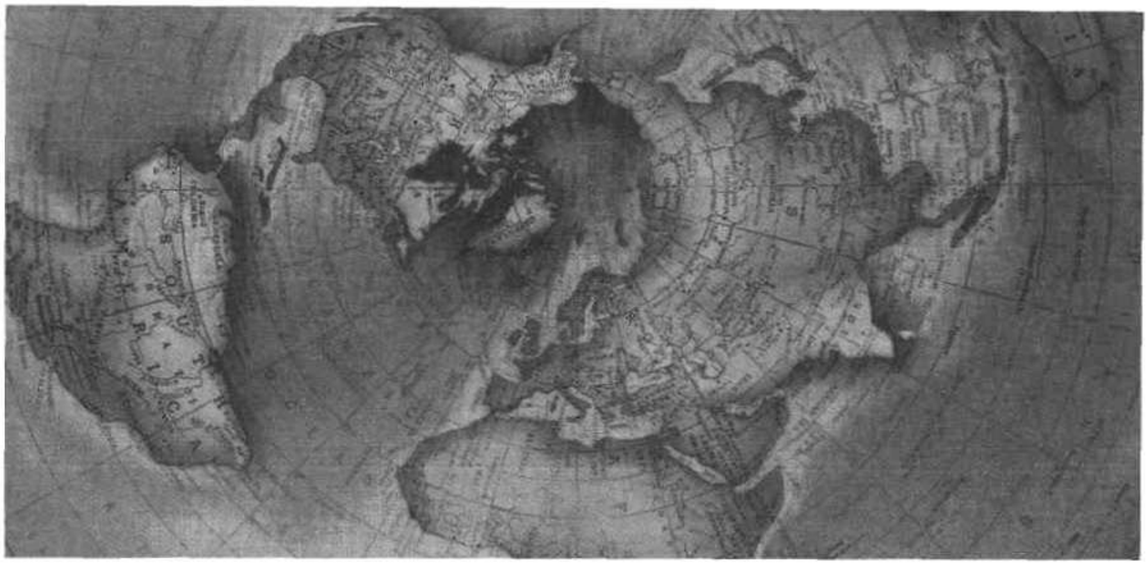
Perspective



Memories Worldwide

Vendor Analysis

U.S. Third-Party Memory Module Manufacturers

Abstract: *There seems to be a third-party memory module manufacturer everywhere we turn. Many of these companies are small, little-known companies that take an opportunistic approach to manufacturing and distributing their products. Rising above the masses are a number of U.S. companies that are working to change this image. This Perspective profiles eight U.S. module manufacturers and the actions they are taking to make their companies successful.*

By George Iwanyc

Introduction

For the last handful of years, third-party memory module manufacturers have been a common part of any list ranking the fastest-growing companies in America. Third-party memory module manufacturers are the middlemen of the memory industry. They buy DRAM directly from DRAM manufacturers or on the open market, install them into single in-line memory module (SIMMs) or dual in-line memory modules (DIMMs), and then sell the memory modules into aftermarket channels or to original equipment manufacturers (OEMs). This industry did not exist when the first personal computers were being built, but since the late 1980s, it has grown from nothing to a total size between $4 billion and $6 billion, by Dataquest's estimate. Considering the dazzling growth this industry has experienced, it is surprising how little information is available about these companies. Most are privately held, and, once past their press releases and technical support phone lines, in-depth information becomes scarce.

This Perspective profiles eight U.S. third-party memory module manufacturers. Table 1 lists the companies that are profiled. They make a diverse group. Leaders in each of the three major distribution channels,

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distribution and resale, retail, and OEMs, are included. Companies that pride themselves on owning and specializing in manufacturing and companies that believe in outsourcing manufacturing are included, both feeling they offer the best solution. The revenue of these companies ranges from the fringes of $100 million to a company with revenue over $1 billion. This Perspective sheds light on an interesting industry that continues to offer the potential for impressive growth.

The companies profiled are all major third-party memory module manufacturers, but this list should not be construed as the top eight U.S. manufacturers. Dataquest is still researching third-party module manufacturers, and a number of companies not included here are still to be profiled. All of the companies will be included in a Dataquest Focus Report on the third-party DRAM module market at a later date.

Table 1
U.S. Third-Party Memory Module Manufacturer Information

Company	Company Headquarters	First Year of Operation	Number of Employees	1996 Revenue ($M)	1996 U.S. Sales (%)	1996 International Sales (%)
Centon Electronics	Irvine, CA	1978	180	220	80	20
Century Micro Electronics	Santa Clara, CA	1989	100	400	40	60
Kingston Technology	Fountain Valley, CA	1987	523	1,300	70	30
PNY Electronics	Moonachie, NJ	1985	236	500		
Simple Technology	Santa Ana, CA	1990	425	165	90	10
Smart Modular Technologies	Fremont, CA	1988	500	400	80	20
Viking Components	Laguna Hills, CA	1988	260	260	85	15
VisionTek	Gurnee, IL	1988	300	300	97	3

Source: Dataquest (February 1997)

Centon Electronics

Centon Electronics Inc.
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Centon Electronics was founded in 1978 by Gene Miscione, its president and CEO. Originally a distributor of DRAM, Centon began the transition to memory module manufacturer in 1990, which it completed in 1993. Centon's 1996 revenue is estimated to be $220 million. Although revenue was impacted by 1996's DRAM price declines, 1996's profit margin was double 1995's level, and unit shipments grew.

The company's goal is to be "a worldwide supplier of memory add-on solutions through leadership in the design and marketing of new products to all segments of the market." Strategic partnerships and long-term relationships with its customers, qualified contract manufacturers, and suppliers are the keys Centon has identified to meeting its goals.

OEM relationships account for the lion's share of Centon's business, at 50 percent, the distribution and reseller channel accounts for 30 percent, and the retail channel makes up the remaining 10 percent. Centon believes that once all true costs are considered, each of the channels offers similar margins. Retail, however, is cited as the most difficult channel in which to participate. Centon maintains its presence in retail through very tight management. The OEM channel is a wild card at this time. Centon claims to lead this market, but because there is sometimes a blurry line between contract manufacturer and third-party memory module manufacturer, it is difficult to measure the accuracy of Centon's claim.

Centon is shipping about an equal number of fast page mode (FPM) and extended data out (EDO) modules, but it is moving quickly toward EDO. Centon's most popular products are 8MB and 16MB EDO SIMMs. DIMMs are growing in significance but are still considered a differentiator at this time.

Centon believes in emphasizing its operating strengths, which it believes to be managing the logistics involved in manufacturing memory modules, not the actual physical assembly of the module. Centon manages its own planning, procures its own parts, inventories its own components, tests its own parts, and manages the inventory and distribution of finished goods. What Centon is content to outsource is assembly.

Four to five subcontract assembly houses are used by Centon at any given time to manufacture its memory modules. Centon provides complete assembly kits to its subcontractors and maintains a support engineering staff on site. The engineering support is to deal with problems as they arise and to ensure that proper manufacturing principles are followed. Before working with an assembler, Centon does a full team review of the facility and processes used. Centon is also in the process of becoming ISO 9001 certified.

Centon uses both the contract and spot market, at about equal levels, to obtain its DRAM supply. The split between contract and spot market usage varies depending on market conditions. Centon uses the spot market more than many of its competitors, leveraging its experience as a distributor. Even though Centon chooses to use the spot market more than many of its competitors, it also works to maintain strong relationships with its contract DRAM suppliers. Centon maintains an inventory level of raw material and finished goods of about two weeks.

Centon believes the entire third-party memory module market is still growing, and because of this, it expects to grow in size and revenue without having to grow its market share. International, OEM, notebook, and workstations are all areas targeted by Centon for growth. Centon already has an international presence, with 20 percent of its sales coming from outside of the United States, but it hopes to expand this area.

Century Micro Electronics

Century Micro Electronics Inc.
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Century Micro Electronics was founded in 1989 by principals from Japan and Hong Kong. Dataquest estimates Century's 1996 worldwide revenue to be $400 million. Century did enjoy a higher profit margin in 1996 and an increase in unit volume. Century supports all three distribution channels. About 60 percent of Century's revenue comes from the distribution and reseller channel. The OEM channel accounts for a little over 30 percent of revenue. The retail channel and contract manufacturing make up the rest. Century's high volume products are 8MB and 16MB modules.

Manufacturing is split among Japan, Hong Kong, and the United States. Fifty percent of Century's 100 employees are devoted to manufacturing. Century's Japanese manufacturing facility is located 35 miles southwest of Tokyo. Century operates five fully equipped surface-mount technology lines at this facility. In the United States, Century uses contract assembly for quick turnaround situations to avoid heavy inventory exposure.

Century's Japanese plant features test equipment with the capability of performing full printed circuit board (PCB) analysis, timing analysis, wave form measurement, wave temperature testing, and parametric testing. Environmental and reliability testing, including operational life test, burn-in, and insertion testing, is also performed.

Century differs from many of its competitors in that more than half its revenue is derived from outside the United States. The United States is the largest single region, accounting for 40 percent of Century's sales. The Japan and Asia/Pacific regions account for about 50 percent of sales, which is not surprising considering this is where most of Century's manufacturing is located.

Century uses both the spot market and contract arrangements with DRAM suppliers to purchase its DRAM. The dependency on either source varies considerably, depending on market conditions.

Kingston Technology

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In 1987, Kingston Technology was formed to support the emerging market for memory upgrades. Today, Kingston's objective is to be the OEM of memory throughout the computer industry. Kingston is by far the largest of the third-party memory module manufacturers, with estimated revenue of $1.3 billion in 1996. Kingston has an image and strategy of supporting the high-end, machine-specific memory module market and avoiding generic, commodity modules. Kingston also sells processor, networking, and storage upgrades, but these products are completely overshadowed by memory modules, which account for over 80 percent of Kingston's revenue. Although 1996 revenue is expected to be flat, Kingston expects a threefold increase in unit shipments.

Kingston's prominence among memory module manufacturers comes from its domination of U.S. distribution channels. Kingston's dominant position in distribution is in contrast to its position in the PC OEM and retail channels, where it has little or no presence. Kingston had a first mover advantage in the distribution channel, having entered this channel before there was any significant competition. This allowed Kingston the opportunity to develop tight working relationships with its distribution and reseller customers, without having to worry about cutthroat price competition. Because Kingston is already so well positioned in the U.S. distribution channel, it is difficult to forecast above-average growth in this channel. This constraint explains why Kingston has targeted international expansion as the best way of expanding this line of business. It also explains why Kingston is interested in expanding its presence in the OEM channel. Kingston recently made a public entrance into the OEM channel when it announced it will supply the memory modules for Toshiba America Information Systems' memory upgrade program.

Kingston has traditionally sourced 100 percent of its DRAM through contract arrangements with DRAM manufacturers. Even in 1996, when the spot market provided the opportunity for significant cost savings, 95 percent of Kingston's DRAM was purchased through contracts. Kingston avoids relying on the spot market for a number of reasons. The most important is the need to maintain strong relationships with DRAM manufacturers. Kingston fears opportunistic use of the spot market would alienate its suppliers, creating the potential for problems during allocation periods. Kingston's size also prohibits it from relying heavily on the spot market.

For more information on Kingston Technology, see the Dataquest Perspective "Kingston Technology—King of the Memory Module Hill" (MMRY-WW-DP-9701, January 13, 1997).

PNY Electronics

PNY Electronics Inc.
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PNY Electronics was founded in 1985 as a memory chip broker. In 1991, PNY made the transition to third-party memory module manufacturer, and since then, PNY has progressed from a company with a manufacturing mind-set to one with a design mind-set. PNY operates three manufacturing facilities, one at its headquarters in Moonachie, New Jersey, a second U.S. facility in Santa Clara, California, and a third facility in Bordeaux, France. PNY's annual sales have virtually doubled every year since its transition to manufacturer in 1991. Revenue growth did stall in 1996 and is expected to remain at the level of 1995's revenue, which approached $500 million. However, unit volume increased 400 percent in 1996.

PNY sells its memory modules through the three dominant channels and is the leading third-party manufacturer in the retail channel, which includes mail order, where its memory modules are available at over 7,500 retail locations and 22 mail-order catalogs. PNY is as dominant in the retail channel as Kingston is in the distribution channel. The retail channel accounts for about 60 percent of PNY's sales.

PNY also provides contract assembly services to semiconductor manufacturers and OEMs. PNY's high-volume production lines and automated testing equipment in America and Europe result in a combined surface-mount placement capacity of more than 200,000 components per hour. In December of 1994, PNY's New Jersey operation became ISO 9001 certified.

PNY sources its parts primarily through contract arrangements with DRAM suppliers. The spot market is used for about 10 percent of PNY's DRAM needs.

PNY's approach to the thousands of potential combinations of memory modules is its UNIMEM asset management program. Fewer than 45 UNIMEM products replace over 1,000 OEM part numbers. PNY uses this approach to dramatically reduce the amount of inventory its resellers need to carry. In 1996, PNY favored FPM as its dominant module type, with a 60/40 split between FPM and EDO. A significant part of PNY's EDO modules are being packaged as DIMMs. By the end of 1997, PUY Electronics estimates 10 percent of its modules will be SDRAM.

Simple Technology

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Founded in 1990 by the Moshayedi brothers as a memory module manufacturer, Simple Technology expanded its product line in 1993. Simple now offers a number of PC-directed products, including small form-factor memory cards, high-density portable storage devices, and mobile networking and communications products. Memory modules are Simple's primary business, accounting for about 70 percent of Simple's sales. Simple's

1996 revenue is estimated to be $165 million. Although Simple's revenue was impacted by the dramatic DRAM price slide of 1996, its unit shipments grew over 100 percent when compared to 1995. Twenty percent of Simple's business is international.

Simple concentrates on the distribution and OEM channels. Simple does have a retail channel presence, but it is minimal and not a key business area. The OEM channel accounts for 30 percent of Simple's business, and the distribution channel accounts for most of the remaining 70 percent. Simple deals with five or six major OEMs, providing turnkey products for drop shipping. When dealing with distributors and resellers, Simple maintains a same-day shipping policy at a 96 percent success rate.

Simple takes pride in being one of the memory vendors that designs, engineers, produces, and tests each memory module in-house. Simple maintains manufacturing plants in the United States, Scotland, and Canada, with an additional plant planned for the Pacific Rim. The combined manufacturing space Simple has is about 130,000 square feet. Simple Technology is undergoing the final qualification procedures for ISO 9001 standards. Simple expects certification will be completed within the first quarter of 1997.

About 90 percent of Simple's DRAM is obtained via contact arrangements with Japanese manufacturers. Simple's inventory level has been worked down from 45 days to around 21 days. Inventory is maintained in a mix of finished goods and raw material.

Simple expects growth to come from a number of areas, including expanded OEM sales and an increased international presence. Simple, like most module manufacturers, expanded as quickly as its monthly cash flow would allow, but it has made the big jump to strategically growing its OEM business. Simple's presence in the OEM market was helped greatly in the allocation years of 1994 and 1995. Simple hopes to expand the OEM channel to 40 or 50 percent of its total module business in 1997.

Smart Modular Technologies

Smart Modular Technologies Inc.
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Launched as an independent memory module maker in 1988, Smart Modular Technologies offers its products under the Smart and Apex Data brand names to leading OEMs and distribution channels in the computer, printer, networking, and telecommunications industries. Smart is made up of three divisions: the Memory Products division, the Embedded Computer division, and the Apex Data Products division.

Smart's revenue for 1996 was a little over $400 million, an increase of 46 percent from 1995's revenue of $275 million. Smart's success in 1996 may seem odd when compared with its third-party competitors, which have ha generally flat revenue growth, and with DRAM manufacturers, whose revenue dropped almost 40 percent. One reason behind Smart's success is the OEM channel. One of the most visible trends in 1996 regarding third-party module manufacturers was the move to establishing OEM relationships. Smart was already well established in this channel and has leveraged its position to continue its strong growth pattern. Smart, however, is aware of the pitfalls of unmanaged growth, citing a concern about adding customers faster than capacity.

Smart is unusual for a third-party memory module manufacturer because it is one of a few that is publicly held (Nasdaq: SMOD) and its memory modules are targeted 100 percent at the OEM channel. Smart's strength is in its manufacturing capability. This area is where Smart provides value-add to its customers. The benefits Smart offers to its OEM customers are speed and flexibility in manufacturing. Typically, large computer OEMs are slower to turn around their production lines to new product variations than a focused company like Smart. Smart leverages its capability to offer quick turnarounds to OEM customers when needed and then drop ship the product with the OEM brand name to the desired location. Because of its strengths, Smart is service oriented and not intent on owning the technology it manufactures. In fact, in some instances, Smart's customers provide their own parts and design.

Over 90 percent of Smart's business comes from DRAM modules. Right now, the modules are about equally split between EDO and FPM DRAM, with SDRAM starting to make its presence felt. Sixteen megabyte and 32MB are the most popular densities, while 8MB modules are being shipped at an increasingly slower rate.

Smart runs three manufacturing facilities: a 90,000-square-foot facility in Fremont, California, a 25,000-square-foot facility in Puerto Rico, and a 50,000-square-foot facility in Scotland. To facilitate round-the-clock design service, the company operates an additional design center in Bangalore, India. At this time, Smart ships in excess of 1.2 million units a month and is in the process of becoming ISO 9001 certified.

Viking Components

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Viking Components was founded in 1988 by President and CEO Glenn McCusker. Originally, Viking was a memory sales and distribution company, but Mr. McCusker decided that the best way to grow his company was to invest in on-site design and manufacturing capability. In addition to memory upgrades, Viking's product line has also expanded to include PC Cards and connectivity products.

Viking's business plan focuses on the reseller part of the distribution channel. The OEM channel accounts for a small part of Viking's business, and it is an area Viking is interested in expanding. In 1996, Viking's revenue remained flat at an estimated $260 million, and the company experienced a 400 percent increase in the number of units shipped. However, it was a challenging year from a customer service point of view, with customers increasingly looking for price protection.

Viking is in the process of preparing to move to a new company headquarters in Rancho Santa Margarita, California. The new facility will be 130,000 square feet, with 25,000 square feet devoted to manufacturing. The move is expected to occur in the second quarter of 1997. To better serve the European market, Viking has also opened a manufacturing facility in Dublin, Ireland.

Inventory control and quality management are keys to Viking's business model. DRAM is primarily sourced directly from Japanese and Korean manufacturers. Most product is maintained in an unfinished state to increase flexibility. At this time, inventory is turned twice a month.

VisionTek

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VisionTek was founded by Chairman of the Board Allen J. Sutker and Chief Executive Officer Mark Polinsky in 1988 with the mission to "consistently deliver first to the market, value-added peripheral and memory products that meet the highest standards for quality and value." VisionTek's 1996 revenue is estimated to be $300 million, and it experienced unit volume growth of three to four times 1995's level. The distribution channel accounts for about 70 percent of VisionTek's business, with OEM relationships accounting for the remainder. VisionTek has no presence in the retail channel.

In addition to memory modules, VisionTek also designs and offers a full line of peripheral products such as fax/modems, PC Cards, and hard drive and processor upgrades. To help its resellers and corporate customers, VisionTek offers an inventory buyback program and various "Tek" support programs. When dealing with corporate customers, VisionTek's goal is to provide products that extend the life of its customer's computers.

VisionTek's memory modules are designed on-site, in the company's 60,000 square foot corporate headquarters in Gurnee, Illinois. VisionTek also designs and manufactures on an OEM and contract basis. In the OEM channel, VisionTek considers itself a logistics partner, helping with the ups and downs of inventory management. DRAM is sourced primarily through contract relationships with DRAM suppliers, with little spot market use.

Inventory levels are measured in the number of days, with no huge stockpiles of any one memory module.

Growth in 1997 is expected to come from an enhanced sales program targeting major accounts. VisionTek's own direct salesforce will target the accounts, fulfilling a customer's order through the most convenient distribution or reseller channel for the customer.

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Market Analysis

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Spot Market Prices Continue to Fall

After taking some time off at Christmas, we came back to see that the DRAM market is still headed down, with more difficulties on the horizon. The mix problem we discussed a couple of issues ago is still with us, and this is the reason that the lines diverge in Figure 1. We obviously have much better availability (overavailability) for the 1Mx16 extended data out (EDO) than we see for the 1Mx4 fast page mode (FPM), for example. Some find it amazing that FPM currently fetches higher prices than EDO, but this is the nature of supply and demand.

DQ Take

What, then, does Dataquest expect for 1997? Well, it appears from a preliminary look that Christmas 1996 was below expectations, so there should be softness in early 1997. There is still a lot of capacity coming up, which will help keep prices low. Finally, this year is going to see the transition from EDO to synchronous DRAM (SDRAM). This will have a further negative impact on EDO pricing.

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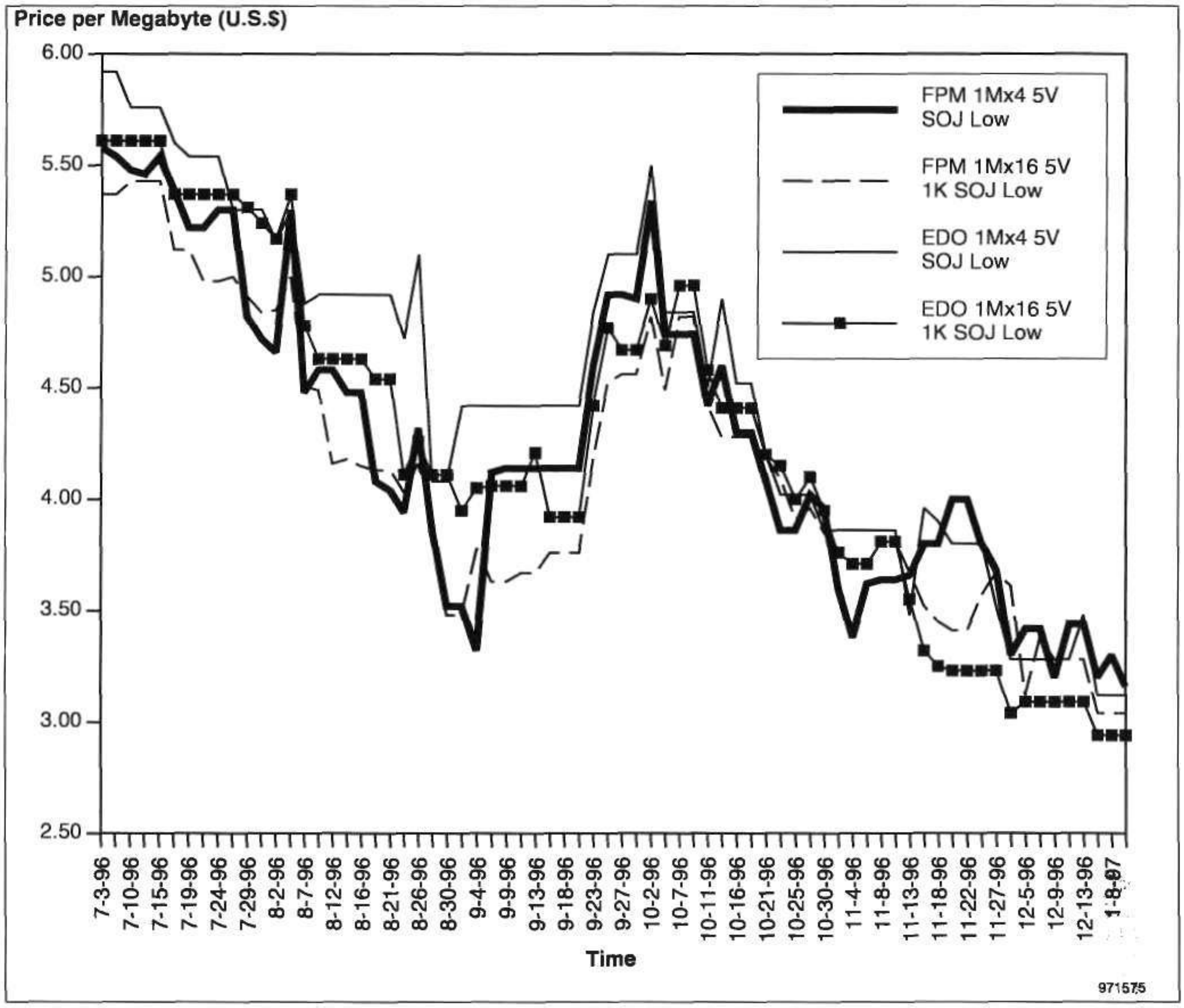
Figure 1
Spot Price per Megabyte for Key DRAMs, July 3, 1996, to January 10, 1997



Source: American IC Exchange and Dataquest (January 1997)

The strength of the dollar against the yen could lead to further price pressure on DRAMs. If this persists medium to long term and the oversupply continues, 1997 could be a bumpy ride for DRAM suppliers!

By Jim Handy, Memories Worldwide, jhandy@dataquest.com
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Rambus Shows Big Numbers

Rambus Inc. disclosed that worldwide revenue from Rambus-licensed ICs exceeded $400 million during 1996.

Rambus IC sales increased exponentially during 1996. Sales of Rambus ICs, which first became available in production in fourth quarter 1995, exceeded $100 million for the first half of 1996, $200 million for the first nine months, and $400 million for the year, driven by the retail availability of Rambus-equipped products like the Nintendo 64 video game machine and the Creative Labs Graphics Blaster MA 302 add-in graphics card for PCs. According to Nintendo of America, 1.6 million Nintendo 64 systems were sold in the United States in the last three months of 1996. Three Rambus-based ICs ship in every Nintendo 64 system.

Rambus reminded us that Intel disclosed in December its intention to use Rambus DRAMs (RDRAMs) for PC main memory starting in 1999, stating that PC main memory applications consume half of the DRAMs shipped.

DQ Take

That's a big number for a little company! But this is why you pay us to analyze the data, so what does the $400 million really mean? So far, the main DRAMs using a Rambus interface are 16Mb devices, and we can assume that these commanded an average price in the neighborhood of $20 over the course of 1996. This would imply that 20 million Rambus DRAMs shipped in 1996, if the only chips that shipped were DRAMs. There's the confusion!

What is much more likely is that all of the Rambus DRAMs that shipped did so in systems that used two RDRAMs per ASIC, as mentioned in the Nintendo portion of this announcement. Dataquest's teardown reports suggest that the ASICs in the Ultra 64 should have carried a price tag of about $25 (averaged over 1996), making the total solution cost in this case $65 (one $25 ASIC and two $20 RDRAMs.) Divide this into $400 million and you get about 6 million solutions, for twice that many, or 12 million, RDRAM ICs. This works well with the statement that 1.6 million Nintendo 64s sold in the United States, and probably an equivalent number sold in Japan. Add to this the Creative Labs and workstation applications, and you can pretty easily come up with 6 million solutions.

Although 12 million DRAMs isn't that big a share of the billion or so 16Mb DRAMs that shipped in 1996, this is still a win for Rambus, and one for which the company has worked hard for a number of years. Still, when we look at DRAM unit shipments, the numbers do not appear anywhere near as significant as the $400 million number originally seems.

By Jim Handy, Memories Worldwide, jhandy@dataquest.com

DRAM/Parallel Processor Hybrid in Research

A recent *Electronic Engineering Times* article reported on a new consortium of more than 20 companies and research centers, founded to develop systems based on parallel-processing random access memories, or PPRAMs, a name for parallel-processing units with on-board memory. The effort will continue for three years. Participants include Kyushu University, which appears to be spearheading the effort, Fujitsu, Fuji, Xerox, Hitachi, Matsushita, Mitsubishi Electric, NEC, NTT, Sanyo, SGS-Thomson, Sony, Texas Instruments Japan, and Toshiba.

The new architecture is claimed to have an advantage over the conventional computer structure, in which a bus connects the MPU and DRAM. On a PPRAM, as many as 1,024 on-chip signal lines can be used to connect the integrated CPU and DRAM at speeds up to about 10 GB/sec. That is far faster than can be obtained with chip-to-chip interface architectures, such as the Rambus architecture. Consortium members claim that system designers can make a system of any scale by combining the necessary number and kind of PPRAM chips.

The technical aspects will be discussed at the 1997 International Solid State Circuits Conference next February. Consortium membership is open; headquarters are at the Institute of Systems and Information Technologies/Kyushu (PPRAM@k-isit.or.jp).

DQ Take

This effort sounds suspiciously similar to an effort we heard of back in the late 1980s. An individual in Connecticut (whose name and company escape us at the moment) took great pains to patent the idea of a single-instruction, multiple-data (SIMD) computer with one processing node attached to each sense amplifier of a DRAM array. SIMD architectures are very efficient at array manipulations, which are required to perform digital signal processing and graphics processing.

As we recall, the gent tried, without any success, to market rights to his patents to DRAM manufacturers worldwide. The target application for his suggested massively parallel IC was 3-D graphics engines. He was probably rejected by some of the same companies represented in the current consortium. Let's hope, for the sake of the consortium, that the patents have expired.

By Jim Handy, Memories Worldwide, jhandy@dataquest.com

More Fab Delays

In addition to the delay in fab construction at the Hitachi/LG Semicon joint venture we mentioned in the last newsletter, we have received news that Siemens has postponed a project, as well as receiving news of a delayed stock offering by a nascent Thai semiconductor company. Japanese newspapers also said that Toshiba and NEC were pushing back fab building plans and that Toshiba and Motorola have put off a decision to build a joint-venture DRAM fab in Japan.

A *Daily Telegraph* report indicated that Siemens might scale back the size of the first phase of its North Tyneside fab in England, in light of memory price softness. The factory is still expected to begin production next spring, but the original run rate of 5,000 wafers per week is expected to be cut in half.

Separately, Submicron Technology of Thailand said it was postponing an initial public offering on the Thai stock market because of poor market conditions but indicated that construction and tooling up at its Cherngsao wafer fab would continue as planned, with funding already in place. Production is to start ramping in June, said Reuters reports.

DQ Take

One exercise we have considered undertaking at Dataquest would be to put the names of all the current fab projects into a hat and to pull them out, one by one, and discuss what market conditions would be necessary to force each of these projects to be abandoned. We see the prolonged price depression in the DRAM market as the driver for these announcements, whereas the very first softening of the market was enough to cause less serious efforts to be postponed (most notably, Micron's Lehigh, Utah, fab and Fujitsu's expansion plans in Scotland). As the DRAM market continues through its current depressed cycle, we expect to see more announcements of this sort.

By Jim Handy, Memories Worldwide, jhandy@dataquest.com

AMD Announces Financial Results

Advanced Micro Devices announced financial results for its fourth quarter, which ended on December 29, 1996. For the fourth quarter of 1996, AMD reported a net loss of $21,243,000 on sales of $496,868,000, which amounted to a loss of $0.15 per share. Sales for the fourth quarter of 1995 were $595,178,000, which resulted in net income of $9,344,000, or $0.07 per share. In the prior quarter, AMD reported sales of $456,862,000, which resulted in a loss of $38,362,000, or $0.28 per share.

Revenue for 1996 amounted to $1,953,019,000, which resulted in a net loss of $68,950,000, or $0.51 per common share. In 1995, AMD reported revenue of $2,468,379,000 and net income of $216,326,000, or $1.57 per common share on a fully diluted basis.

Highlights:

- AMD's book-to-bill ratio exceeded 1:1 for the first time since the second quarter of 1995.
- Revenue growth over the third quarter came primarily from Microsoft Windows-compatible microprocessors.
- AMD is sampling the K6 MMX processor to a broad customer base.

DQ Take

The financial market responded favorably to AMD's earnings announcement. Two reasons for the favorable response were that AMD beat earnings estimates and that the outlook for its K5 and K6 microprocessors is positive. But what Dataquest's Memories Worldwide program is interested in is AMD's flash memory devices. One thing Dataquest found interesting is that AMD didn't disclose any flash memory information in its announcement. Flash memory is a significant part of AMD's revenue, and has been a part of past earnings announcements. AMD's strong position in the flash memory market (ranked second behind Intel in Dataquest's 1995 market share) has helped provide AMD with the resources it needed to work on its microprocessor efforts. However, flash average selling prices came down in 1996, and this did impact AMD to the point that Dataquest expects AMD's flash revenue to be relatively flat in 1996. AMD's flat revenue contrasts with the overall positive growth in the flash market, which Dataquest estimates to be about 45 percent in 1996. These points make Dataquest wonder if AMD is facing difficulties in the flash area.

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Dataquest's Tactical Memories Newsletter
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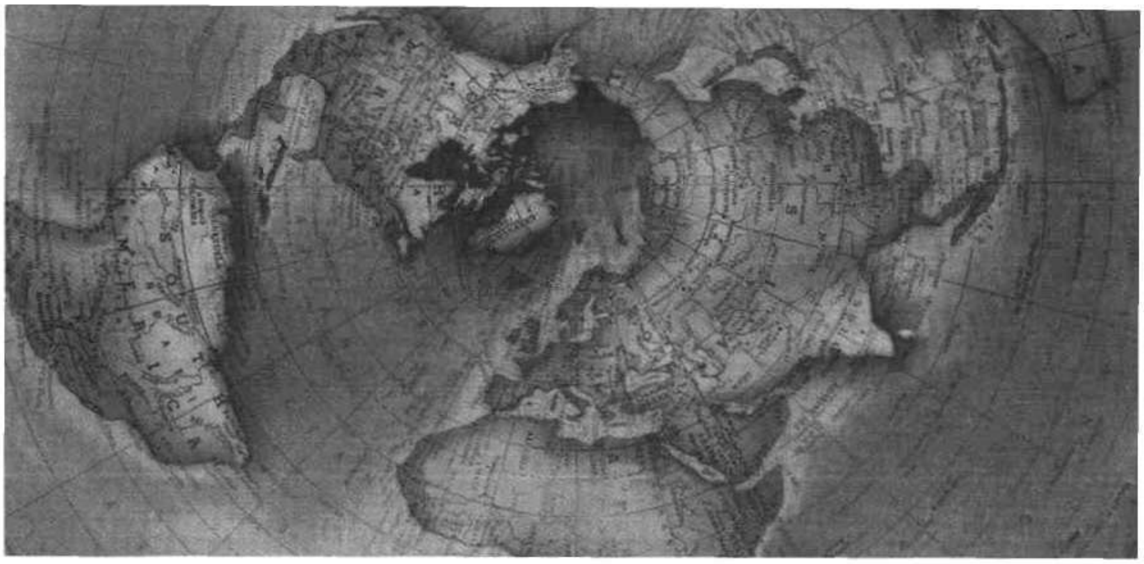
Perspective



Memories Worldwide

Vendor Analysis

Kingston Technology—King of the Memory Module Hill

Abstract: *Kingston Technology, the largest third-party memory module manufacturer, has enjoyed enormous growth since its inception in 1987—from revenue of $13 million in 1988, its first full year, to revenue of $1.3 billion last year. Will it continue this aggressive growth or is 1996's flat revenue an indication of things to come? Kingston's position as the largest memory module manufacturer comes from its dominance of the distribution channels selling to America's Fortune 1000. In this Perspective, Dataquest will look at Kingston's channel strategy and whether it can continue its aggressive growth.*

By George Iwanyc

A Year of Change

Third-party memory module manufacturers buy DRAM directly from DRAM manufacturers or on the open market, install them into Single In-Line Memory Modules (SIMMs), or Dual In-Line Memory Modules (DIMMs), and then sell the memory modules into aftermarket channels or to OEMs. The entire third-party memory module market by Dataquest's estimate is between $4 billion and $6 billion. A nonexhaustive listing of third-party memory manufacturers is presented on the next page. Fountain Valley, California-based Kingston Technology is by far the largest of the third-party memory module manufacturers with revenue of $1.3 billion in 1995. Kingston has an image and strategy of supporting the high-end, machine-specific memory module market, and avoiding generic, commodity modules. Kingston also sells processor, networking, and storage upgrades, but these products are completely overshadowed by memory modules, which account for more than 80 percent of Kingston's revenue. While 1996 revenue is expected to be flat, Kingston expects a threefold increase in unit shipments. Last year's flat growth is a stark contrast to Kingston's near 60 percent growth from 1994 to 1995, and Kingston's own early projections of

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over $2 billion in revenue in 1996. When taken within the context of 1996's dramatic DRAM price slide, flat revenue in 1996 is welcome. But it does bring up the question: Will Kingston return to its historical explosive growth, or has it reached the start of a mature growth pattern instead?

The following is a nonexhaustive list of third-party memory module manufacturers. With the exception of I.O. Data and Melco, which are based in Japan, all companies are headquartered in the United States.

- Camintonn/Z-RAM
- Centon Electronics
- Century Micro Electronics
- GoldenRAM
- I.O. Data
- Kingston Technology
- MA Laboratories
- Melco
- PNY Electronics
- Simple Technology
- SMART Modular Technologies
- Southland Micro Systems
- TechWorks
- Unigen
- Viking Components
- VisionTek
- Wintec Industries

Two recent events, Softbank's acquisition of Kingston and Kingston's entrance into the PC OEM channel, are pivotal for Kingston's return to aggressive growth. Both are clear indicators of where Kingston is looking for growth, and, if successfully leveraged, offer Kingston the possibility of returning to its impressive growth pattern.

Softbank's Acquisition of Kingston

The acquisition of Kingston by Softbank is surprising. Kingston seemed to be staunchly proud of its independence, and appeared to have strengths that would see it past all the turmoil in DRAM pricing, and leave the company stronger as a result of the current DRAM IC oversupply. DRAM price volatility, both up and down, should help Kingston's position as market leader. Price increases indicate DRAM availability is an issue. Kingston is one of the top 10 DRAM purchasers in the world, and its large buying power helps the company source product much more quickly and steadily than its smaller competitors in times of tight supply. On the other hand, rapid price erosion, as experienced in 1996, creates a situation where Kingston can expand market share by leveraging its strong brand image and strategically lowering prices. Price stability, actually slow price erosion, offers little to Kingston. DRAM availability isn't an issue and there is nothing extremely difficult about manufacturing today's standard SIMMs to give one module manufacturer a significant competitive advantage over another.

What is perhaps the most peculiar part of this acquisition is the fact that Kingston, an extremely financially conservative company, has agreed to be bought out by a company that some say is spending dangerously on takeovers. Some financial analysts have said that Masayoshi Son, the president of Softbank, is placing too high a reliance on bank loans and a projected price/earnings ratio of about 70 times to finance an acquisition binge. Softbank's strategy appears to be that its acquisitions will continue to grow and be profitable, and that high-priced stock can be used to raise additional capital.

Kingston, on the other hand, was founded by two men, John Tu and David Sun, with $7,000 of savings, and has been financed for its entire nine years without the help of a bank loan, capital infusion, or equity offering of any kind! The company even owns its own headquarters building outright. These two entrepreneurs traded their ownership of Kingston for $1.1 billion in cash, and $425 million in Softbank stock. Softbank is financing the acquisition from its cash reserves and bank loans, raising its bank debt, already at $2.4 billion (on about $1.5 billion in revenue) up by an additional $750 million.

What does Softbank gain from these takeovers? President Masayoshi Son has a penchant for paying top dollar to acquire industry leaders. He says that the acquisitions that he has put together to date, including COMDEX and Ziff Davis, over 30 percent of Yahoo!, and CyberCash, are aimed at making the company "own the infrastructure of the PC industry." About the issue of the company's mounting debt, Son said that "the company will be free of debt in about seven years," based on solid group earnings.

How does this takeover help Kingston? Kingston hopes to immediately leverage Softbank's strong distribution channels in Japan. Interestingly enough, Softbank's acquisition mushroomed out of Kingston approaching Softbank to ask the Japanese company to distribute Kingston's memory modules in Japan, where it had virtually no presence. The leading memory module companies in Japan are Melco and I.O. Data. At this time, four months after the acquisition, Kingston is not yet a significant player in Japan.

In addition to memory modules, Melco and I.O. Data also sell peripheral computer equipment. Softbank will probably use Kingston's Japanese operation in a similar way, not only as a supply base for memory modules, but also for other PC peripheral equipment. Kingston already sells processor, networking, and storage upgrades so it is possible for Kingston to support this type of business.

Kingston may also be able to expand its market share in Europe. Currently, 30 percent of Kingston's revenue comes from Europe, a hot area of interest for module manufacturers because of its market potential. Simple Technology, SMART Modular Technologies, and TechWorks have established European manufacturing facilities within the last year, and most major module manufacturers have at least one sales office in Europe. Europe offers a number of challenges for U.S. module manufacturers such as warehousing, duties, logistics, accounting differences, and language barriers. While Kingston and its competitors are faced with the same challenges, the Softbank acquisition offers Kingston the opportunity to leverage a large salesforce that is already present throughout Europe. While this opportunity isn't as golden as Japan, Kingston should enjoy a significant salesforce advantage over its competitors.

Third-Party Channel Profile

Before addressing Kingston's second growth target, the PC OEM channel, a brief examination of the traditional third-party module manufacturer business model is in order. The following are three distinct channels for third-party module manufacturers:

- Distribution
  - Commercial, industrial, and specialized distributors—This group targets value-added resellers (VARs), large corporations, retailers, systems integrators, and master distributors.
  - Master resellers/systems integrators (formerly known as aggregators)—This group has a split business model, with half of its business operating as a distributor and half as a large corporate reseller/systems integrator.
- PC OEMs and other system OEMs
- Retail

As mentioned earlier, third-party memory module manufacturers source DRAM, install them on a module, and then sell the memory modules to aftermarket channels. For the majority of third-party manufacturers, the aftermarket means the distribution channel and the customer is America's large corporations. There is no one approach for memory module manufacturers in the distribution channel. Some specialize by product lines—for example, memory modules for printers—others concentrate on a type of distributor, and others champion service, quality, or price.

The PC OEM and system OEM channel is characterized by third-party module manufacturers that specialize in providing manufacturing services for OEMs. SMART Modular Technologies is an example of a module manufacturer that focuses on the PC OEM channel. The keys to success in this channel are quick and flexible manufacturing. The higher margins that this channel offers is one of the reasons it is attracting the interest of the larger third-party module manufacturers.

The retail channel entails selling through retailers, like Wal-Mart and Best Buy, or directly to the end user, via mail order or the Internet. PNY Electronics and Centon Electronics are two memory module companies with significant retail presence. The retail channel is particularly harsh on module manufacturers because of price pressure. Payment methods, forced buybacks, and stocking charges are all part of doing retail business. Because of the natural tendency of DRAM to decrease in price, these normal attributes of the retail channel become very difficult to manage. There is also very little brand loyalty in this channel, aggravating the problem further. Because of these difficulties, the retail channel is not a popular target for growth.

Kingston Enters the PC OEM Channel

Kingston's prominence among memory module manufacturers comes from its domination of U.S. distribution channels. Kingston's dominant position in distribution is in contrast with its position in the PC OEM and retail channels where it has little or no presence. Kingston had a first mover advantage in the distribution channel, having entered this channel before any significant competition. This allowed Kingston the opportunity to develop tight working relationships with its distribution and reseller customers, without having to worry about cutthroat price competition. Because Kingston is already so well positioned in the U.S. distribution channel, it is difficult to forecast above-average growth in this channel. This constraint explains why Kingston has targeted international expansion as the best way of expanding this line of business. It also explains why Kingston is interested in expanding its presence in the OEM channel.

In November, Kingston announced that it was selected by Toshiba America Information Systems (TAIS) as Toshiba's official supplier of memory upgrades for its entire line of notebook and desktop personal computers. Under the agreement, Kingston will design and manufacture memory modules to the exact specifications of individual Toshiba systems. These modules will be cobranded with the Kingston brand and Toshiba's Noteworthy brand and sold through both companies' current distribution channels. This is a significant announcement for Kingston. Not only does this agreement with Toshiba significantly augment Kingston's existing memory business, it will help Kingston penetrate the PC OEM channel.

The most surprising part of this announcement is the cobranding. It seems logical that a PC manufacturer's own brand name would be the best at selling its own aftermarket modules. PC OEMs have worked with third-party module manufacturers for some time, but normally the third-party source is invisible to the end user. Kingston and Toshiba are entering this relationship as equally visible partners, symbolized by the cobranding of the memory module. This indicates the strength of Kingston's brand image and company reputation.

Third-party module manufacturers, whether visible or invisible, have something important to offer PC OEMs. Toshiba believes this agreement will increase efficiencies, resulting in better availability and more competitive pricing on memory upgrades for Toshiba customers. Where will these efficiencies come from? In the case of Kingston, its business model is clearly oriented to accommodate quick manufacturing and delivery cycles. And Kingston's long-standing relationships with top-tier DRAM suppliers enables flexibility during changing market and supply conditions.

Working with Toshiba should also help Kingston to source DRAM. Not only is Toshiba the premier notebook manufacturer, it is also the world's fifth largest manufacturer of DRAM (according to Dataquest's 1995 market share ranking). While Toshiba's semiconductor and computer companies are separate entities, Kingston's relationship with TAIS may be helpful during the next DRAM allocation period.

PC OEMs understand the importance of the aftermarket memory module business, but there are a number of pitfalls for those that choose to run their own aftermarket business—the need to manufacture modules for discontinued computers, small production runs, tremendous price pressure, and logistic nightmares, to name a few. Dataquest believes that more PC OEMs will team up with third-party manufacturers, but it's unlikely that the team-ups will use cobranding as Toshiba is doing with Kingston.

In a strange way, Kingston, and all of the larger third-party manufacturers, already support PC OEMs by providing OEM specific modules with unique part numbers. Some PC OEMs provide module manufacturers with designs or product specifications to work from, but many provide no direction. This forces the module manufacturer to reverse engineer a unique module. A module manufacturer with a well-exercised reverse engineering program can have a PC specific memory module available within weeks of getting a new computer. However, situations do occur where early production modules often aren't perfect matches for a specific computer. This in turn creates a touchy situation for the PC OEM. Many computer users are ignorant of whose memory they have because their name brand computer was packaged with aftermarket memory at the time of sale. When problems occur, they complain directly to the PC OEM, forcing the OEM to answer for the aftermarket module. Even if PC OEMs choose to not team up with a third-party module manufacturer, a more open relationship may help both parties.

Dataquest Perspective

What does all this really mean? Kingston, as well as its competitors, has identified two paths for near-term growth, international expansion, and the OEM channel. Both of these opportunities aren't new, but they are relatively undeveloped from the perspective of U.S. module manufacturers. Kingston should begin to gain market share in Japan in 1997, but it won't be uncontested. Melco and I.O. Data will ensure that. Europe is a great opportunity, but it is one that everyone has identified. Adding to the difficulty is competition from DRAM suppliers who ship DRAM into Europe as modules to avoid tariffs. The OEM channel may be the best opportunity for the industry as a whole, but Dataquest wonders how many PC OEMs will be willing to team up with the same module company. The key to this market is service, and Dataquest anticipates that every PC OEM will insist on being the No. 1 priority of any module company it works with.

Kingston is an important indicator for what is happening in the module world, not only because it is the market leader, but because it is also a company that many other module companies model themselves after. One encouraging point for the memory module industry as a whole is that module companies are still able to enjoy growth without having to take it from each other.

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DRAM Transitions and Their Impact on Modules

Market Trends

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Chapter 1

Executive Summary

The DRAM industry seems to be in perpetual transition, but 1997 shows promise of exceeding the normal density or technology transition. Hot on the heels of the 4Mb-to-16Mb density transition, some DRAM manufacturers are ramping for the transition from 16Mb to 64Mb. From a technology standpoint, extended data out (EDO) DRAM is soon to give way to synchronous DRAM (SDRAM), and voltages are moving from 5V to 3V.

While these density and technology transitions are happening, DRAM pricing is in the midst of a nervous calm. During 1996's DRAM price fall, the DRAM spot market consistently offered the lowest prices. In 1997, spot market pricing has vacillated around contract pricing, indicating a DRAM market in balance. In reality, the market is still faced with overcapacity and the fact that the current price stability is tenuous.

What do all these transitions mean for DRAM modules? The switch from EDO DRAM to SDRAM will force the transition from single in-line memory modules (SIMMs) to dual in-line memory modules (DIMMs). The transition to 16Mb DRAM offers the potential for a sustained period in which 16Mb DRAM is the obvious low-cost DRAM. This in turn offers original equipment manufacturers (OEMs) the option of not using modules and soldering down base memory, saving costs by avoiding the use of a connector and module. OEMs drive the implementation of these module transitions, while DRAM manufacturers enable them. In this report, Dataquest examines DRAM market conditions and the reactive impact they have on DRAM module trends.

Report Structure and Content

There are three sections in this report. The first examines the effects of DRAM density transitions on module production and PC main memory sizes. The second examines DRAM technology transitions and the impact these transitions have on module technology and production. The final section looks at DRAM module manufacturers and how the DRAM transitions impact them.

Project Analyst: George Iwanyc

Chapter 2
Effects of DRAM Density Transitions

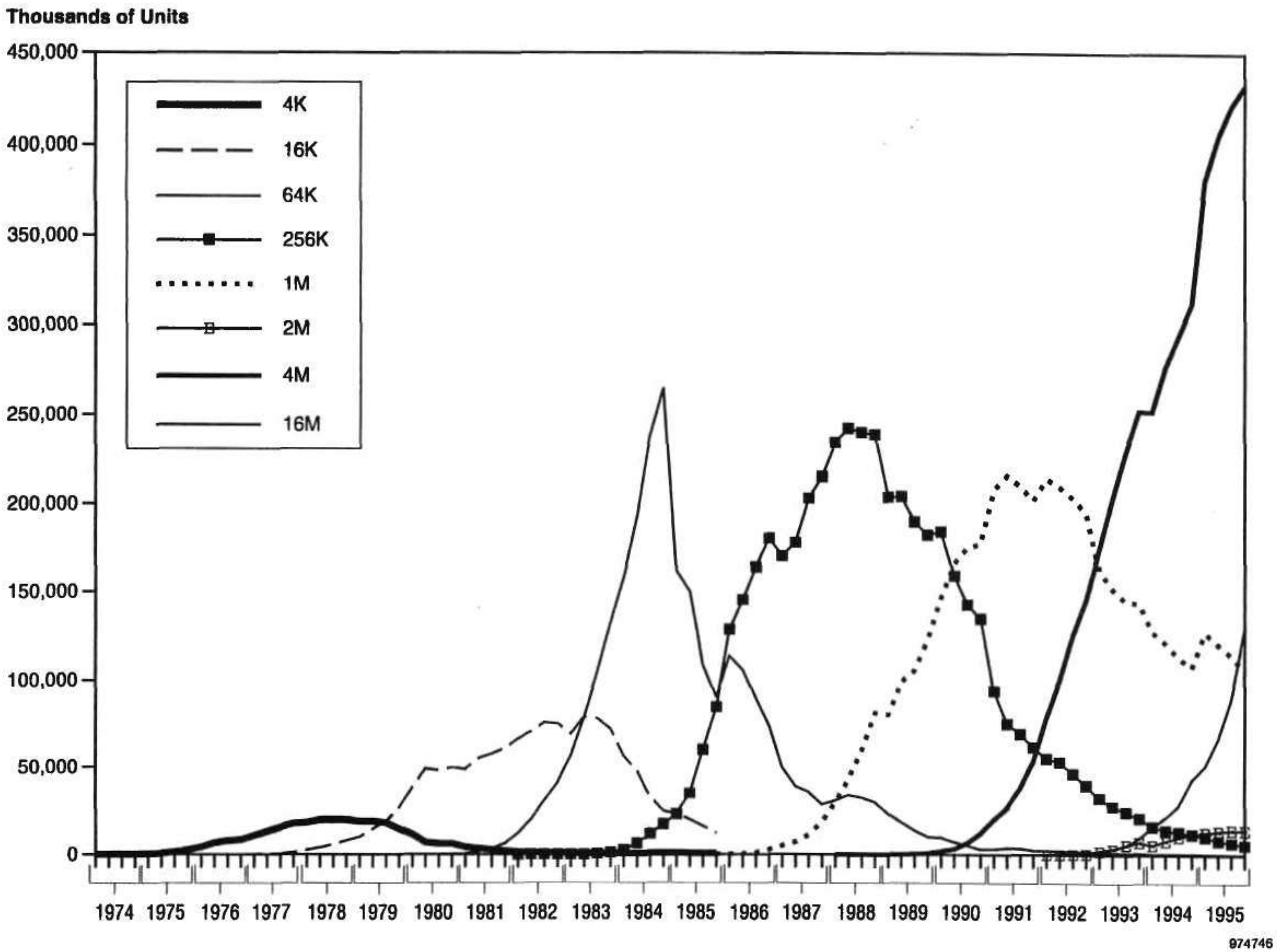
DRAM ICs follow a predictable trend, where the density of the leading chip increases by a factor of four every three years. In 1997, the majority of devices shipped will be 16Mb DRAMs, whereas three years earlier, in 1994, the leading density was 4Mb, and in 1991, the 1Mb DRAM was the sales leader. The shift from one density to the next is driven mainly by the maturation of leading-edge DRAM production processes. This continual density increase drives down the price per megabyte of memory and has an interesting effect on the DRAM module market.

Figure 2-1 shows unit shipments of DRAM ICs by density from 1974 through 1995. Transitions from one density to another are relatively sharp, and a predictable life cycle repeats itself for each generation of DRAM. During the transitions from one density to another, adjacent densities compete with each other for the same sockets. For example, during the transition from the 4Mb to the 16Mb density in 1996, the two devices competed in price against each other. The 16Mb device has four times as many bits (or megabytes) as the 4Mb density, so any 16Mb price that is lower than four times the 4Mb's price makes the 16Mb chip more economical per megabyte. In 1994, when the manufacturing processes for the 16Mb chip were much less mature, the price per megabyte for 16Mb chips was significantly higher than that for 4Mb DRAMs, and the 4Mb chip had a cheaper price per megabyte than any of its predecessors, so the 4Mb was in a stable period in which it was the most cost-effective DRAM density.

These two phases in a DRAM's life, the one in which two densities compete for the cheapest price per megabyte and the one in which one density alone is the most cost-effective, are very important to the overall DRAM module market. During the phase in which one density is the most cost-effective, there is no reason for the base memory of a system to switch from one density to another, so PC OEMs can design their motherboards to have the base memory configuration soldered directly onto the motherboard. Sockets are provided for upgrades, but the socket used for the base memory configuration is avoided, and cost savings can be realized.

During the transition phase in the DRAM life cycle, where two DRAM densities are competing for lowest cost per megabyte, the PC OEM's purchasing department is confronted with a difficult question of which DRAM to procure. The transition will take a number of quarters. In order for the OEM to be able to take advantage of the lower costs, modules are used during this time for the base memory configuration. This means that the OEM adds to the motherboard's cost by adding a socket, but this socket gives the purchasing department more flexibility, because it can purchase the least-expensive modules of a given density, no matter which DRAM chips are used to populate these modules. At this point, there is a surge in module unit volumes, and most DRAM manufacturers ship the bulk of their product in modular form.

Figure 2-1
DRAM Quarterly Unit Shipments, 1974 through 1995



Source: Dataquest (July 1997)

Testing the Cost Savings Model

Since the transition from 4Mb to 16Mb DRAM was recently completed, one would expect that a stable period of 16Mb dominance would follow. Based on the cost savings model, this would also drive the transition away from modules to soldered-down base memory. The module transition has not occurred. Does this indicate that the model is changing? It is unclear whether the model has changed, because the normal sharp density transition did not occur. The 4Mb-to-16Mb transition took longer than expected, and some DRAM manufacturers are already ramping for the next transition from 16Mb to 64Mb DRAM.

The cost savings model holds only when there are density transitions bridged by stable periods of single-density cost leadership. Sixteen megabit DRAM will be the highest-volume DRAM shipped in 1997, but current 16Mb pricing does not indicate it will remain the clear lowest cost per megabyte DRAM when compared to some 64Mb price projections.

What is driving the expectation of a short 16Mb product life cycle? In 1996, DRAM manufacturers suffered a 39 percent decline in revenue, but profit margins for the year were supported by high average selling prices (ASPs) in the first quarter of 1996. In 1997, DRAM manufacturers' revenue is expected to decline 5 percent, but profit margins are expected to be lower than those experienced in 1996. A switch to 64Mb DRAM provides a high-margin product that would in part alleviate the anticipated lower profit margins for some manufacturers.

Despite the discussion of the mainstream transition to 64Mb DRAM, reality shows the transition is hampered by the current low yields on these devices. This means that 16Mb unit shipments will outpace 64Mb production for the rest of 1997 and well into 1998. Once DRAM companies achieve 60 percent to 65 percent yields on 64Mb devices, 64Mb DRAM will displace the 16Mb device as the profit generator. As with profits, companies dislike revealing yield rates, so the best way of gauging these trends will be to monitor for the five-to-one and four-to-one price crossover from 16Mb to 64Mb DRAM.

Regardless of the true length of the 16Mb life cycle, the uncertainty regarding the lowest cost per megabyte DRAM eliminates the clear benefit to OEMs of switching to soldered-down base memory. Ironically, a short 16Mb life cycle also lowers the higher profit margin expected for 64Mb DRAM, eliminating the benefit DRAM manufacturers hope to obtain from the transition.

Granularity

Past density transitions offered relatively small increases in absolute amounts of memory. For example, the transition from 4Mb to 16Mb DRAM was a transition of half a megabyte to 2MB. Beginning with the 16Mb-to-64Mb transition, but especially with transitions after that, the typical four times capacity increase in DRAM density results in a significant absolute increase in memory size. For example, the transition from 64Mb to 256Mb is an increase of 8MB to 32MB of memory. A 168-pin x64 DIMM configured with 64Mbx16 DRAM results in minimum module increments of 32MB; with a 256Mbx16 DRAM, this increases to 128MB.

Potential impacts on DRAM module production depend on PC performance and the related main memory size requirements during these transitions. One possible impact is that the large DRAM granularity enables PC OEMs to cost-effectively solder down all base memory, eliminating the need for base memory modules. Another possibility is that large base memory configurations will eliminate the current DRAM module aftermarket structure of point-of-purchase customized configurations and follow-up upgrades.

The problem with the solder-down scenario is it ignores the price volatility of DRAM, which forces PC OEMs to carefully plan base memory increases and whether they should solder down memory. Changes to the module aftermarket may occur, but software application memory requirements will likely grow and compensate for larger main memory sizes. This will support some aftermarket business servicing the installed base of PCs.

128Mb DRAM

One response by DRAM manufacturers to the granularity issue of the 64Mb-to-256Mb density transition is a half-step solution, to 128Mb. A x64 DIMM manufactured with 128Mbx16 parts results in a minimum module increment of 64MB, a reasonable module size relative to the time period concerned. A half-step increment to 128Mb also gives DRAM manufacturers a higher margin product to offset the anticipated short period of high profitability on 64Mb DRAM.

The three-year, four-times-increase DRAM product life cycle is driven by economics. A cost-effective 128Mb DRAM most likely would be designed with the same design rules as a 256Mb DRAM, but it would come at a die size penalty when compared on a bit-size efficiency basis. The implementation of a full-production 128Mb DRAM requires a profitability period to follow the original investment in research and development and production equipment. This implies that the three-year, four-times-increase product life cycle would have to lengthen for a two-times solution to offer sufficient return of investment.

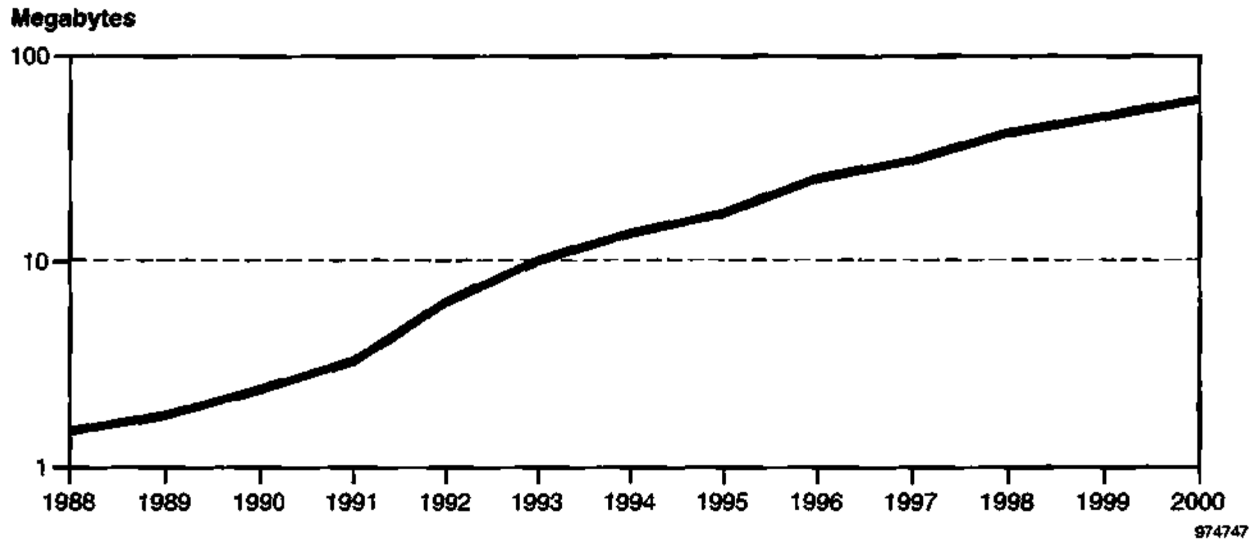
Since PC base memory growth historically has not kept up with the pace of DRAM density growth, a lengthened product life cycle is conceivable (the longer 4Mb life cycle may be foreshadowing this occurrence). However, it is likely that the four-times-increase life cycle would have to nearly double to six years to offer a two-times-increase solution ample time to provide the required return on investment. This indicates that the current environment would not support a 128Mb density, but it may support the next half-step increment, which would be a 512Mb device.

It is worth noting that a 128Mb equivalent device does not require a single 128Mb density die. IBM recently announced a stacking technology that enables two IBM 64Mb parts to be stacked on a module using normal pick-and-place equipment. This stacking technique provides the equivalent of a 128Mb density device. Another option is for manufacturers to offer two 64Mb dice packaged together in one molded package.

Main Memory Size

Figure 2-2 shows Dataquest's estimates of main memory sizes from 1988 through 2000, from Dataquest's *DRAM Supply/Demand Quarterly Statistics*. Main memory size expands at a rate of 30 percent per year.

Figure 2-2
PC Main Memory Sizes, 1988 through 2000



Source: Dataquest (July 1997)

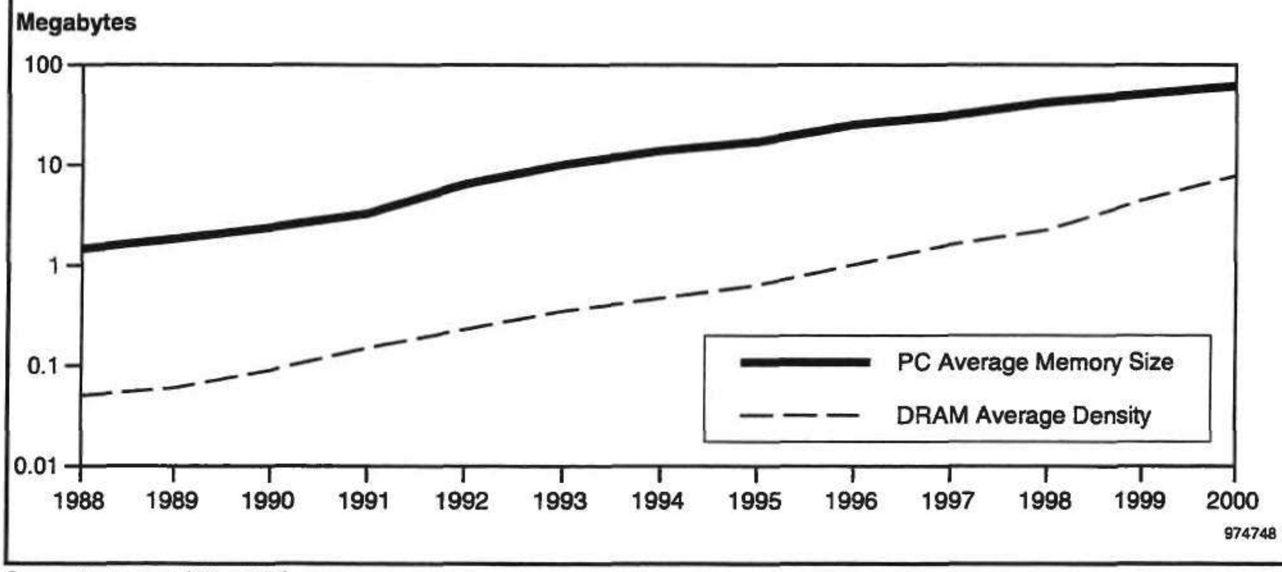
Figure 2-3 shows the average density of DRAM ICs over the same period. The main memory size increases at a rate of 30 percent per year, but the rate of memory per IC increases far more sharply, 56 percent per year. This means that the number of DRAM chips in a system should be expected to decrease slowly, at a rate of 17 percent over time, as shown in Figure 2-4.

This effect affects the types of DRAMs required on the market. The first impact was felt in 1995, when the 16Mb DRAM was expected to start to displace the 4Mb part. This displacement was slowed because DRAM manufacturers had experience manufacturing only 1-bit-wide and 4-bit-wide DRAMs, and the version of the 16Mb density that was needed was a 16-bit-wide device. The transition from a 4-bit to a 16-bit width was slowed for about a year because of the manufacturing difficulties faced by most DRAM manufacturers.

The decrease in number of DRAM ICs used is coupled with a need for increased bandwidth, a problem that in past years was often approached through the use of more ICs put together on a very wide bus. This approach is not feasible for the future because the number of DRAM ICs will be decreasing in the system. For this reason, approaches are being tried that will increase the data output rate of each DRAM chip without forcing the DRAM ICs to go to 64-bit-wide and 256-bit-wide buses.

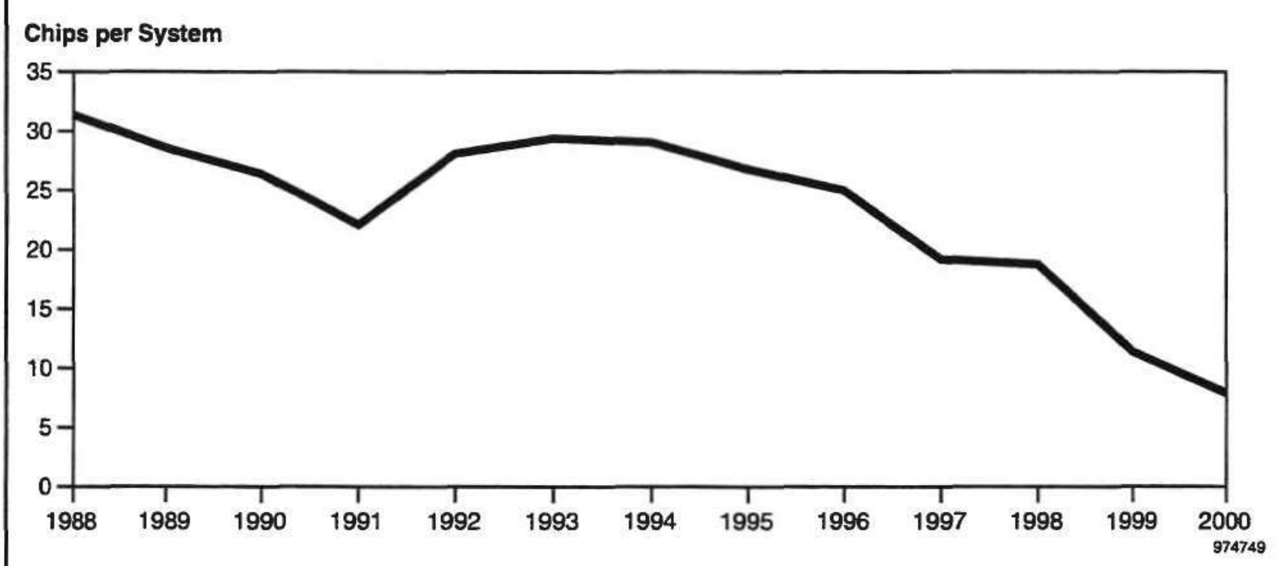
One argument for the 128Mb device is that it can be manufactured in a x16 width, where a 256Mb device ideally would be produced in a x32 width. With next-generation DRAM, like Rambus, the issue of increasing DRAM width requirements changes because of the likely implementation of a narrower bus. For example, the current Rambus DRAM uses an 8-bit bus. This impact of next-generation memory is discussed later in this report.

Figure 2-3
PC Main Memory Sizes Compared to Average DRAM Chip Density, 1988 through 2000



Source: Dataquest (July 1997)

Figure 2-4
Average Number of DRAM ICs Required in a PC, 1988 through 2000



Source: Dataquest (July 1997)

Windows 95 and NT Memory Requirements

Clearly, Microsoft responded to the memory crisis that formed at the end of 1993. Although arguably now too late, given the current memory climate, Windows NT 4.0 runs itself and applications happily in just 16MB of system memory. We were able to load Word, Excel, and PowerPoint simultaneously and switch between them without noticeable delays, even with relatively large files open. Indeed, NT seems to be better than Windows 95, which struggles when many applications are open in a 16MB configuration.

Although this may appear to be bad news for memory manufacturers, Dataquest does expect NT systems to be configured with 32MB as standard; 16MB is an awkward configuration because it uses double-sided SIMMs (which can cause complications in some systems) or consumes all four SIMM sockets. Therefore, a 32MB base configuration leaves the door open for upgrades to 64MB later in the life of the product. Note that, with the recent precipitous decline in memory prices, 64MB configuration prices are the same as last year's 16MB memory configurations. Now that the memory capacity brakes are off, we believe that application developers will regain their appetite for memory, so memory demand will continue to grow.

Notebook manufacturers will find 16MB to be a viable base configuration, using eight 16Mb DRAMs in a x8 configuration, with Windows NT 4.0. A 32MB base configuration is less attractive because it doubles the number of memory devices required. Dataquest believes that 32MB will become the base configuration with the availability of 64Mb x16 DRAMs.

Build-to-Order PCs

One issue that may change the relationship between density transitions and the cost-driving switch from base memory modules to soldered-down base memory is the PC build-to-order manufacturing model. PC OEMs compete in a market where gross margins are about 20 percent. Tight margins coupled with the trend of ever-shortening product life cycles force PC OEMs to minimize the time between taking delivery of components and delivering the finished product to the customer. At the same time, this strategy forces an increase in the number of inventory turns by the PC OEM that takes place in any one period. These facts are important to profitability for the following reasons:

- The value of components, such as DRAM, typically decreases. The loss on inventory depreciation while in the PC OEM's possession is minimized if the OEM holds on to the inventory for a shorter time.
- Each time the inventory turns, the PC OEM makes a gross margin, which translates into a higher return on investment.

From the inventory turn perspective, the best model to adopt is build-to-order. In this model, the PC OEM builds product only when it has received an order from the customer. Inventories for components are kept to the minimum level appropriate for demand, depending on the price volatility of the component in question. The attraction of the build-to-order procurement process for end users is that they are able to specify exactly what they want and are not limited by what has been decided for them.

Direct and Indirect PC OEMs

For direct channel PC OEMs, such as Dell Computer Corporation and Gateway 2000 Inc., the build-to-order business model has been extremely successful. The unit market share gains made by Dell and Gateway 2000 in 1996 are very noticeable and cannot be ignored by the indirect players, like Hewlett-Packard Company and IBM, that deliver their product through distribution channels.

One approach to reducing the risk of building up inventory for indirect PC OEMs is to try to move the final assembly of the product closer to the end user. In this model, resellers hold limited inventory of semifinished goods or parts. When the distributor receives an order, it finishes the product using PC OEM-approved components. The crucial components in terms of price erosion are the hard disk, memory, and CPU. Another approach for indirect PC OEMs is to develop their own version of an internal build-to-order program that blends the benefits of this model with the distribution channel structure.

As more PC OEMs move to a build-to-order-based model, the configuration flexibility that DRAM modules offer outweighs the potential cost savings of soldered-down base memory. The greater benefit of DRAM modules would be especially applicable to indirect manufacturers that use channel assembly. In this case, the PC OEMs could ship their PCs with no memory and have DRAM manufacturers drop ship DRAM modules to the reseller.

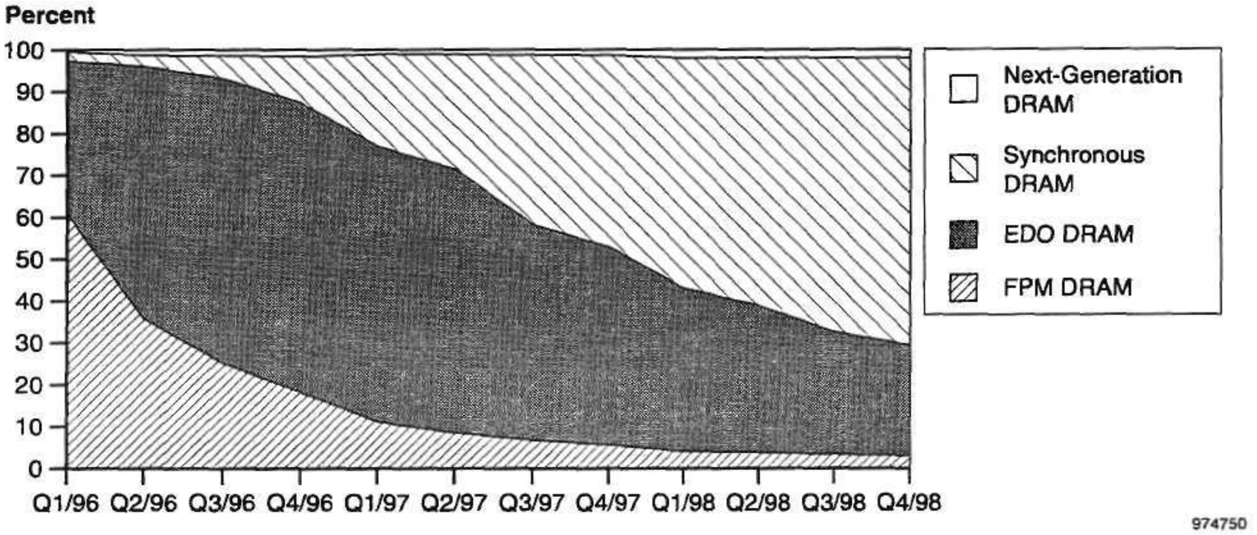
Another trend emerging from the build-to-order model is the partnering of PC OEMs and module manufacturers. At one time, it was common for PC OEMs to manufacture their own modules in-house. Now PC manufacturers are using DRAM manufacturers, electronic equipment contract manufacturers, and third-party manufacturers to do module assembly. The impact this is having on module production is addressed in Chapter 4, "Module Manufacturers."

Chapter 3

Effects of DRAM Technology Transitions

There is a wide range of emerging DRAM interface alternatives. All of these emerging interfaces will cause some discussion when it comes to DRAM module support, but few look like sure winners. Today's interface standard for main memory applications is EDO, also known as hyperpage mode, but SDRAM, which is a JEDEC-standard interface, should become the main memory standard by late 1997 or early 1998. Figure 3-1 shows Dataquest's forecast for DRAM I/O transitions. EDO was a relatively simple change from the previous main memory standard, fast page mode (FPM), and it could be accommodated by the standard fast page mode module pinout. The switch to SDRAM is more difficult from a manufacturing perspective, as well as requiring a transition to the DIMM module format.

Figure 3-1
DRAM I/O Transition, 1996 to 1998



Source: Dataquest (July 1997)

Synchronous DRAM

SDRAM is an attempt to gain consensus within a standards body—the Electronic Industries Association (EIA) and the Joint Electronic Device Engineering Council (JEDEC)—for an improved evolution of the standard DRAM interface, without the concerns accompanying proprietary architectures, intellectual property, and the like.

There are two main advantages of an SDRAM architecture. First, the generation of pulses for RAS, CAS, and WE is very difficult at high clock frequencies. To ensure the absence of false writes or erroneous addressing, the system designer is forced to slow the entire memory system down. An SDRAM architecture removes the need for these inputs to be shaped as pulses and allows them to be sampled within a narrow window of the rising edge of a high-speed system clock signal. While this is by no means a trivial task, it is far more simple than forming several clean, well-timed pulses. The effect is that the entire system can be run at a higher speed more easily if a synchronous interface is used.

The second advantage of the synchronous approach is that the definition supports the use of bursts of data to harness some of the inherent high bandwidth locked within the DRAM chip itself. DRAMs are usually very wide internally, meaning that every access involves the reading or writing of thousands of bits at a time. In asynchronous DRAMs, this bandwidth is unavailable for the user, restrained by the bottleneck presented by the narrow pinout. In the SDRAM's burst mode, a new piece of data from the thousands of accessed bits can be transferred every clock cycle after the original address has been accessed.

The EDO-to-SDRAM Transition

One way of looking at DRAM technology transitions is determining whether the change is evolutionary or revolutionary. The transition from FPM to EDO was an evolutionary change. DRAM manufacturers could make this change with a bonding or laser etch option late in the production process. PC OEMs did not need to drastically change their motherboard designs (it did require an EDO-enabled chipset), and from a module perspective, this transition did not require a change from the standard 72-pin SIMM.

The transition from EDO to SDRAM is a revolutionary change. From a manufacturing perspective, this transition requires an entire mask set change. PC OEMs need to design their memory interface to deal with the synchronous interface. From a module perspective, it requires a corresponding module transition from SIMMs to DIMMs to accommodate a clock input signal that the 72-pin SIMM does not have.

SDRAMs will be used in the majority of PCs when DRAM manufacturers provide SDRAMs at price parity with comparable EDO DRAMs. Intel's 430VX and 430TX chipsets already support SDRAM, and Compaq Computer Corporation, Dell, Gateway 2000, and others are now using SDRAM. The Accelerated Graphics Port (AGP) Pentium II platform will use SDRAM and will likely set off a transition to this new technology. Dataquest does not expect SDRAM to carry a premium over EDO DRAM; rather, SDRAM-capable suppliers will use it to increase market share.

SIMMs and DIMMs

The most important DRAM module technology issue is speed. The intent of the 72-pin SIMM was the implementation of a commodity product using FPM DRAM for a 32-bit bus, operating at 25 MHz. The primary benefit over the 30-pin SIMM was the convenience of a single x32 module, instead of the four x8 modules needed for a x32 bus. One limiting factor of the 72-pin SIMM is that there are only six power and ground pins for the 32-bit bus. The more power and ground pins per output, the less noise is an issue.

The design of the 168-pin DIMM followed the transition from the 32-bit bus of 386- and 486-class machines to the 64-bit bus of Pentium-class machines. Although some Pentium-class PCs use a two x32 SIMM solution to support the 64-bit bus, a DIMM provides an optimized, single x64 module solution. The Pentium transition also begged for an increase in DRAM module speed. This need is addressed with the switch from EDO DRAM to SDRAM. To reduce noise problems and to increase module performance, there are 32 power and ground pins for the 64-bit bus. The 168-pin DIMM will be used in SDRAM implementations supporting up to a 100-MHz bus.

66-MHz and 100-MHz SDRAM DIMMs

The switch to SDRAM DIMMs may result in some troublesome industry issues. In addition to the clock signal supporting a synchronous interface, DIMMs also come in 5V and 3V, buffered and unbuffered, and serial presence detect options. These options, coupled with the inherent difficulty of designing high-speed interfaces, work against the easy implementation of a standard, generic SDRAM DIMM.

The biggest challenge for module designers is designing for the faster bus speeds. At bus speeds of 25 MHz, problems with signal reflection and cross talk exist, but there is room for error. Starting with 66-MHz SDRAM DIMMs, but especially with 100-MHz SDRAM DIMMs, this room for error disappears.

Originally, the DIMM was a loosely defined JEDEC standard that detailed little more than the mechanical form factor and pinout requirements. For EDO DIMMs, this does not pose much of a problem; however, with SDRAM DIMMs, it does. The JEDEC standard does not detail the module board layout. The result is a situation in which 66-MHz DIMMs with different board layouts may have compatibility issues, which forces PC OEMs to carefully qualify each DIMM for each of their PCs. Not only is this a qualification problem for PC OEMs, it poses a postsales support problem.

It is inevitable that incompatible aftermarket SDRAM DIMMs will be added to PCs by resellers or end users. When this occurs, it creates a technical support nightmare for the PC OEM, which must provide costly warranty and technical support. Intel, a company with a significant interest in the smooth implementation of new technology in the PC industry, is taking a leadership role in correcting this problem. With the 100-MHz SDRAM DIMM, Intel is developing a recommended module design guideline that is backward compatible with 66-MHz SDRAM.

Intel's guidelines will provide the exact board layout for DIMMs manufactured with x8 and x16 SDRAM ICs. The guideline also addresses signal tolerance levels, single- and double-sided DIMM designs, and parity and error correction code (ECC) options. Intel expects the guidelines to be available to module manufacturers and PC OEMs in the third quarter of 1997.

Buffered/Unbuffered DIMMs

One way of addressing the timing issues is the buffered DIMM. A buffered module has a buffer between the address inputs and the CRAM chips. This isolates the DRAM chips' signal attenuation and capacitiveloading from the PC motherboard. It may be possible to design a 100-MHz system that supports two, or even four, DIMM sockets with unbuffered DIMMs, but it does pose a challenge. At 100 MHz, there is a 10ns propagation time, during which the DRAM output and the chipset skew must be accounted for. Also, propagation along the board traces, which are transmission lines at these frequencies, can have some undesirable effects. Buffered DIMMs solve these problems to a large extent, but at the expense of performance, unless exotic fast buffers are used.

Serial Presence Detect

DIMMs can also implement serial presence detect. Serial presence detect is the capability of providing module characteristics, such as density, to the PC during the initialization process through a serial EEPROM. Not only does this help with the plug-and-play aspect of modules, but half of the EEPROM is unspecified. This allows the PC OEM to include information such as a serial number or date code that will help with inventory tracking and field failure support. Because each module will contain unique information, the use of serial presence detect will add a level of difficulty to DRAM module manufacturers, which will have to offer specific programmed modules to specific accounts.

One feature that serial presence detect enables is the potential for PC OEMs to include information on the DIMM that is checked for during the initialization process of their PCs. This would force end users to purchase only OEM-approved modules for their PCs. It is unlikely that this feature would be implemented because aftermarket module revenue is relatively small for PC OEMs.

Next-Generation DRAM

Potential main memories beyond SDRAM are Rambus, a licensed technology; SDRAM II; double data rate (DDR) DRAM; SyncLink; and MoSys' MDRAM.

Intel Endorses Rambus

Intel and DRAM manufacturers are acutely aware of the importance of developing a next-generation DRAM that will break open the bandwidth constraints of today's EDO DRAM and the emerging SDRAM. To bring attention to this need, Intel revealed in December its main memory road map, and the next-generation memory solution identified on this road map was a Rambus-based memory now named Direct RDRAM (Rambus DRAM). Intel is working with Rambus to develop this next generation of main memory. In choosing Rambus, Intel cites Rambus' demonstrated ability to develop, license, and promote a new DRAM interface, as evidenced by the system design-wins with Nintendo and Cirrus.

The Direct RDRAM interface will be a licensed technology available to DRAM manufacturers and digital logic manufacturers that economically supports extremely high bandwidth data communications. It does this by taking a revolutionary approach to several facets of the system speed problem, as follows:

- Packaging limitations
- Circuit board limitations
- Logic level limitations
- Bus width limitations
- Protocol limitations

A Rambus DRAM-to-system interface has already been developed, using existing technological know-how to address all of these problems at once, that supports peak transfers of 500 MB/sec on a bytewide bus, using semiconductor process technology that today also supports asynchronous DRAMs. The two trade-offs are that all devices on the high-speed channel must use the licensed Rambus technology and that the circuit card must be designed expressly to the rules of the Rambus interface.

From a module perspective, for Rambus and nearly all of the interfaces mentioned, the pins of the memory module will have to be redefined to support the special functions required to operate these parts. Rambus has taken the initiative and has issued a specification for a Rambus module that has all of the interface problems already solved. This is of key importance for the Rambus high-frequency bus. Rambus has realized that the only way to make its interface operate uniformly in all systems is to exert very tight control over all aspects of the bus design, including the specifications for both motherboard layout and module layout.

Other Module Issues

Parity checking once was a common feature of DRAM modules. This stems back to the original Wang 9-bit configuration and was driven in part by the parity checking supported by the Intel 486 microprocessor. One reason the 486 supports parity was the close relationship between Intel and IBM, a staunch believer in parity, in the middle 1980s, when the 486 was being defined.

Today parity is much less popular, although still supported in multiuser systems. Cost is more important to single-user systems purchasers than data integrity—the single-system user is willing to put up with a rare malfunction in order to save appreciably (13 percent off the price of main memory). Dataquest sees a continuing reduction in the market for parity modules, although the market is not expected to disappear altogether.

Another technology used instead of parity is error correction code. ECC corrects single-bit errors automatically and flags two-bit errors, which are exceptionally rare. Two-bit errors instigate a bad parity bit on the module's edge connector, signaling the need for the system to abort the current instruction stream. Error correction of this kind is costly and is used almost exclusively in file servers, where errors cannot be tolerated.

Chapter 4

Module Manufacturers

The DRAM module industry is supported by three types of manufacturers, DRAM companies, captive electronic equipment manufacturers, and third-party manufacturers. DRAM manufacturers sell the majority of their DRAM to OEMs and offer DRAM modules primarily as a packaging option. Because of the dynamics of this relationship, high-volume shipments with limited technical support are normal. This also creates a situation in which OEMs are willing to pay only a small adder for the module on top of the DRAM IC price.

The third-party business model is based on adding value by manufacturing modules and providing a high service level. Providing technical support, manufacturing PC-specific and proprietary modules, and supporting small niche markets enable third-party companies to survive. The services that third-party companies offer appeal to end users and resellers, not PC OEMs, the largest purchasers of DRAM and DRAM modules. Because of the different needs of these two types of customers, third-party module manufacturers and DRAM manufacturers have avoided direct competition. For more information on third-party module manufacturers, see the Dataquest Focus Report *Third-Party DRAM Module Manufacturer Study* (DPGR-WW-FR-9702, April 21, 1997).

Electronic equipment contract manufacturers assemble memory modules for DRAM manufacturers, OEMs, and third-party manufacturers. What differentiates contract manufacturers from third-party module suppliers is that they are captive manufacturers that do not sell the modules they assemble under their own brand name.

Naturally, DRAM manufacturers have a relatively simple procurement procedure if they choose to manufacture modules in-house. The bulk of the parts used are manufactured in-house. These are transferred at a cost that reflects the manufacturer's internal accounting practices, where the internal transfer price is usually set to be one of three options: zero cost, cost, or prevailing prices. Preferential treatment is often given to the module-producing division in decisions of allocation, costing, and slippage.

Third-party module manufacturers, on the other hand, must be nimble purchasers and have placed themselves in novel situations and partnerships. Some buy directly from the DRAM manufacturer and have good ongoing business relationships with major DRAM producers. Others purchase almost exclusively through brokers, putting themselves at the mercy of the availability of surplus devices. Sometimes this means cheaper DRAMs for the SIMM manufacturer, but at other times this means far more expensive DRAMs.

Module companies need to maintain relationships with DRAM manufacturers. Without these relationships, there is little chance a module company will be able to weather technology transitions and allocation periods without losing customers. However, during allocation periods, a module company faces the fact that when the DRAM manufacturer has to set account priorities, the module company is likely to face an allotment cut.

There is also a price penalty during oversupply periods when the spot market offers cheap DRAM.

The Outsourcing Triangle

PC OEMs are choosing to move their module production to DRAM suppliers or subcontractors. The result is a triangle of DRAM and DRAM module movement between the DRAM manufacturer, the PC OEM, and contract assemblers or third-party manufacturers.

Top-tier OEMs procure most of their DRAM and DRAM modules directly from DRAM manufacturers. However, these same OEMs are embracing third-party memory module manufacturers in a combined effort to run their upgrade and options business. This combined effort offers OEMs the ability to profit from the aftermarket while avoiding the pitfalls of managing their own program. This has created an environment where third-party manufacturers are scrambling to align themselves with OEM partners. One very public example was the 1996 teaming of Toshiba and Kingston. In this arrangement, Toshiba's computer group will cobrand its modules with Kingston, while letting Kingston run the upgrade program.

On the flip side, third-party manufacturers are also teaming up with DRAM manufacturers. DRAM manufacturers run into situations in which they need quick turnaround for key accounts. For unusual requests or short production runs, this level of support is costly. One cost-effective approach is to use a third-party module company in these situations. By doing so, the DRAM company leverages the flexibility and dedication of a third-party module company while cost-effectively meeting the needs of its key accounts.

Although the relationships just described are beneficial to both parties, it may be best to look at them as marriages of convenience. OEMs and DRAM manufacturers control the power in these relationships, and they can easily exercise it by taking their business and their DRAM elsewhere or creating an in-house equivalent.

Dataquest Perspective

The question still to be answered is whether the switch to SDRAM and next-generation modules will force a change in the DRAM module business structure. Although technology advancement is not expected to significantly impact the module production of DRAM manufacturers, it may shake out weaker third-party companies. The reasoning behind this technology fallout is the difficulty involved in designing, manufacturing, and testing SDRAM and next-generation modules.

The third-party industry has grown by supplying the aftermarket with relatively standard DRAM modules. The transition to SDRAM DIMMs is a step away from the standard module business many of these companies are familiar with. It requires a whole new level of capital expenditure and engineering know-how, which may squeeze out many small third-party companies.

The larger third-party companies see the SDRAM transition as a good thing. They already have an infrastructure set up for managing hundreds of PC-specific modules, which may be a necessity with first-generation SDRAM DIMMs. They also see their larger size as an asset in setting up the engineering infrastructure needed to deal with the technology. In fact, many of these companies have published press releases touting their acquisition of an HP 83000, a popular test bed for SDRAM and next-generation DRAM, as a signal to the industry that they are ready for business.

Larger third-party companies are in a better position to handle technology transitions, but their future is still very much dependent on the actions of the DRAM manufacturers that control the allotment of their DRAM. This may force third-party companies to become full-fledged electronic equipment contract manufacturers or into a distributor role handling a wide variety of PC peripherals.

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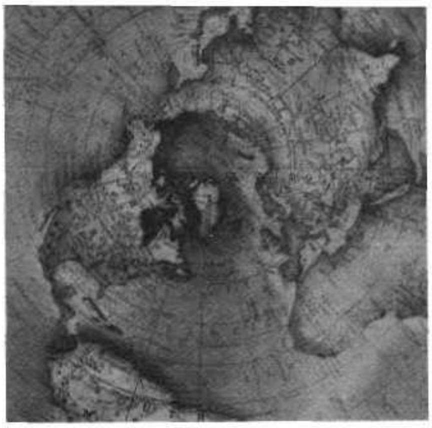

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Flash Memory Applications

Market Trends

Program: Memories Worldwide
Product Code: MMRY-WW-MT-9701
Publication Date: May 12, 1997
Filing: Market Trends

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Chapter 1

Executive Summary

The 1996 flash memory market was the third-largest memory market and the largest nonvolatile one. Dataquest's forecast for 1996 was $2.5 billion, and preliminary estimates indicate actual shipments to be $2.8 billion. Furthermore, the number of companies garnering over $100 million in flash sales expanded from four in 1995 to six in 1996, and those exceeding $50 million went from six to 10 companies. All this indicates that the flash memory market is becoming a force to be reckoned with, after years of hype predicting just that. It has become a "real" market, not just a niche.

Dominant applications for flash are beginning to emerge from the mist. They are wireless telecommunications handsets, internetworking infrastructure, PC BIOS, rigid disk drives (RDDs), and automotive engine control units (ECUs). That is the good news. The bad news is that they all have very different user wants and needs, so one basic chip design, or perhaps even a single technology, cannot be used for all of them.

A very hard fact of high-tech life is that the development and production costs for semiconductor products are very high. Small markets can sustain only a small number of suppliers with the profit necessary to continue for the long term. But as that market grows, it creates space, and opportunities, for additional companies. Flash is such a case, and the number of competitors will continue expanding.

Dataquest expects investments in flash technology to be aimed in three distinct directions. The first is low-voltage technology for battery-powered code storage. The second variation will be mass storage optimized for lower cost per bit and higher densities. The remainder will be a more standardized "generic" type of flash that has little technical differentiation and lower prices. New, hungry entrants will search out the potentially explosive applications and give the designers the products they want, not just need.

What this paints is a very exciting picture for those in the flash memory market. Its size and growth make it attractive for new entrants. Targets are becoming clearer. More competitors are vying for customers' attention, using new technologies that either propel the industry forward or just confuse the issue, depending on point of view. All of these make selecting the best business and technical strategies difficult but not impossible, as is detailed in this report.

Chapter 2

Flash Market Trends

Larger, More Mature

The 1996 flash memory market was the third-largest memory market and the largest nonvolatile one. Dataquest's forecast for 1996 was $2.5 billion, and preliminary estimates indicate actual shipments to be $2.8 billion. Furthermore, the number of companies garnering over $100 million in flash sales expanded from four in 1995 to six in 1996, and those exceeding $50 million went from six to 10 companies. All this indicates that the flash memory market is becoming a force to be reckoned with, after years of hype predicting just that. It has become a "real" market, not just a niche.

Overall market dynamics and growth mechanisms are becoming more mature, like other, older, memory technologies, such as DRAM, SRAM, and EPROM. One indication of this is a developing second-tier supplier base that focuses on volume production instead of market creation and expansion. Another is that supply, demand, and capacity are starting to determine prices instead of sole-source vendors dictating them.

Finally, market growth is being seen from both key applications and overall usage. The first requirement for market development is a "killer application" to consume a large amount of the product or technology and kick it off; for flash, this has been the digital cellular telephone. The next stage is for other uses to come to the fore and broaden the customer base to give it sustainable energy, even if the initial sponsor stumbles. But what are these applications that are driving the future of the flash market?

Key Markets Coming into Focus

Dominant applications for flash are beginning to emerge from the mist. They are wireless telecommunications handsets, internetworking infrastructure, PC BIOS, rigid disk drives, and automotive engine control units. That is the good news. The bad news is that they all have very different user wants and needs, so one basic chip design cannot be used for all of them (more on that later).

Each of these is large enough to justify individual investment for unique designs and technology, because they will grow to an average of $1 billion each by the year 2000. Also, unlike the past growth of flash, which has come at the expense of EPROM sales, future expansion will be in totally new markets that do more than swap sales in one nonvolatile memory product line for another.

Dataquest expects the investments in flash technology to be aimed in three distinct directions. The first is low-voltage technology for battery-powered code storage. The second variation will be mass storage optimized for lower cost per bit and higher densities. The remainder will be a more standardized "generic" type of flash that has little technical differentiation and lower prices. New, hungry entrants will search out the potentially explosive applications and give the designers the products they want, not just need.

More Competitors

A very hard fact of high-tech life is that the development and production costs for semiconductor products are very high. Small markets can sustain only a small number of suppliers with the profits necessary to continue for the long term. But as that market grows, it creates space, and opportunities, for additional companies. Flash is such a case.

The user base for flash to date has been very broad and has lacked the overlapping requirements that bring about common device specifications that could drive economies of scale. Instead, the response has been proprietary products developed by pioneers that make design-wins, profit, and market share more secure.

Opportunities are available for new players that have not been addressed by the existing "full line card" vendors, but these can be taken advantage of only by new, creative thinking.

More Technologies

New entrants must "bring something to the table" to be considered by big buyers. This is especially true in the flash arena, because the incumbents are world-class semiconductor manufacturers like Intel Corporation and Advanced Micro Devices Inc. There are two solutions to this problem: give customers either a better price or a better product to motivate them to change. Because basic technology approaches dictate functionality, even if practiced by different companies, a basic strategy for capturing a key account is to use a better technical implementation for that specific application. This could be focused to give a better cost or performance.

Using this strategy, new entrants are causing flash technology battles, with different solutions to the same problem, at key customers. The end to this confusing situation comes with de facto standards that are created by shipping the most (not necessarily the best) product. This competition benefits the users by furnishing better products that are a better value.

Stormy Weather

What this paints is a very exciting picture for those in the flash memory market. Its size and growth make it attractive for new entrants. Targets are becoming clearer. More competitors are vying for customers' attention, using new technologies that either propel the industry forward or just confuse the issue, depending on point of view. All of these make selecting the best business and technical strategies difficult but not impossible, as will be explained later.

Chapter 3
Flash Technical Trends and Issues

Code or Data?

The most basic segmentation for the flash market is dividing it into "code" or "data" halves. The basic model for code storage is where executable software for a microcontroller is stored in a flash chip and subsequently directly executed from it at the processor clock frequency. A variation on this theme is when code is stored in a flash chip, but not directly executed. Instead the program is moved to RAM and executed there. This report will call this situation "indirect execution." This distinction is important because of its bearing on device specifications and bit growth rates, as embedded code tends to be smaller and less prone to expansion than data, especially if it is recording sounds or images.

Data storage is where information is stored (written) in the flash chip but not read at top speed. A variation of data storage is used for remembering a small number of critical program parameters, such as user setup preferences, that the operating software refers to for decisions. Systems without flash often use an EEPROM for this function, but having a flash chip in the system allows the designer to remove a redundant chip if he or she wishes. Table 3-1 shows the characteristics of code and data flash.

Table 3-1
Code versus Data Flash Characteristics

	Fast Read Speed	Boot Block Organization	In-System Update	Fast Write Speed	Low Price per Bit	High Density	Small Erase Blocks
Code Storage	X	X	X				
Data Storage				X	X	X	X

Source: Dataquest (April 1997)

Low Voltage?

Another flash market segmentation is operating voltage. Battery-operated handheld equipment, such as digital cellular telephones, increases battery life by reducing the supply voltage internally, usually driven by logic components in the design. But the flash chip needs to be compatible with them, meaning that it needs to be low voltage, too.

In the past, the issue of supplying a higher voltage for programming and erase (V_{PP}) versus using just one supply voltage was bitterly fought, but newer designs can assume that only a single voltage is needed. Some vendors give the user the option of using a higher V_{PP} voltage, too, which speeds production line programming considerably. This is the Intel Smart Voltage approach. Another Intel strategy is to operate the flash device at a higher supply voltage, say 2.7V, but to make it compatible with a 1.8V system bus. Advanced Micro Devices is taking a different tack in achieving the ideal of a 1.8V-only part with an intermediate step of 2.2V.

Code Store General Technical Trends

Most (about 90 percent) of the current flash market is classified as code storage applications. The system capacity is controlled by selecting the proper density of flash chip, where density increases in two-times multiples—different from DRAM, which has four-times density multiples. Code storage applications generally value read speed most. The next most important specification is how the erase blocks are organized, with the "boot block" style the most popular.

The boot block organization was promoted by Intel for embedded applications wishing to periodically update the operating code stored in the flash chip. This asymmetrical blocking organization has the first block, which is locked after programming, store a minimal operating system and an update program that is invoked when the machine is first turned on. System control is then turned over to code residing in the larger blocks at the end of the chips address space, which can be updated via the boot-block code if necessary. Also, if the main block information is corrupted somehow during an update, the boot-block method ensures that it can be overwritten even though it is nonfunctional. New flash chips are moving away from an asymmetrical organization to a symmetrical one that has smaller, lockable, blocks inside the first big block, typically 64KB.

Another current key issue for code store parts is low-voltage operation for handheld electronic devices, such as digital cellular phones, which was discussed previously.

Data Store General Technical Trends

System capacity for data storage flash applications is modulated by adjusting the number of flash chips, which is how DRAM is frequently used. The particular chip density selected usually is the one with the lowest price per bit. And guess what? The most important current issue for data chips is reducing price per bit. Low price per bit allows either lower absolute price for constant density or more bits for a constant price.

Erase blocking needs to be symmetrical to facilitate data manipulation or disk drive emulation. That much is without dispute, but the *size* of the blocks is a controversial subject between NOR flash technology devotees Advanced Micro Devices and Intel, and NAND purveyors Toshiba and Samsung. NOR designs usually have an erase block size of 64KB, while the NAND chips get closer to the 512-byte blocks of rigid disk drives (RDDs). Because OS software is written with RDDs in mind, emulating them is desirable for flash solid-state storage. An Israeli company, M-Systems, is the leader in providing software for this and is providing Microsoft the flash card driver software for Windows 95.

Flash is technically superior to rotating magnetic storage in almost every way; it is rugged, low power, and small. The one exception is effective write speed. The start of the problem is that flash memory must first be erased before data is written to it instead of offering the direct overwrite feature of a true random access memory, such as DRAM or SRAM. Because the erase block size can be as large as 64KB, the erase operation does not need to be performed with every write. But an erase cycle must be done eventually, and it can be slow when it is, up to one second. The second issue is that writing requires that electrons be moved, somehow, to the floating gate of the flash cell. This action takes much more time to effect than creating an electrical current, so it is much slower than reading from a flash memory cell. The top programming speed, including both write and erase times, of current flash memories, is about 1 MB/sec, a fraction of even inexpensive RDDs. This is not an issue for most flash applications, those using code storage, which do not update the stored contents often over the life of flash chip. But newer data storage applications, such as the digital still camera, are limited by the write speed of flash for rapid picture taking.

Many of the emerging applications for flash require it to be in a card package for user convenience. The venerable Personal Computer Memory Card International Association (PCMCIA) standard, which has the same footprint as a credit card, is acceptable for commercial and industrial applications, but consumer uses see a need for a smaller form-factor card than PCMCIA. The industry has jumped in to solve this issue so enthusiastically that there are now three competing standards for it:

- Miniature Card—Intel/Advanced Micro Devices/Fujitsu/Sharp
- CompactFlash—SanDisk
- Solid-State Floppy Disk Card (SSFDC)—Toshiba/Samsung

Right now CompactFlash seems to be winning, but because of the changing character of digital photography and the small number of both OEMs and design-wins, it is too early to call a winner. The red flag here is that this *has* already hurt this fledgling industry because camera manufacturers have decided in some cases not to include any type of removable medium or have chosen media that are different from their competitors'. This is delaying the emergence of a standardized digital film market.

Standardization

High-technology component markets go through three phases. First is the "better mousetrap" stage where a company brings a unique product to market that satisfies a large unfulfilled need. Price is almost no object because the function it performs is so valuable. The second stage is "price/performance," where the same function is implemented in different proprietary ways that make different vendors products incompatible. An example of this is RISC versus CISC microprocessors. The third and final step is as a "commodity" product, where either formal or informal specifications and standards ensure compatibility and interchangeability among different suppliers' parts. This promotes a high level of competition that drives prices down and performance up.

Currently, the flash memory market is in the second stage, price/performance, on average. Lower-density parts, up through 2Mb, *are* at the commodity stage with plug-and-play products available from multiple sources. Above that density, there are multiple sources of popular parts but not with good pricing and availability and only from second-tier manufacturers. The two market leaders, Intel and AMD, almost seem to make a point of having their similar products be incompatible in some manner, although design engineers can usually overcome this with clever layouts.

Finally, for leading-edge flash components, Intel, AMD, and others will have singular products that give a new feature or specification for which they are the sole source. OEMs will often accept this limitation if flash is a limiting factor in the system but know they are taking a risk for future availability and higher pricing.

Dataquest expects that the flash memory market will gradually move toward the third maturity stage by the year 2000, with the high-volume, basic products available from multiple sources, much as the DRAM market is today.

Chapter 4

Largest, Fastest-Growing Flash Markets

This chapter ranks which applications will consume the most flash units and bits, both now and in the future, and are predicted to have the highest growth.

Current Market Situation

This section recaps the breakdown of application and flash shipments for 1996.

Unit Shipments

Most electronic systems that contain flash use just one flash memory chip in them, and therefore the systems with the highest unit shipments are also the ones that use the most flash devices. The 1996 top 10 electronic equipment applications (not just flash) are shown in Table 4-1. The only application in this list that uses flash in almost every unit sold is the personal computer, and it is not surprising to see it as the top user of flash chips.

Table 4-1
Top 10 Electronic Equipment Applications for 1996 (Thousands of Units)

Application	Industry	1996 Units
Corded Telephones	Communications	153,699
Personal/Portable Stereos	Consumer	133,445
Color TVs	Consumer	113,671
RDDs	Data processing	107,422
Central Office Line Cards	Communications	103,115
PC Motherboards	Data processing	82,429
Game Cartridges	Consumer	73,781
Personal Computers	Data processing	72,021
Monitors	Data processing	64,323
VCRs	Consumer	59,456

Source: Dataquest (April 1997)

The highest-unit-volume flash applications for 1996 are shown in Table 4-2. The obvious major ones that are above 20 million units annually are PCs, digital cellular phones, rigid disk drives, and ECUs. Past these, the field is much less distinct for leading users, a trend that would continue if the list were extended fully, as it is in Appendix A. This would explain why the largest flash vendors have broad catalogs of parts to fit these varied uses.

Table 4-2
Top 10 Flash Memory Unit Applications for 1996 (Thousands of Units)

Application	Industry	1996 Units
PCs	Data processing	61,218
Digital Cellular Phones	Communications	48,764
RDDs	Data processing	27,469
Auto ECU	Transportation	23,552
Mobile Communications Infrastructure	Communications	7,878
Networking Hubs	Communications	6,848
Digital Cordless Phones	Communications	6,778
Digital Set-Top Boxes	Consumer	6,076
Wired Telecom/Central Office Line Cards	Communications	5,156
Networking Routers	Communications	3,368

Source: Dataquest (April 1997)

Bits

Another usage metric to track for semiconductor memory is the number of bits used by an application, and the top 10 applications are shown in Table 4-3. This is a function of both the number of chips and the average density of those chips. To say it another way, the biggest purchaser of flash bits could be a company that uses a lot of units or a company that buys a good number of higher-density parts. First of all, one can see that looking at the market this way makes for fewer dominant categories, with the digital cellular phone being the sole exception. Past this, there are no runaway top applications, again supporting broad product offering by leading suppliers.

Table 4-3
Top 10 Flash Memory Bit Applications for 1996 (Trillions of Bits)

Application	Industry	Main Usage	1996 Bits
Digital Cellular Phones	Communications	Code, direct execution	341,345
PCs	Data processing	Code, indirect execution	68,258
Mobile Communications Infrastructure	Communications	Code/data, direct execution	63,024
Auto ECU	Transportation	Code, direct execution	47,103
Digital Set-Top Boxes	Consumer	Code, direct execution	42,532
RDDs	Data Processing	Code, direct execution	27,469
Hubs	Communications	Code, direct execution	27,391
Routers	Communications	Code/data, indirect execution	26,944
Auto Navigation	Transportation	Code/data, direct execution	26,637
Fax	Communications	Data	18,023

Source: Dataquest (April 1997)

Analysis

The current large applications of flash memory are using it as a better electrically programmable ROM (EPROM), where it is used to store executable machine code and is hardly ever updated or written to. This is a problem for suppliers because the value of flash is only slightly above other lower-cost alternatives such as EPROM or ROM. New applications, such as digital still photography, write to flash many times and are using it to full advantage, getting better value from it.

Future Market Situation

We will now jump ahead to the year 2001 for what Dataquest forecasts will be the top applications then.

Units

Dataquest's prediction for the 2001 flash market, as measured by units, is shown in Table 4-4. It is similar to the present, except that the auto ECU market will not grow as fast as the others, causing it to tumble into the second tier of flash unit consumers, predicted to be below 100 million units annually. The top five *second-tier* applications for 2001, defined as above 20 million units a year, are auto ECU, digital set-top boxes, answering machines, automotive navigation, and DVD players, none of which are large today, except for ECUs.

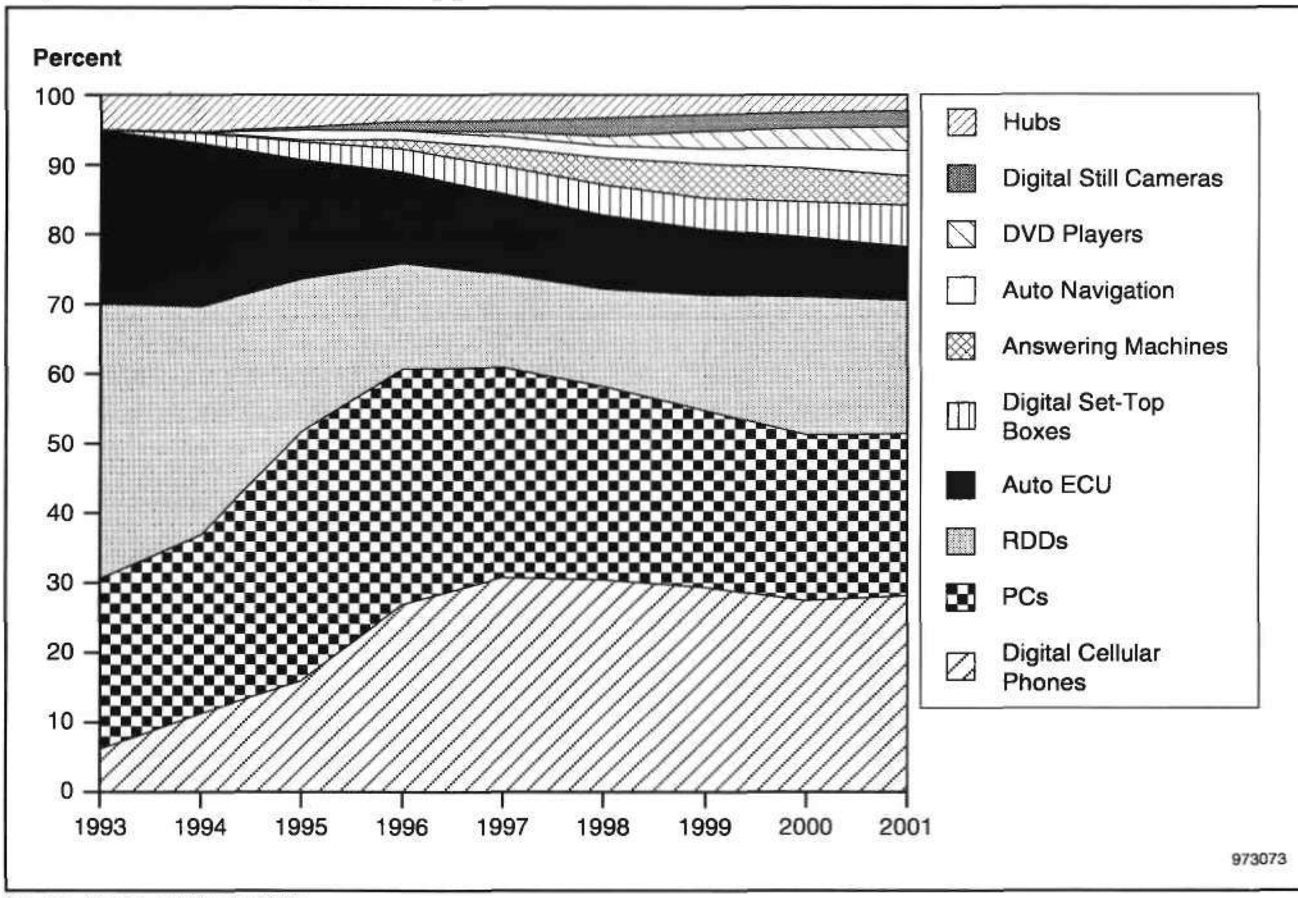
It can be seen in Figure 4-1 that digital cellular phones and PCs will maintain their current market position. RDDs, Automotive ECU, and hubs will shrink in market share, and digital set-top boxes, answering machines, automotive navigation, DVD players, and digital still cameras will increase their portion of the total available unit business.

Table 4-4
Top 10 Flash Memory Unit Applications for 2001 (Thousands of Units)

Application	Industry	Units
Digital Cellular Phones	Communications	174,651
PCs	Data processing	143,952
RDDs	Data processing	118,915
Auto ECU	Transportation	47,181
Digital Set-Top Boxes	Consumer	36,878
Answering Machines	Communications	26,250
Auto Navigation	Transportation	22,478
DVD Players	Consumer	21,000
Digital Still Cameras	Consumer	14,200
Hubs	Communications	14,000

Source: Dataquest (April 1997)

Figure 4-1
Top 10 Flash Memory Unit Applications over Time



Source: Dataquest (April 1997)

Bits

Table 4-5, the year 2001 top flash bit uses, shows that the lead of cellular phones over the next largest application will have shrunk from a 5:1 ratio to a 4:1 ratio, but it is still far ahead of the others. Also, a dark horse has emerged from the pack to take the runner-up position: digital still cameras. Images have large file sizes (as anyone who has e-mailed one can attest), and therefore use a lot of bits if they are stored in flash memory. Network routers are another application that uses many megabytes per system, and it has advanced in the standings because of that.

As shown in Figure 4-2, between now and the end of the forecast period, a long list of applications will maintain the status quo in terms of general bit market share: digital cellular phones, routers, digital set-top boxes, PCs, auto navigation, and RDDs. A few will show shrinking share, namely, automotive ECU, hubs, and fax. The swelling items are digital still cameras, routers, answering machines, and pagers.

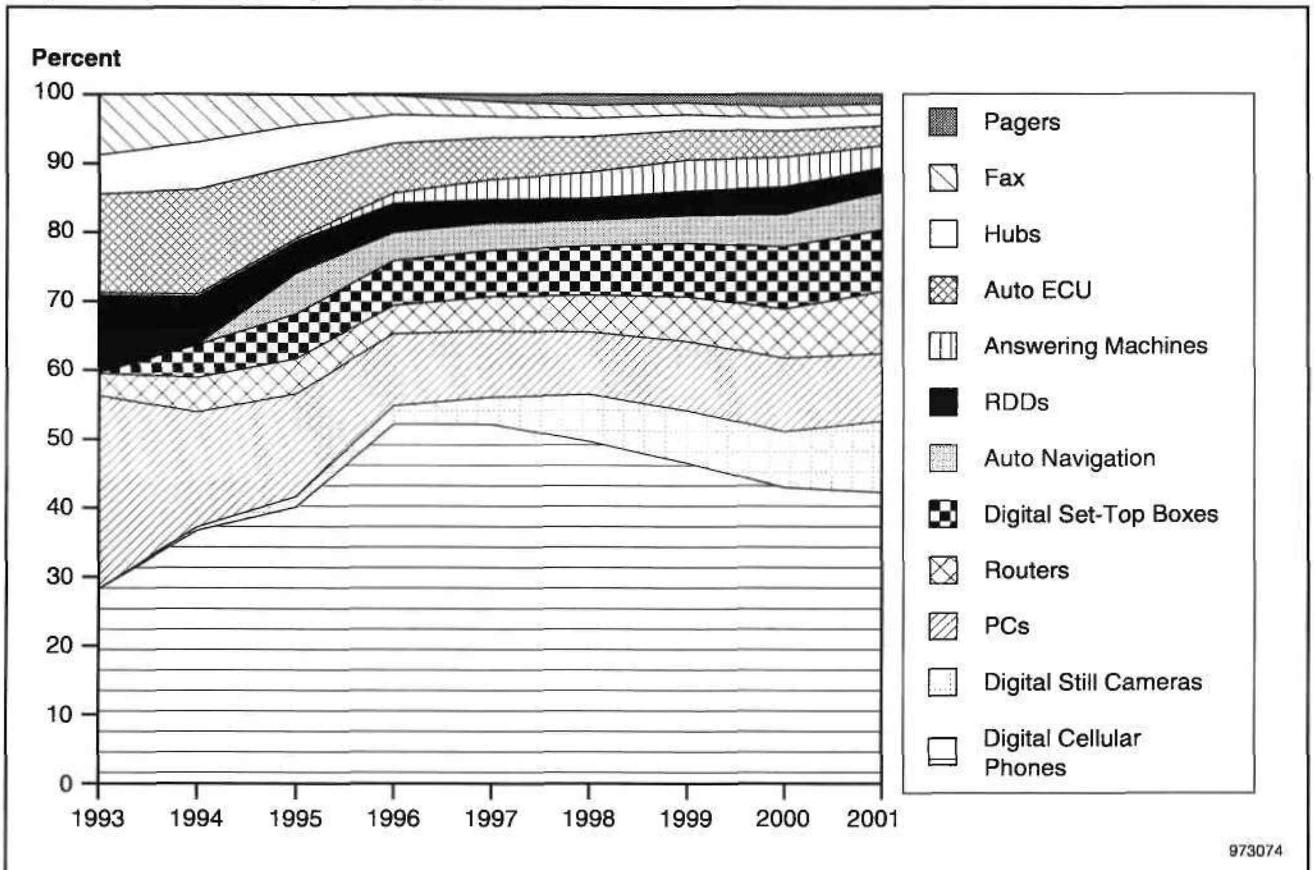
There is a very high correlation between the growing flash bit applications and the amount of flash they use per system, as seen in Table 4-6. The top five bit consumers are all in the top 10 list for system density, with the exception of PCs, which overwhelm bit consumption by brute force with very high unit volume.

Table 4-5
Top 10 Flash Memory Bit Applications for 2001 (Trillions of Bits)

Application	Industry	Bits
Digital Cellular Phones	Communications	2,794,416
Digital Still Cameras	Consumer	681,600
PCs	Data processing	647,785
Routers	Communications	595,200
Digital Set-Top Boxes	Consumer	590,048
Auto Navigation	Transportation	359,648
RDDs	Data processing	237,831
Answering Machines	Communications	210,000
Auto ECU	Transportation	188,724
Hubs	Communications	112,000

Source: Dataquest (April 1997)

Figure 4-2
Top 10 Flash Memory Bit Applications over Time



Source: Dataquest (April 1997)

Table 4-6
Top 10 Flash Memory System Density Applications for 2001 (Megabits)

Application	Industry	Main Usage	1996 Density	2001 Density	1996-2001 CAGR (%)
Routers	Communications	Code/data, indirect execution	32	192	43
Digital Still Cameras	Consumer	Data	16	96	43
Mainframe/Super Computers	Data processing	Code, indirect execution	9	48	40
Auto Navigation	Transportation	Code/data, direct execution	22	32	8
Midrange Computers	Data processing	Code, indirect execution	4	18	32
Digital Cellular Phones	Communications	Code, direct execution	7	16	18
Digital Set-Top Boxes	Consumer	Code, direct execution	7	16	18
Hubs	Communications	Code, direct execution	4	8	15
Fax	Communications	Data	2	8	36
Mobile Communications Infrastructure	Communications	Code/data, direct execution	8	8	0

Source: Dataquest (April 1997)

Analysis

Something surprising about the "top 10" standings between 1996 and 2001 is the overlap between the lists for units and bits. The top unit applications are also the top bit applications, but in different order. This would indicate that, for the foreseeable future, unit volume will continue to be a driving force in the flash market. The only density-dominated application to make it to the top 10 bit chart but not the top 10 unit chart is the network router.

Growth, Market Share

Table 4-7 below lists the flash applications that Dataquest expects to have the highest five-year growth for flash units into the year 2001. Note that the ones with the highest growth do *not* have high market share, which is typical because high growth is much more difficult with larger business bases and longer time intervals. An example of this is the digital cellular phone; it has the highest market share but the lowest growth.

The applications with the largest bit growth are shown in Table 4-8. Note that PCs are on this list but *not* on the unit rankings. This comes from modest PC unit growth, but with an increasing density trend. Something else to notice is the rapid unit growth of data storage applications, which has a multiplying effect when applied to a category that also has good density growth.

Analysis

From a flash supplier strategy standpoint, the goal is to pick markets that have both good growth and size. A market could have phenomenal growth but not be large enough to be worthy of investment. A graphical analysis of flash memory markets is shown in Figure 4-3. Another investment question is whether a market is unit driven or bit driven.

A graphical representation of unit- and bit-driven markets is shown in Figure 4-4. Unit-driven markets sell mature densities that have been avail-

Table 4-7
Top 10 Five-Year Unit Growth Applications for Flash Memory

	1996-2001 CAGR (%)		2001 Market Share (%)	
Flash Applications	**Units**	**Bits**	**Units**	**Bits**
Pagers	110	142	1.1	0.7
Answering Machines	60	84	2.6	1.6
Auto Navigation	56	68	2.2	2.7
Digital Camcorders	52	52	0.8	0.1
Digital Still Cameras	45	108	1.4	5.2
Digital Set-Top Boxes	43	69	3.6	4.5
RDDs	34	54	11.8	1.8
LAN Cards	32	32	0.7	0.1
Routers	30	86	1.2	4.5
Digital Cellular Phones	29	52	17.3	21.1

Source: Dataquest (April 1997)

Table 4-8
Top 10 Five-Year Bit Growth Applications for Flash Memory

	1996-2001 CAGR (%)		2001 Market Share (%)	
Flash Applications	**Units**	**Bits**	**Units**	**Bits**
Pagers	110	142	1.1	0.7
Digital Still Cameras	45	108	1.4	5.2
Routers	30	86	1.2	4.5
Answering Machines	60	84	2.6	1.6
Digital Set-Top Boxes	43	69	3.6	4.5
Auto Navigation	56	68	2.2	2.7
PCs	19	57	14.2	4.9
RDDs	34	54	11.8	1.8
Digital Cellular Phones	29	52	17.3	21.1
Digital Camcorders	52	52	0.8	0.1

Source: Dataquest (April 1997)

able for a long time, have lost most of their high density premium, and are thought of as commodity items by purchasers. They are profitable to sell but have relatively low margins. The way a commodity manufacturer increases profitability is to generate more revenue, which is directly proportional to the number of units sold. Manufacturers also are very interested in getting the highest margin for a specific density, so suppliers focus on cost reductions, (shrinks) to minimize die size and cost.

Dataquest believes the best unit-driven market opportunities are solid-state answering machines and digital set-top boxes.

In a bit-driven environment, there are different motivations for the seller and buyer. The buyer wants either a high-density memory for technical reasons or wants the lowest cost per bit. Sellers, on the other hand, prefer

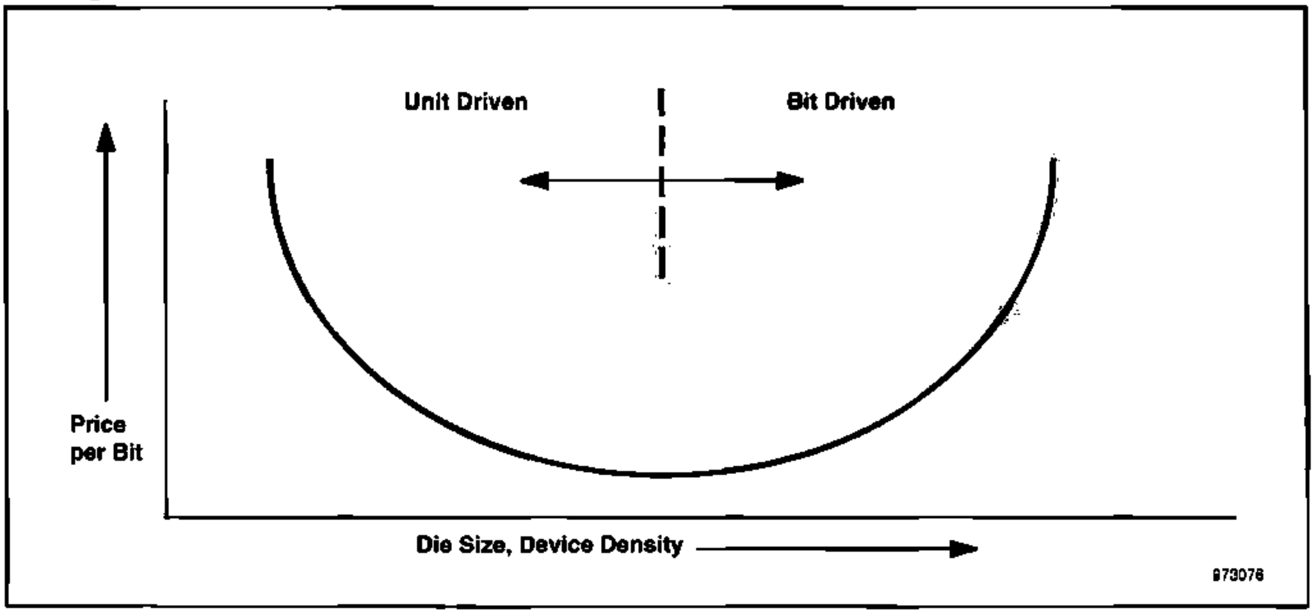
Figure 4-3
Growth and Size Analysis by Flash Application

Flash Application	Units		Bits	
	High Growth Rate	*High Market Share*	*High Growth Rate*	*High Market Share*
Pagers	X		X	
Digital Still Cameras	X		X	X
Routers			X	X
Answering Machines	X	X	X	
Digital Set-Top Boxes	X	X		X
Auto Navigation	X	X		X
PCs		X		X
RDDs		X		
Digital Cellular Phones		X		X
Digital Camcorders	X			

973075

Source: Dataquest (April 1997)

Figure 4-4
Price-per-Bit Characteristics of Unit-Driven and Bit-Driven Memories



Source: Dataquest (April 1997)

to sell the highest possible density because there is a possible price premium that will increase profits. The device with the lowest price per bit is at the juncture of becoming a unit-driven product—the price may be lowest because of competition.

Dataquest believes that the best bit-driven market opportunities are internetworking routers, digital still cameras, and automotive navigation systems.

Chapter 5
Application Trends and Requirements

This chapter details the characteristics of the largest flash applications. Specifically, it gives a description of the equipment manufactured in the target market, notes what value and function flash provide, lists key device specifications, shows market size and market share figures, and analyzes growth drivers and overall segment trends.

Background

Flash memory has had a high price compared to other nonvolatile memory types. This has made the decision to use it in a product an important one, with alternatives explored fully. It also is somewhat tricky to use in a design, with the design engineer needing training or experience to use it fully and effectively. Table 5-1 shows the alternatives to flash memory.

Table 5-1
Storage Technology Advantages

	Nonvolatile	In-System Writable	High Density/ Low Cost per Bit	High-Speed Write
DRAM		X	X	X
SRAM	With battery	X		X
Flash	X	X	X	
EPROM	X			
EEPROM	X	X		
MROM	X		X	
RDD	X	X	X	

Source: Dataquest (April 1997)

For instance, the reason that flash is not used in a PC instead of DRAM is that the system software requires both high-speed read and write, and flash can provide only the read half of that.

Analysis Format

Applications are listed in decreasing order of flash memory unit market size.

Application Description

This section defines both the general category and what parts of that category use flash.

Flash Usage, Value in Application

This section tells what function flash provides in this specific case and which unique characteristics of flash got it this design-win. The general functional categories are:

- Code, indirect execution
- Data

The typical values of flash are:

- Nonvolatility, compared to RAM
- Ruggedness, compared to mechanical storage
- Low power, compared to mechanical storage or battery-backed-up SRAM
- High density/low cost per megabyte, compared to SRAM or EEPROM
- In-system update, compared to EPROM or ROM

Key Flash Device Specifications

This section documents the particulars of flash devices used in this specific application:

- Density, in megabits (Mb) or megabytes (MB)
- Speed, in nanoseconds (ns) for read, in kilobytes per second (KB/sec) or megabytes per second (MB/sec) for write transfer rate, which includes both write and erase times
- Voltage—the supply voltage available to flash memory in the system
- Packaging
  - CSP, or chip scale packaging, such as micro-BGA
  - KGD, or known good die, where a singulated die is delivered to an OEM for chip on board (COB) or multichip module (MCM) usage
- Price, not in absolute terms, but in terms of whether it is an issue or not
  - Whether it is a prime concern of buyers, usually because of low system price or lack of special technical needs
  - Whether it is not critical, meaning that while the pricing must be generally competitive, purchasers are more concerned about other particulars when making a purchasing decision
  - Whether it is a bit-driven or unit-driven application

Flash Market Size Estimates for Application

This is the forecast for just this application and is extracted from the full lists in Appendix A.

Market Growth Rate, Drivers, and Dynamics

This is the forecast for just this application and is extracted from the full lists in Appendix A. There also is an explanation of what drives growth in this market and any market dynamics that can cause significant changes in demand.

Dataquest Perspective

This is the Dataquest "take" on this flash market.

Digital Cellular Telephones

Application Description

Digital-based cellular telephones are handsets based on digital transmission standards, versus older analog-based ones that send and receive audio information.

Flash Usage, Value in Application

Flash is an enabling technology for digital cellular telephones, such as GSM types, to allow for regulatory approval of code that could change. To date, it has mainly been used as a updatable read-only memory (an insurance policy for code and network changes), but newer models are also moving the temporary data storage from EEPROMs to the flash chip.

Key Flash Device Specifications

Key specifications include:

- Density: 8Mb now, going to 16Mb with multifunction units
- Speed: 120ns nominal
- Voltage: 2.7V/3.3V now, going to 1.8V by the end of the forecast period
- Packaging: TSOP now, going quickly to CSP, KGD
- Price: Lowest-voltage parts usually have 5 to 10 percent premium

Low-voltage operation allows shrinking the battery size and weight. Chip scale packaging options facilitates system miniaturization.

Flash Market Size Estimates for Application

Table 5-2 shows digital cellular telephone flash consumption.

Table 5-2
Digital Cellular Telephone Flash Consumption

	1993	1994	1995	1996	1997	1998	1999	2000	2001
Units (K)	2,467	6,951	17,791	48,764	75,734	97,321	122,334	144,182	174,651
Bits (Trillions)	9,868	34,755	106,746	341,345	605,872	973,210	1,468,008	2,018,554	2,794,416

Source: Dataquest (April 1997)

Market Growth Rate, Drivers, and Dynamics

Table 5-3 shows growth and market share.

Table 5-3
Digital Cellular Telephone Growth and Market Share

	Units	Bits
1996-2001 CAGR (%)	29	52
2001 Market Share (%)	17.3	21.1

Source: Dataquest (April 1997)

The tremendous surge in sales of digital cellular telephones makes this the largest opportunity by far for flash vendors. As these units ramp up in underdeveloped areas, worldwide sales will continue to expand. Because the cost of a wireless phone many times is subsidized by a service provider, normal consumer demand elasticity is not an issue; the true cost of the handset can be hidden from consumers and amortized into monthly charges.

Dataquest Perspective

Low-voltage operation is a key issue because the logic components in the handsets are considerably advanced, in some cases getting down to 0.9V! Flash is the slow boat in this convoy. AMD's recent 2.2V 8Mb announcement is an indication of the intensity of this battle. Intel has responded with a product line operating from 2.7V, but compatible with 1.8V logic levels, allowing flash to get out of the critical path of other components, such as the microcontroller or SRAM, from operating at 1.8V.

Another interesting aspect of the AMD 2.2V product is what it calls "zero power." This is an automatic power down to the "sleep" mode when the device is not being accessed, which takes only nanoamperes of supply current. This addressed another concern of digital cellular phone designers: low energy usage. Instantaneous power consumption does not matter, per se. What is important is *energy*, and energy equals power times time. To say it another way, the key is the "area under the curve." This is an issue for flash because the physics of operating a flash chip do not change just because the operating voltage goes down. It still takes so many electrons on the floating gate to program a cell, and the energy required to do that stays constant no matter what the supply voltage is. This is a prime area for innovation in different technology approaches, such as DiNOR. New thinking is probably required for substantial energy usage reductions.

As discussed previously in the technical trends section, cellular phones use flash for "code storage," but the handsets also need to store small amounts of data during operation. Currently, this need is being filled by EEPROMs, sometimes with multiple EEPROMs in a single unit. The obstacle to moving this auxiliary storage to the flash chip is that flash is not a direct-overwrite implementation as EEPROM is, and the erase block where the data is located must sometimes be used to reset the information. But currently an erase function in a flash chip puts it offline, not allowing it to continue executing code in parallel, which is a need for real-time operation. Writing data also has the same issue. This is a problem.

One solution to this problem is called "read while write" (RWW). The flash device can be designed with a separate erase blocks and related circuitry for separate sections of the flash memory array. This allows simultaneous reading of program information while a write or erase operation is occurring in different part of the chip. Another solution is putting a small EEPROM section on a larger flash chip, giving an integrated solution to the same problem. A third approach is "software read while write," where a mini-OS in the phone manages the read/write transactions to the flash chip. Phone design engineers to date have preferred the "hardware" RWW approach, but Intel recently announced a new part that has a hybrid hardware-plus-software solution that has gained early acceptance from some key cellular phone manufacturers.

A final trend in the wireless phone industry is the constant push to make the electronics in them as physically small as possible. For flash, this will vector off in two directions: either including flash in another system chip, such as the digital signal processor (DSP) or using advanced packaging techniques to shrink the footprint of the chip on the printed circuit board (PCB). Embedding flash (or any memory type, for that matter) is an important trend in the consumer electronics industry, and it will be used when the amount of memory is small enough not to raise the cost of the one-chip solution significantly over the cost of a two-chip one. Because the code size in these products is currently 4Mb to 8Mb, this merging of functions is not economical yet, so a physical approach is more appealing.

An attractive way to shrink the flash package is with chip scale packaging technology. Most of these are variations of a ball grid array (BGA) method of electrically and mechanically attaching the device to the PCB. Another is to place a memory die directly on the PCB and attach by the chip-on-board (COB) method. Although this is theoretically possible, COB has many hurdles to overcome for high-volume supply and usage, most of which are fixed by CSP. Dataquest expects chip scale packaging to win in the digital wireless flash market.

Personal Computers

Application Description

This category consists of personal computers, mostly IBM or Apple style.

Flash Usage, Value in Application

Flash memory is used to store pre-OS operating code and system parameter settings in the system BIOS. The values it offers are nonvolatility and the ability to update BIOS code if necessary for bug or feature updates. It is physically on the motherboard and connected to the processor through a slower peripheral bus. The code in it is downloaded ("shadowed") to system RAM for execution.

Key Flash Device Specifications

Key specifications include:

- Density: 1Mb now for Pentium-class machines, 2Mb now for Pentium Pro-class machines, going to 4Mb by the end of the forecast period
- Speed: Not critical
- Voltage: Not critical, 5V now, going to 3.3V
- Packaging: Not critical, SSOP or TSOP
- Price: Key specification, must be low as possible

Price must be very low. The density for PC BIOS is 1Mb for a Pentium PC and 2Mb for a Pentium Pro system. Dataquest expects the BIOS density to increase faster than it has in the past because the traditional 1Mb limit has been broken and more capacity can be added in the future for the same cost because of Moore's law of technology advances.

Flash Market Size Estimates for Application

Table 5-4 shows personal computer flash consumption.

Table 5-4
Personal Computer Flash Consumption

	1993	1994	1995	1996	1997	1998	1999	2000	2001
Units (K)	9,772	15,805	39,713	61,218	74,194	88,614	105,552	124,920	143,952
Bits (Trillions)	9,772	15,805	39,713	68,258	111,291	177,228	316,656	499,680	647,785

Source: Dataquest (April 1997)

Market Growth Rate, Drivers, and Dynamics

Table 5-5 shows growth and market share percentages.

Table 5-5
Personal Computer Growth and Market Share

	Units	Bits
1996-2001 CAGR (%)	19	57
2001 Market Share (%)	14.2	4.9

Source: Dataquest (April 1997)

This report will not attempt to address why the PC market is so vigorous, but it is. Anything tied to it, such as rigid disk drives and the flash BIOS, also experiences sustained high growth. Starting with Pentium-class machines, flash became a standard feature, whereas before it was in top-end desktop and notebook computers only.

Dataquest Perspective

The key specification, if it can be called that, for BIOS flash is price. Any component in a PC has incredible price pressure on it, both from a competitive and budget standpoint, and flash is no exception. The general price for a 1Mb flash chip is $3.50, and Dataquest expects this price point will be honored for 2Mb chips when the BIOS density sweet spot increases to that. No other specification is allowed to increase the cost above this point, except for low-volume models that are somehow unique, such as ruggedized notebooks. Also note that flash BIOS parts are usually programmed only one time, and that is when the part is prepared for operation in the PC or motherboard factory. After that, it is only an "insurance policy," so the flash benefit of reprogrammability is not used much by users. The new Macronix limited-cycle flash memory is a good fit for this application.

Rigid Disk Drives

Application Description

Rigid disk drives are used as mass, nonvolatile, storage for computers. A microcontroller or digital signal processor is used to control the mechanism and data flow.

Flash Usage, Value in Application

Flash devices are used to store operating firmware for the embedded processor in high-end rigid disk drives, such as those with SCSI interfaces. It is too expensive for use in the higher-volume ATA-IDE versions. Its value is that it offers updatable nonvolatile storage in the event the firmware has a bug, usually caught in the factory, but it can also be upgraded in a customer system.

Key Flash Device Specifications

Key specifications include:

- Density: 1Mb going to 2Mb by the end of the forecast period
- Speed: 70ns nominal, but faster speed, such as 50ns would be better because of high DSP performance, but are not willing to pay extra.
- Voltage: Desktop performance supply voltage, 5V going to 3.3V
- Packaging: Not critical, except in 1.8-inch units where CSP will be used
- Price: Need world's best prices with high reliability

Low price is important because of the price pressure on RDD component suppliers. Cost-effective increases in read performance are appreciated. Density is currently about 1Mb, but Dataquest expects it to increase to 2Mb by the end of the forecast period.

Flash Market Size Estimates for Application

Table 5-6 shows rigid disk drive flash consumption.

Table 5-6
Rigid Disk Drive Flash Consumption

	1993	1994	1995	1996	1997	1998	1999	2000	2001
Units (K)	15,758	20,197	24,379	27,469	33,139	44,799	69,163	103,680	118,915
Bits (Trillions)	3,939	6,665	12,190	27,469	39,767	62,719	110,661	186,623	237,831

Source: Dataquest (April 1997)

Market Growth Rate, Drivers, and Dynamics

Table 5-7 shows growth and market share percentages.

Fundamental market growth is a result of PC growth, because PCs are the largest user of RDDs. Dataquest expects the market to experience both good unit and bit growth, with units fueled by PC sales and bit expansion resulting from the larger firmware sizes needed to maintain RDD capacity growth.

Table 5-7
Rigid Disk Drive Growth and Market Share

	Units	Bits
1996-2001 CAGR (%)	34	54
2001 Market Share (%)	11.8	1.8

Source: Dataquest (April 1997)

Dataquest Perspective

Although unit growth is robust, there is some risk that the flash will be integrated into the core logic or microcontroller of the disk drive. Mitsubishi and IBM have collaborated in a well-publicized example of this. Dataquest believes that the price-per-bit premium of embedded memory combined with larger densities will forestall the widespread integration of flash memory in RDDs.

Automotive Engine Control Units

Application Description

Auto ECUs control the engine and transmission of a vehicle and enhance fuel efficiency and pollution control compared to mechanical systems.

Flash Usage, Value in Application

Flash is used as both an updatable nonvolatile program store and for memorization of operating settings for engine tuning and options. Flash is used in high-end units almost universally, but EPROM or ROM can be used in low-end units for vehicles *not* sold in the United States. U.S. pollution controls, especially in California, have been a boon to flash sales in this application.

Key Flash Device Specifications

Key specifications include:

- Density: Just going to 4Mb in high end, 1Mb to 2Mb in midrange; high end will start to move to 8Mb around 2000
- Speed: About 80ns for midrange, 25-MHz synchronous for high end, 33-MHz synchronous starting in 2000
- Voltage: 5V now, starting 3.3V in 2000
- Packaging: SOP for high volume today, CSP starting in 2000
- Price: 25 percent premium over commercial parts

From a technical perspective, the most demanding aspects of this segment are the need for a wide operating temperature range (minus 40°C to plus 125°C) and absolutely top quality. Auto OEMs are requesting a QS-9000 quality certification by semiconductor suppliers, which are resisting it. Future trends are for high-speed operation (yes, at low and high temperature) to coincide with the switch to RISC processors after the year 2000. Leading OEMs are also requesting known good die programs or CSP-packaged product to facilitate product miniaturization. Finally, because of government transportation and safety regulations and long product development cycles, flash products, whatever they are, need to be directly supported for about 10 years, making them somewhat incompatible with the PC cycles that are now driving the semiconductor industry.

Flash Market Size Estimates for Application

Table 5-8 shows automotive engine control unit flash consumption.

Table 5-8
Automotive Engine Control Unit Flash Consumption

	1993	1994	1995	1996	1997	1998	1999	2000	2001
Units (K)	9,952	14,412	18,962	23,552	28,299	33,681	39,081	44,868	47,181
Bits (Trillions)	4,976	14,412	28,443	47,103	70,748	101,042	136,784	179,471	188,724

Source: Dataquest (April 1997)

Market Growth Rate, Drivers, and Dynamics

Table 5-9 shows growth and market share percentages.

Table 5-9
Automotive Engine Control Unit Growth and Market Share

	Units	Bits
1996-2001 CAGR (%)	15	32
2001 Market Share (%)	4.7	1.4

Source: Dataquest (April 1997)

The automotive flash market is flat, with any increase in unit volume offset by expected normal price declines

Dataquest Perspective

Even though it is a flat market, its size makes it one that needs to be addressed. Intel is the current leader in this segment but could be displaced by a well-financed and -supported effort by a mature competitor.

Digital Set-Top Boxes

Application Description

These control and decode for digital satellite systems, digital cable systems, and "Web TV" boxes that link a television receiver to the Internet.

Flash Usage, Value in Application

Flash is used for updatable, nonvolatile, direct execution program storage and option storage.

This application uses flash memory as an updatable code storage mechanism where all or part of the operating firmware is stored. As much as the networking applications like the updatability of flash, so do these for the same reasons. The attached network can change, the user setup can change and, of course, the software has a bug in it. Or maybe the user just likes the secure feeling of having the latest (daily?) version of Netscape. And to be clear, the "set-top" boxes of flash interest here are the ones linked to either a digital satellite dish or a digital cable system.

Current versions mostly use flash for direct execute code storage and some sort of RAM for temporary data storage. If this information disappears with the plug being pulled out, there is no issue now. However, in the future, the user may have a small amount of what looks like a hard disk drive, but is a solid-state flash drive instead.

Key Flash Device Specifications

Key specifications include:

- Density: 1MB to 2MB
- Speed: 100ns or slower for reading, write speed not critical
- Voltage: Not critical, 5V going to 3.3V
- Packaging: Not critical
- Price: Not critical, but usually getting orders is very competitive

Flash Market Size Estimates for Application

Table 5-10 shows digital set-top box flash consumption.

Table 5-10
Digital Set-Top Box Flash Consumption

	1993	1994	1995	1996	1997	1998	1999	2000	2001
Units (K)	9	894	2,904	6,076	9,661	13,945	18,829	26,552	36,878
Bits (Trillions)	34	4,472	17,423	42,532	77,288	139,450	244,777	424,832	590,048

Source: Dataquest (April 1997)

Market Growth Rate, Drivers, and Dynamics

Table 5-11 shows growth and market share percentages.

Table 5-11
Digital Set-Top Box Growth and Market Share

	Units	Bits
1996-2001 CAGR (%)	43	69
2001 Market Share (%)	3.6	4.5

Source: Dataquest (April 1997)

Rapid growth is coming from the wide adaptation of digital transmission technology, both in wired and wireless environments. Growth will also be fueled in developing parts of the world that bypass a wired infrastructure in favor of a wireless one, similar to digital cellular expansion.

Dataquest Perspective

This application is potentially a huge opportunity for flash if the market takes off and flash stays in the product instead of being replaced by mask ROM (MROM). Dataquest is somewhat skeptical about the NetPC and WebTV but will continue to closely monitor this area for potential wild success.

Answering Machines (Solid State)

Application Description

These telephone answering machines record and play back messages using digital technology and semiconductor memory instead of magnetic tape. The memory type is making a transition from DRAM to flash memory. Usually these are a single-line configuration, with larger "voice mail" units using RDDs.

Flash Usage, Value in Application

Flash is used for writable nonvolatile audio data storage. The main value of flash is that of a semiconductor memory over a mechanical sequential access device, namely, instant access for fast forward and fast reverse and search procedures. Reliability is enhanced also, but the typical user may not see an improvement.

Key Flash Device Specifications

Key specifications include:

- Density: 4Mb to 8Mb
- Speed: Write—50KB/sec; read—not critical
- Voltage: Not critical, 5V going to 3.3V
- Packaging: Not critical, SSOP or TSOP
- Price: Very competitive

Flash Market Size Estimates for Application

Table 5-12 shows flash consumption in answering machines.

Table 5-12
Answering Machine (Solid State) Flash Consumption

	1993	1994	1995	1996	1997	1998	1999	2000	2001
Units (K)	32	81	261	2,475	6,651	12,357	20,478	25,412	26,250
Bits (Trillions)	127	326	1,043	9,899	33,254	74,145	143,343	203,299	210,000

Source: Dataquest (April 1997)

Market Growth Rate, Drivers, and Dynamics

Table 5-13 shows growth and market share percentages.

Table 5-13
Answering Machine (Solid State) Growth and Market Share

	Units	Bits
1996-2001 CAGR (%)	60	84
2001 Market Share (%)	2.6	1.6

Source: Dataquest (April 1997)

The switch to solid-state recorders from magnetic tape is driving growth in this segment.

Dataquest Perspective

Competition for flash comes from audio RAM (ARAM), which are DRAMs with partial bit defects and are sold at a steep discount. The present low price of 4Mb DRAM, which is below the price of a 4Mb flash chip, keeps this technical option alive, but nonvolatility seems to be winning the day.

Automotive Navigation

Application Description

This equipment uses Global Positioning System (GPS)-driven location information in conjunction with CD-ROM map-based geographic information database; it gives location and driving directions to driver.

Flash Usage, Value in Application

Flash is used for both microcode and temporary location data storage, with typically one chip used for each. The chip density is expected to grow to 16Mb by the year 2001.

Key Flash Device Specifications

Key specifications include:

- Density: 4Mb to 8Mb for code store, 8Mb to 16Mb for data storage
- Speed: Not critical, 120ns sufficient
- Voltage: Not critical, 5V going to 3.3V
- Packaging: CSP or known good die needed many times because the equivalent of an entire PC must fit in a standard car radio slot in an automobile
- Price: Must be competitive

Because there are no special technical requirements in this application for flash, except for a somewhat expanded temperature range, price will be the key specification. In coming years, the two chips will be different types, with one being faster and optimized for code-storage applications and the other being higher in density and lower in cost per bit.

Flash Market Size Estimates for Application

Table 5-14 shows automotive navigation flash consumption.

Table 5-14
Automotive Navigation Flash Consumption

	1993	1994	1995	1996	1997	1998	1999	2000	2001
Units (K)	NA	NA	1,581	2,422	3,878	5,524	9,060	14,652	22,478
Bits (Trillions)	NA	NA	15,810	26,637	46,536	71,812	126,840	219,780	359,648

NA = Not applicable
Source: Dataquest (April 1997)

Market Growth Rate, Drivers, and Dynamics

Table 5-15 shows growth and market share percentages.

Table 5-15
Automotive Navigation Growth and Market Share

	Units	Bits
1996-2001 CAGR (%)	56	68
2001 Market Share (%)	2.2	2.7

Source: Dataquest (April 1997)

Standalone navigation units are now being sold and used worldwide, but usually only in special cases such as rental cars. Growth is highest in Europe and Japan and lower in North America, correlating to the complexity of the road network in the geographic area. This is not currently a big market, and there is a large risk that this market will not grow as fast as proponents hope.

Dataquest Perspective

This is a good market for flash vendors because they can sell products they already have, but with a lot of competition from others doing the same thing. It also has a higher level of market risk.

DVD Players

Application Description

DVD players are consumer electronics devices used to play movies and other prerecorded entertainment and information content.

Flash Usage, Value in Application

Flash offers updatable lower-density code storage.

Key Flash Device Specifications

Key specifications include:

- Density: 1Mb
- Speed: Not critical, about 120ns
- Voltage: Not critical, 5v going to 3.3V
- Packaging: Not critical, SSOP or TSOP
- Price: Must be competitive

There are no driving technical requirements, so price is expected to be the key differentiator among vendors.

Flash Market Size Estimates for Application

Table 5-16 shows DVD player flash consumption.

Table 5-16
DVD Player Flash Consumption

	1993	1994	1995	1996	1997	1998	1999	2000	2001
Units (K)	NA	NA	NA	65	1,720	4,469	10,322	15,425	21,000
Bits (Trillions)	NA	NA	NA	65	1,720	4,469	10,322	15,425	21,000

NA = Not applicable
Source: Dataquest (April 1997)

Market Growth Rate, Drivers, and Dynamics

Table 5-17 shows growth and market share percentages.

Table 5-17
DVD Player Growth and Market Share

	Units	Bits
1996-2001 CAGR (%)	NA	NA
2001 Market Share (%)	2.1	0.2

NA = Not applicable
Source: Dataquest (April 1997)

Dataquest Perspective

The need for flash exists only as long as the system code is changing. If the code becomes very stable, then ROM is a better choice for an OEM. Dataquest sees flash being used through the forecast period as DVD ramps up and features are not standardized. But the longer-term perspective for flash is not good as change moderates.

Digital Still Cameras

Application Description

Digital still cameras are consumer equipment to capture images directly in digital form for use in Internet communications and desktop publishing.

Flash Usage, Value in Application

Flash is used for nonvolatile data storage of images, offering low power, high shock resistance, and small size, compared to mechanical alternatives.

Current implementations tend to use two megabytes of flash for about 20 to 24 images. This is limited by both the cost of higher-resolution charge-coupled devices (CCDs) for image sensing and the cost of flash. Dataquest believes that the flash sweet spot for digital photography will be the capacity (density) of the lowest-cost-per-bit flash memory. Samsung is now shipping a 32Mb (4MB) NAND flash chip, and is starting to sell a 64Mb (8MB) device. Because of the rapid advances being made in flash memory technology, such as the use of multilevel cell (MLC) techniques, Dataquest feels that flash will not be a limiting factor but that the technology will be used when it is available for those users that need the extra capacity and are willing to pay a premium for it.

Key Flash Device Specifications

Key specifications include:

- Density: 1MB to 2MB now, going to 2MB to 4MB soon, and to 8MB to 16MB by the end of the forecast period
- Speed: Read speed not critical, write speed must allow storage of at least one image per second, if not more
- Voltage: Not critical, but lower is better; 5V going to 3.3V now

- Packaging: Removable, small-form-factor card (CompactFlash, Miniature Card, SSFDC Smart Media)
- Price: Needs to be below $10 per megabyte now, $1 to $2 per megabyte by the end of the forecast period

Flash Market Size Estimates for Application

Table 5-18 shows digital still camera flash consumption.

Table 5-18
Digital Still Camera Flash Consumption

	1993	1994	1995	1996	1997	1998	1999	2000	2001
Units (K)	NA	60	508	2,200	3,828	8,307	9,969	11,962	14,200
Bits (Trillions)	NA	480	4,064	17,600	45,936	132,915	239,247	382,796	681,600

NA = Not applicable
Source: Dataquest (April 1997)

Market Growth Rate, Drivers, and Dynamics

Table 5-19 shows growth and market share percentages.

Table 5-19
Digital Still Camera Growth and Market Share

	Units	Bits
1996-2001 CAGR (%)	45	108
2001 Market Share (%)	1.4	5.2

Source: Dataquest (April 1997)

Digital photography is currently growing very rapidly, about 100 percent a year, with 1997 unit sales estimated to be 1.9 million units. The product is used to capture images in a native electronic format for use in desktop publishing, presentations, and Web publishing. This positions it squarely as a PC peripheral as opposed to a replacement for traditional silver halide film. But this is the wild card aspect of it; if it does start to be used as a better camera, the way cellular phones have been used to supplement wired telephones, this could be an incredible growth market.

Dataquest Perspective

With current market estimates, this is a good market but not a great market. Because images require such large storage, all flash suppliers covet this market. This will make it very oversupplied and therefore low priced, which may help drive this market more strongly than it might otherwise have been. If digital photography, and handheld imaging in general, turns out to be larger than can be reasonably predicted, this will be *the* market for high-density flash components. If it is not, too much money is being thrown at it in the form of advanced R&D that may otherwise have been better spent (in hindsight) on more mainstream flash memory technologies.

A problem for the market today is the lack of a small-form-factor flash card. There are three competing standards:

- Miniature Card: Intel/AMD/Fujitsu/Sharp
- CompactFlash: SanDisk
- Solid-State Floppy Disk Card (SSFDC): Toshiba/Samsung

Right now, CompactFlash seems to be winning, but because of the rapidly changing character of digital photography and the small number of both OEMs and design-wins, it is too early to call a winner. The red flag here is that this *has* already hurt this fledgling industry because camera manufacturers have decided in some cases not to include any type of removable media or have chosen media that are different from their competitors. This is delaying the emergence of a standardized digital film market. It is to be hoped that this will be sorted out quickly.

Networking Hubs

Application Description

These are network components that concentrate multiple individual connections or data streams into a single network connection.

Flash Usage, Value in Application

Flash is used for nonvolatile, updatable code storage for the system operating program and a small amount of storage of system setup parameters. Flash is not used in low-end units (under $200) because of price but is used in midrange and high-range products.

Key Flash Device Specifications

Key specifications include:

- Density: 4Mb now, going to 8Mb by the end of the forecast period
- Speed: Not critical, 120ns nominal
- Voltage: Not critical, 5V now, going to 3.3V
- Packaging: Not critical
- Price: Generic part, so winning business is very competitive

Flash Market Size Estimates for Application

Table 5-20 shows networking hub flash consumption.

Table 5-20
Networking Hub Flash Consumption

	1993	1994	1995	1996	1997	1998	1999	2000	2001
Units (K)	1,982	3,241	5,084	6,848	9,026	10,459	11,726	12,977	14,000
Bits (Trillions)	1,982	6,482	15,253	27,391	36,104	52,297	70,358	90,840	112,000

Source: Dataquest (April 1997)

Market Growth Rate, Drivers, and Dynamics

Table 5-21 shows growth and market share percentages.

Table 5-21
Networking Hub Growth and Market Share

	Units	Bits
1996-2001 CAGR (%)	15	33
2001 Market Share (%)	1.4	0.8

Source: Dataquest (April 1997)

The market for hubs is good, but it is not gaining as much benefit from Internet growth as routers are.

Dataquest Perspective

Networking in general has high growth, and hubs will benefit from this. Because of limited functionality and tight component budgets (hubs are very price competitive), this application uses much less flash than routers do, making this just an "OK" market for flash.

Digital Cordless Telephones

Application Description

These are telephone handsets for user-owned base stations or low-mobility cellular telephones. Answering machine function is optional and may be in the base station unit. Models with flash are CT-2 and PHS types, not DECT or 900-MHz types. PHS phones can be used at walking speeds but not in a moving car.

Flash Usage, Value in Application

Flash is used for updatable nonvolatile code storage and some option data storage. It can be used for user data storage, such as an answering machine voice storage in high-end units.

Key Flash Device Specifications

Key specifications include:

- Density: Code—1Mb, now going to 2Mb; data—4Mb nominal for voice storage. (Note that this optional device is not in our forecast.)
- Speed: 120ns is nominal now, but because the system processor is a RISC type in some cases (PHS), flash is limiting microcontroller performance, and at a reasonable cost premium, faster performance would be valued.
- Voltage: 3.3V now, going to 1.8V by the end of the forecast period
- Packaging: CSP or KGD
- Price: Some premium over generic parts because of low voltage and packaging requirements

Flash Market Size Estimates for Application

Table 5-22 shows digital cordless telephone flash consumption.

Table 5-22
Digital Cordless Telephone Flash Consumption

	1993	1994	1995	1996	1997	1998	1999	2000	2001
Units (K)	85	394	2,917	6,778	7,614	9,236	10,412	12,613	12,902
Bits (Trillions)	21	130	1,459	6,778	9,136	12,930	16,659	22,703	25,804

Source: Dataquest (April 1997)

Market Growth Rate, Drivers, and Dynamics

Table 5-23 shows growth and market share percentages.

Table 5-23
Digital Cordless Telephone Growth and Market Share

	Units	Bits
1996-2001 CAGR (%)	14	31
2001 Market Share (%)	1.3	0.2

Source: Dataquest (April 1997)

The PHS handset is very popular in Japan as a lower-cost, lower-fidelity alternative to more expensive digital cellular phones. It also may find success as a general-purpose wireless digital link for handheld or notebook computers.

Dataquest Perspective

The win with this segment is the ability for suppliers to leverage investments made to satisfy the digital cellular phone market. There is some risk that the flash will be integrated into ASICs or core logic because of its low density and the ability of Asia/Pacific foundries to produce low-density flash.

Network Routers

Application Description

These are a link in local area and Internet networks that directs traffic and translates protocols.

Flash Usage, Value in Application

Flash is used for nonvolatile data storage of the system operating program and network configuration information. This information is downloaded into system DRAM at boot time for program execution and data usage.

The technology of these systems is that of high-end PC systems, either because they *are* PCs or because they are built with similar hardware. This means they are "plugged into the wall," that is, have no demanding power budgets, and therefore do not want to pay any premium for low-voltage-enabled memories. Another similarity to a PC is the way flash is used; it is downloaded to DRAM for execution, so access speed is of no concern.

Key Flash Device Specifications

Key specifications include:

- Density: 4MB now, to 24MB
- Speed: Not critical for either read or write
- Voltage: Not critical, 5V going to 3.3V
- Packaging: Usually used in card form, currently PCMCIA, to allow for different capacities and upgradability. Some companies use SIMM or DIMM instead, but for the same reasons. May move to Miniature Card, CompactFlash, or SSFDC because of better pricing than PCMCIA.
- Price: Needs low cost per megabyte because of the high densities used
- Interface: ATA interface may be required in the future instead of "linear" card interface currently used.

Flash Market Size Estimates for Application

Table 5-24 shows network router flash consumption.

Table 5-24
Network Router Flash Consumption

	1993	1994	1995	1996	1997	1998	1999	2000	2001
Units (K)	140	592	1,677	3,368	4,864	6,584	8,528	10,524	12,400
Bits (Trillions)	1,120	4,736	13,416	26,944	58,368	105,344	204,672	336,768	595,200

Source: Dataquest (April 1997)

Market Growth Rate, Drivers, and Dynamics

Table 5-25 shows growth and market share percentages.

Table 5-25
Network Router Growth and Market Share

	Units	Bits
1996-2001 CAGR (%)	30	86
2001 Market Share (%)	1.2	4.5

Source: Dataquest (April 1997)

Consumption is being driven by the astounding growth of the Internet and the resulting success of Cisco, 3Com, and Bay Networks. The premier example of this are the high-end Internet routers that use 10MB to 20MB in each system. Although the unit volume is modest compared to some consumer applications, the high density and resulting high sales prices for the flash chips make this a short-term gold mine. Hubs and switches also use a lot of flash bits, but with fewer megabytes per system.

Dataquest Perspective

Networking is the only large-scale data storage flash application to date. It is a bit-driven market. Specifically it is low price per bit, also known as dollars per megabyte, that turns this market on. This is a fixed-capacity application, and reducing dollars per megabyte lowers the purchaser's cost for that capacity. Another similarity to the PC—to the DRAM used in it—is the use of installable modules with multiple flash chips. Again, the necessary capacity is fixed for a specific machine, but the number of flash chips used to make up that amount is not. Like DRAM, one can use the density with the lowest cost per bit and then assemble the parts on a single or double in-line memory module (SIMM or DIMM) or PCMCIA card for use in a particular installation. In theory, a hard disk drive could be used, but because uptime is of paramount importance for Internet hardware, flash is the preferred medium because of its high reliability and fast read performance.

Two-Way Pagers

Application Description

Two-way pagers offer a return data path from the pager unit. This both allows system knowledge of receiver location to maximize system bandwidth and permits the user to have a range of functions, from sending small electronic messages, such as text-only e-mail, to receiving voice messages.

Flash Usage, Value in Application

Flash is used for updatable, nonvolatile code storage for the unit program and nonvolatile data storage for messages.

Key Flash Device Specifications

Key specifications include:

- Density: 4Mb now, going to 8Mb by the end of the forecast period
- Speed: Not critical, 120ns nominal
- Voltage: 3.3V now, going to 1.8V, possibly to 0.9V
- Packaging: TSOP now, going to CSP, KGD
- Price: Will pay premium for low voltage and miniature packaging

Flash Market Size Estimates for Application

Table 5-26 shows two-way pager flash consumption.

Table 5-26
Two-Way Pager Flash Consumption

	1993	1994	1995	1996	1997	1998	1999	2000	2001
Units (K)	-	2	21	264	2,218	4,957	5,271	10,071	10,861
Bits (Trillions)	-	8	84	1,056	11,092	29,744	36,897	80,568	86,892

Source: Dataquest (April 1997)

Market Growth Rate, Drivers, and Dynamics

Table 5-27 shows growth and market share percentages.

The paging market is strongest in North America and Asia but is starting to take off in other geographies and is the fastest-growing flash market for

Table 5-27
Two-Way Pager Growth and Market Share

	Units	Bits
1996-2001 CAGR (%)	110	142
2001 Market Share (%)	1.1	0.7

Source: Dataquest (April 1997)

both units and bits. In North America, the growth is assumed to come from upgrading older-technology users to new features.

Dataquest Perspective

This forecast is based on up to a 16 percent penetration of two-way technology in the overall pager market. Because the pager market is very price sensitive (it is viewed as a low-cost alternative to a cellular phone), the higher costs of these devices may price them out of the market. The risk here is not whether flash will be used, but whether two-way pagers will be as successful as their proponents say. If this market takes off, it will be a great place to sell lots of flash at good prices.

Mobile Communications Infrastructure

Application Description

This refers to base stations and switches to support cellular telephones and two-way pagers.

Flash Usage, Value in Application

Flash is used for updatable nonvolatile code storage for the system software and nonvolatile data storage for network configuration specifics.

Key Flash Device Specifications

Key specifications include:

- Density: 1Mb
- Speed: Not critical, 120ns nominal
- Voltage: Not critical, 5V going to 3.3V
- Packaging: Not critical, SSOP or TSOP
- Price: Not critical because of high system cost

Flash Market Size Estimates for Application

Table 5-28 shows mobile communications infrastructure flash consumption.

Market Growth Rate, Drivers, and Dynamics

Table 5-29 shows growth and market share percentages.

Table 5-28
Mobile Communications Infrastructure Flash Consumption

	1993	1994	1995	1996	1997	1998	1999	2000	2001
Units (K)	NA	NA	5,476	7,878	9,935	10,489	10,400	10,200	10,200
Bits (Trillions)	NA	NA	43,808	63,024	79,480	83,912	83,200	81,600	81,600

NA = Not applicable
Source: Dataquest (April 1997)

Table 5-29
Mobile Communications Infrastructure Growth and Market Share

	Units	Bits
1996-2001 CAGR (%)	5	5
2001 Market Share (%)	1.0	0.6

Source: Dataquest (April 1997)

The growth of this segment is mediocre—there is only a general connection between the number of cellular phones and pagers and the number of base stations supporting them because only a small percentage of units are in use at any one time.

Dataquest Perspective

This is a good market for suppliers to sell their general-purpose flash memory products into. It does not justify special designs.

Modems

Application Description

This consists of dial-up modems in or connected to single-user PCs.

Flash Usage, Value in Application

Flash is used for updatable nonvolatile code storage for DSPs.

Key Flash Device Specifications

Key specifications include:

- Density: 1Mb
- Speed: Not critical for some, but many want 50ns or better
- Voltage: Not critical except for mobile, which is quickly going to 3.3V
- Packaging: Not critical except for PCMCIA, where CSP is desired
- Price: Very competitive

Flash Market Size Estimates for Application

Table 5-30 shows modem flash consumption.

Market Growth Rate, Drivers, and Dynamics

Table 5-31 shows growth and market share percentages.

Table 5-30
Modem Flash Consumption

	1993	1994	1995	1996	1997	1998	1999	2000	2001
Units (K)	1,132	1,747	2,660	3,224	4,345	5,258	6,279	7,352	8,481
Bits (Trillions)	1,132	1,747	2,660	3,224	4,345	5,258	6,279	7,352	8,481

Source: Dataquest (April 1997)

Table 5-31
Modem Growth and Market Share

	Units	Bits
1996-2001 CAGR (%)	21	21
2001 Market Share (%)	0.8	0.1

Source: Dataquest (April 1997)

The Internet and telecommuting are the drivers for these modems, and this could be viewed as another angle of the PC electronics cornucopia.

Dataquest Perspective

As with all low-density flash applications, there is a good possibility that ASICs or system core logic could absorb the flash memory. Adding it to DSPs gives an effective speed increase but pays a high price-per-bit penalty. If code size starts to increase, there will be good reason for the flash to stay discrete.

Digital Camcorders

Application Description

These are handheld video tape recorders, but with a digital data path instead of the current analog one. This will allow significant image enhancement, driving the conversion from analog units.

Flash Usage, Value in Application

Flash is used for updatable nonvolatile code storage.

Key Flash Device Specifications

Key specifications include:

- Density: 1Mb
- Speed: Not critical, 120ns nominal
- Voltage: 3.3V going to 1.8V
- Packaging: CSP or KGD
- Price: Slight premium for low voltage and CSP

Flash Market Size Estimates for Application

Table 5-32 shows digital camcorder flash consumption.

Table 5-32
Digital Camcorder Flash Consumption

	1993	1994	1995	1996	1997	1998	1999	2000	2001
Units (K)	NA	59	208	956	1,712	3,124	4,808	6,062	7,673
Bits (Trillions)	NA	59	208	956	1,712	3,124	4,808	6,062	7,673

NA = Not applicable
Source: Dataquest (April 1997)

Market Growth Rate, Drivers, and Dynamics

Table 5-33 shows growth and market share percentages.

Table 5-33
Digital Camcorder Growth and Market Share

	Units	Bits
1996-2001 CAGR (%)	52	52
2001 Market Share (%)	0.8	0.1

Source: Dataquest (April 1997)

The driving force for this market is the replacement of analog camcorders with newer-technology digital camcorders that have much better picture quality.

Dataquest Perspective

This market will have good growth but is not predicted to be a large part of the flash memory market in the forecast period.

Local Area Network Cards

Application Description

These are network interface cards (NICs) for PCs and other network peripherals, such as printers.

Flash Usage, Value in Application

Flash is used for updatable nonvolatile code storage in high-end and portable NICs. Nonportable ones are mainly used with printers, not PCs.

Key Flash Device Specifications

Key specifications include:

- Density: 1Mb
- Speed: Not critical for some, but many want 50ns or better for combined modem/NIC units
- Voltage: Not critical except for mobile, which is quickly going to 3.3V
- Packaging: Not critical except for PCMCIA, where CSP is desired
- Price: Very competitive

Flash Market Size Estimates for Application

Table 5-34 shows LAN card flash consumption.

Table 5-34
Local Area Network Card Flash Consumption

	1993	1994	1995	1996	1997	1998	1999	2000	2001
Units (K)	332	798	1,132	1,835	2,665	3,647	4,750	6,022	7,336
Bits (Trillions)	332	798	1,132	1,835	2,665	3,647	4,750	6,022	7,336

Source: Dataquest (April 1997)

Market Growth Rate, Drivers, and Dynamics

Table 5-35 shows growth and market share percentages.

Table 5-35
Local Area Network (LAN) Card Growth and Market Share

	Units	Bits
1996-2001 CAGR (%)	32	32
2001 Market Share (%)	0.7	0.1

Source: Dataquest (April 1997)

The market for LAN cards is good, but there is very low penetration of flash into it.

Dataquest Perspective

Good market growth is expected, but this is a small market satisfied as much as possible by general products from full-line suppliers.

Wired Telecom/Central Office Line Cards

Application Description

Telecom central office (CO) line cards connect local subscriber "loops" to the phone system. This category also includes cluster controllers that control individual line cards.

Flash Usage, Value in Application

Flash is used as updatable nonvolatile program storage.

Key Flash Device Specifications

Key specifications include:

- Density: 1Mb
- Speed: Not critical, 120ns nominal
- Voltage: Not critical, 5V going to 3.3V
- Packaging: SSOP, because TSOP is perceived to have long-term reliability issues relating to thermal expansion coefficient matching of chip and PCB material.
- Price: Not critical; supply and reliability issues more important

Flash Market Size Estimates for Application

Table 5-36 shows wired telecom/central office line card flash consumption.

Table 5-36
Wired Telecom/Central Office Line Card Flash Consumption

	1993	1994	1995	1996	1997	1998	1999	2000	2001
Units (K)	3,737	4,247	4,715	5,156	5,584	6,026	6,469	6,904	7,152
Bits (Trillions)	3,737	4,247	4,715	5,156	5,584	6,026	6,469	6,904	7,152

Source: Dataquest (April 1997)

Market Growth Rate, Drivers, and Dynamics

Table 5-37 shows growth and market share percentages.

This market has a CAGR of only 7 percent, and flash does not have high penetration in it.

Table 5-37
Wired Telecom/Central Office (CO) Line Cards Growth and Market Share

	Units	Bits
1996-2001 CAGR (%)	7	7
2001 Market Share (%)	0.7	0.1

Source: Dataquest (April 1997)

Dataquest Perspective

This is a low-growth, low-density market but is good business for smaller companies that do not mind issues like long support time frames (10 to 20 years).

Facsimile

Application Description

Faxes are standalone business equipment for sending and receiving paper-based images.

Flash Usage, Value in Application

Flash is used for temporary, nonvolatile storage of document images.

Key Flash Device Specifications

Key specifications include:

- Density: 8Mb now, going to 16Mb by the end of the forecast period
- Speed: Read speed not critical, write speed 1 MB/sec
- Voltage: 5V now, going to 3.3V
- Packaging: Not critical, TSOP usually
- Price: Not critical because flash is used only on high-end units

Flash Market Size Estimates for Application

Table 5-38 shows facsimile flash consumption.

Table 5-38
Facsimile Flash Consumption

	1993	1994	1995	1996	1997	1998	1999	2000	2001
Units (K)	764	1,306	1,957	2,575	3,172	3,772	4,528	5,411	6,417
Bits (Trillions)	3,057	6,532	11,741	18,023	25,375	37,720	54,341	75,751	102,677

Source: Dataquest (April 1997)

Market Growth Rate, Drivers, and Dynamics

Table 5-39 shows growth and market share percentages.

Table 5-39
Facsimile Growth and Market Share

	Units	Bits
1996-2001 CAGR (%)	20	42
2001 Market Share (%)	0.6	0.8

Source: Dataquest (April 1997)

This market has a CAGR of 5 percent, and flash does not have high penetration.

Dataquest Perspective

Images use lots of bits, so there is potential for this market. But full-feature e-mail with attached documents also fills the same need. This looks like a good market to "sell what you have," from a supplier's viewpoint.

Removable Magnetic Storage

Application Description

These are rigid disk drives with removable media cartridges or some form of flexible media cartridge.

Flash Usage, Value in Application

Flash is used for updatable nonvolatile program storage.

Key Flash Device Specifications

Key specifications include:

- Density: 1Mb, going to 2Mb by the end of the forecast period
- Speed: 70ns nominal; would like faster speed, such as 50ns, because of DSP, but not willing to pay extra
- Voltage: Desktop supply voltage, 5V going to 3.3V
- Packaging: Not critical, except CSP in 1.8-inch units
- Price: Needs good prices with high reliability

Flash Market Size Estimates for Application

Table 5-40 shows removable magnetic storage flash consumption.

Table 5-40
Removable Magnetic Storage Flash Consumption

	1993	1994	1995	1996	1997	1998	1999	2000	2001
Units (K)	NA	NA	1,480	1,747	1,926	1,953	1,953	1,983	2,014
Bits (Trillions)	NA	NA	740	1,747	2,312	2,735	3,125	3,570	4,027

NA = Not applicable
Source: Dataquest (April 1997)

Market Growth Rate, Drivers, and Dynamics

Table 5-41 shows growth and market share percentages.

Increasing files sizes past 1.44MB has fueled this market. Cartridges are also used extensively in the desktop publishing field.

Dataquest Perspective

Small market, so it is serviced best with general products from full-line suppliers.

Table 5-41
Removable Magnetic Storage Growth and Market Share

	Units	Bits
1996-2001 CAGR (%)	3	18
2001 Market Share (%)	0.2	0

Source: Dataquest (April 1997)

Midrange Computers

Application Description

These are so-called minicomputers that are maxis compared to today's PCs.

Flash Usage, Value in Application

Flash is used for updatable nonvolatile code storage of the initial system "cold boot" operating system.

Key Flash Device Specifications

Key specifications include:

- Density: 8Mb now, going to 16Mb by the end of the forecast period
- Speed: Not critical, 120ns nominal
- Voltage: Not critical, 5V going to 3.3V
- Packaging: Not critical, SSOP or TSOP
- Price: Not critical because of high system cost

Flash Market Size Estimates for Application

Table 5-42 shows midrange computer flash consumption.

Table 5-42
Midrange Computer Flash Consumption

	1993	1994	1995	1996	1997	1998	1999	2000	2001
Units (K)	NA	NA	632	753	844	950	1,053	1,183	1,329
Bits (Trillions)	NA	NA	2,530	3,360	5,065	7,597	12,642	18,922	23,918

NA = Not applicable
Source: Dataquest (April 1997)

Market Growth Rate, Drivers, and Dynamics

Table 5-43 shows growth and market share percentages.

Table 5-43
Midrange Computer Growth and Market Share

	Units	Bits
1996-2001 CAGR (%)	12	48
2001 Market Share (%)	0.1	0.2

Source: Dataquest (April 1997)

This market is expected to show growth through the forecast period.

Dataquest Perspective

This is a small market, so it is serviced with general products from full-line suppliers.

Workstations

Application Description

These are very high-performance, single-user computers that usually use RISC processors.

Flash Usage, Value in Application

Flash is used for updatable nonvolatile code storage of initial system "cold boot" operating system.

Key Flash Device Specifications

Key specifications include:

- Density: 1Mb, going to 4Mb by the end of the forecast period
- Speed: Not critical, 120ns nominal
- Voltage: Not critical, 5V going to 3.3V
- Packaging: Not critical, SSOP or TSOP
- Price: Not critical because of high system cost

Flash Market Size Estimates for Application

Table 5-44 shows workstation flash consumption.

Table 5-44
Workstation Flash Consumption

	1993	1994	1995	1996	1997	1998	1999	2000	2001
Units (K)	620	735	841	829	855	923	995	1,069	1,150
Bits (Trillions)	620	735	841	925	1,283	1,845	2,984	4,277	5,176

Source: Dataquest (April 1997)

Market Growth Rate, Drivers, and Dynamics

Table 5-45 shows growth and market share percentages.

This market has high growth, fueled partly by Internet growth and the digital content explosion.

Table 5-45
Workstation Growth and Market Share

	Units	Bits
1996-2001 CAGR (%)	7	41
2001 Market Share (%)	0.1	0

Source: Dataquest (April 1997)

Dataquest Perspective

This is a small market, so it is serviced with general products from full-line suppliers.

Optical Disc Drives

Application Description

Optical disc drives are mainly for use in PCs. Currently, this means CD-ROM, but this will change to DVD by the end of the forecast period.

Flash Usage, Value in Application

Flash is used for updatable nonvolatile code storage of system software. Code is executed directly from the flash device by an embedded microcontroller.

Key Flash Device Specifications

Key specifications include:

- Density: 1Mb
- Speed: Not critical, 120ns nominal
- Voltage: 5V now, going to 3.3V
- Packaging: Not critical, SSOP or TSOP
- Price: Lowest possible, very competitive

Flash Market Size Estimates for Application

Table 5-46 shows optical disc drive flash consumption.

Table 5-46
Optical Disc Drive Flash Consumption

	1993	1994	1995	1996	1997	1998	1999	2000	2001
Units (K)	73	183	397	513	641	701	730	767	807
Bits (Trillions)	73	183	397	513	641	701	730	767	807

Source: Dataquest (April 1997)

Market Growth Rate, Drivers, and Dynamics

Table 5-47 shows growth and market share percentages.

Table 5-47
Optical Disc Drive Growth and Market Share

	Units	Bits
1996-2001 CAGR (%)	10	10
2001 Market Share (%)	0.1	0

Source: Dataquest (April 1997)

Market growth is driven by multimedia personal computers.

Dataquest Perspective

This market has low penetration by flash, so the typical supplier strategy is to promote existing flash products to these OEMs. It may also have flash incorporated in other system logic chips as embedded memory, instead of as a discrete chip.

Mainframes and Supercomputers

Application Description

These are very large, centrally located computers.

Flash Usage, Value in Application

Flash is used for updatable nonvolatile code storage of initial system "cold boot" operating system.

Key Flash Device Specifications

Key specifications include:

- Density: 8Mb now, going to 32Mb by the end of the forecast period
- Speed: Not critical, 120ns nominal
- Voltage: Not critical, 5V going to 3.3V
- Packaging: Not critical, SSOP or TSOP

- Price: Not critical because of high system cost

Flash Market Size Estimates for Application

Table 5-48 shows mainframe and supercomputer flash consumption.

Table 5-48
Mainframe and Supercomputer Flash Consumption

	1993	1994	1995	1996	1997	1998	1999	2000	2001
Units (K)	NA	NA	11	13	13	13	12	12	12
Bits (Trillions)	NA	NA	90	113	157	213	296	378	557

NA = Not applicable
Source: Dataquest (April 1997)

Market Growth Rate, Drivers, and Dynamics

Table 5-49 shows growth and market share percentages.

Market growth is negative, and few units are sold.

Table 5-49
Mainframe and Supercomputer Growth and Market Share

	Units	Bits
1996-2001 CAGR (%)	-2	38
2001 Market Share (%)	0	0

Source: Dataquest (April 1997)

Dataquest Perspective

This is a small market, so it is best serviced with general products from full-line suppliers.

Appendix A
Flash Market Statistics

Methodology

The foundation of the flash usage model is the Dataquest high-volume electronic equipment production database, which gives unit shipment figures for the largest electronics markets. We estimated flash memory penetration into the applications and densities used. This was done based on interviews with experts both inside and outside Dataquest, which gave preliminary unit and bit figures for the flash market.

These initial figures were then compared to Dataquest memory forecasts for consistency of size, growth, and market share. Results were reviewed by other flash memory experts for validation.

Flash Memory Unit Forecast by Application

Table A-1 shows the flash memory unit forecast by application.

Flash Memory Bit Forecast by Application

Table A-2 shows the flash memory bit forecast by application.

System Unit Shipment Forecast

Table A-3 shows system unit shipment assumptions.

Table A-1
Flash Memory Unit Forecast by Application (Thousands of Units)

	Industry	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001	Market Share (%) 2001
Digital Cellular Phones	Communications	2,467	6,951	17,791	48,764	75,734	97,321	122,334	144,182	174,651	29	17.3
PCs	Data processing	9,772	15,805	39,713	61,218	74,194	88,614	105,552	124,920	143,952	19	14.2
Rigid Disk Drives	Data processing	15,758	20,197	24,379	27,469	33,139	44,799	69,163	103,680	118,915	34	11.8
Auto ECU	Transportation	9,952	14,412	18,962	23,552	28,299	33,681	39,081	44,868	47,181	15	4.7
Digital Set-Top Boxes	Consumer	9	894	2,904	6,076	9,661	13,945	18,829	26,552	36,878	43	3.6
Answering Machines	Communications	32	81	261	2,475	6,651	12,357	20,478	25,412	26,250	60	2.6
Auto Navigation	Transportation	-	-	1,581	2,422	3,878	5,524	9,060	14,652	22,478	56	2.2
DVD Players	Consumer	0	0	0	65	1,720	4,469	10,322	15,425	21,000	NA	2.1
Digital Still Cameras	Consumer	-	60	508	2,200	3,828	8,307	9,969	11,962	14,200	45	1.4
Hubs	Communications	1,982	3,241	5,084	6,848	9,026	10,459	11,726	12,977	14,000	15	1.4
Digital Cordless Phones	Communications	85	394	2,917	6,778	7,614	9,236	10,412	12,613	12,902	14	1.3
Routers	Communications	140	592	1,677	3,368	4,864	6,584	8,528	10,524	12,400	30	1.2
Pagers	Communications	0	2	21	264	2,218	4,957	5,271	10,071	10,861	110	1.1
Mobile Communications Infrastructure	Communications	-	-	5,476	7,878	9,935	10,489	10,400	10,200	10,200	5	1.0
Modems	Communications	1,132	1,747	2,660	3,224	4,345	5,258	6,279	7,352	8,481	21	0.8
Digital Camcorders	Consumer	-	59	208	956	1,712	3,124	4,808	6,062	7,673	52	0.8
LAN Cards	Communications	332	798	1,132	1,835	2,665	3,647	4,750	6,022	7,336	32	0.7
Wired Telecom/CO Line Cards	Communications	3,737	4,247	4,715	5,156	5,584	6,026	6,469	6,904	7,152	7	0.7
Facsimile	Communications	764	1,306	1,957	2,575	3,172	3,772	4,528	5,411	6,417	20	0.6
Removable Magnetic Storage	Data processing	-	-	1,480	1,747	1,926	1,953	1,953	1,983	2,014	3	0.2
Midrange Computers	Data processing	-	-	632	753	844	950	1,053	1,183	1,329	12	0.1
Workstations	Data processing	620	735	841	829	855	923	995	1,069	1,150	7	0.1
Optical Disc Drives	Data processing	73	183	397	513	641	701	730	767	807	10	0.1
Mainframes and Supercomputers	Data processing	-	-	11	13	13	13	12	12	12	-2	0
Motherboards	Data processing	0	0	0	0	0	0	0	0	0	NA	0
Page Printers	Data processing	0	0	0	0	0	0	0	0	0	NA	0
Serial Printers	Data processing	0	0	0	0	0	0	0	0	0	NA	0
Monitors	Data processing	-	-	0	0	0	0	0	0	0	NA	0
Premise Line Cards	Communications	0	0	0	0	0	0	0	0	0	NA	0
Corded Telephones	Communications	0	0	0	0	0	0	0	0	0	NA	0

Table A-1 (Continued)
Flash Memory Unit Forecast by Application (Thousands of Units)

	Industry	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001	Market Share (%) 2001
Analog Cellular Phones	Communications	0	0	0	0	0	0	0	0	0	NA	0
Analog Cordless Phones	Communications	0	0	0	0	0	0	0	0	0	NA	0
Other Mobile Communications	Communications	-	-	0	0	0	0	0	0	0	NA	0
Color TVs	Consumer	0	0	0	0	0	0	0	0	0	NA	0
VCRs	Consumer	0	0	0	0	0	0	0	0	0	NA	0
Analog Camcorders	Consumer	0	0	0	0	0	0	0	0	0	NA	0
Personal/Portable Stereos	Consumer	0	0	0	0	0	0	0	0	0	NA	0
Analog Set-Top Boxes	Consumer	0	0	0	0	0	0	0	0	0	NA	0
Game Consoles	Consumer	0	0	0	0	0	0	0	0	0	NA	0
Game Cartridges	Consumer	0	0	0	0	0	0	0	0	0	NA	0
Auto Stereos	Transportation	0	0	0	0	0	0	0	0	0	NA	0
Antilock Brakes	Transportation	0	0	0	0	0	0	0	0	0	NA	0
Air Bags	Transportation	0	0	0	0	0	0	0	0	0	NA	0
Others	-	20,080	30,731	57,989	92,990	125,365	161,618	206,873	259,201	303,531	27	30.0

NA = Not applicable
Source: Dataquest (April 1997)

Table A-2
Flash Memory Bit Forecast by Application (Trillions of Bits)

	Industry	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001	Market Share (%) 2001
Digital Cellular Phone	Communication	9,868	34,755	106,746	341,345	605,872	973,210	1,468,008	2,018,554	2,794,416	52	21.1
Digital Still Cameras	Consumer	0	480	4,064	17,600	45,936	132,915	239,247	382,796	681,600	108	5.2
PCs	Data Processing	9,772	15,805	39,713	68,258	111,291	177,228	316,656	499,680	647,785	57	4.9
Routers	Communication	1,120	4,736	13,416	26,944	58,368	105,344	204,672	336,768	595,200	86	4.5
Digital Set-Top Boxes	Consumer	34	4,472	17,423	42,532	77,288	139,450	244,777	424,832	590,048	69	4.5
Auto Navigation	Transportation	0	0	15,810	26,637	46,536	71,812	126,840	219,780	359,648	68	2.7
Rigid Disk Drives	Data Processing	3,939	6,665	12,190	27,469	39,767	62,719	110,661	186,623	237,831	54	1.8
Answering Machines	Communication	127	326	1,043	9,899	33,254	74,145	143,343	203,299	210,000	84	1.6
Auto ECU	Transportation	4,976	14,412	28,443	47,103	70,748	101,042	136,784	179,471	188,724	32	1.4
Hubs	Communication	1,982	6,482	15,253	27,391	36,104	52,297	70,358	90,840	112,000	33	0.8
Facsimile	Communication	3,057	6,532	11,741	18,023	25,375	37,720	54,341	75,751	102,677	42	0.8
Pagers	Communication	0	8	84	1,056	11,092	29,744	36,897	80,568	86,892	142	0.7
Mobile Communications Infrastructure	Communication	0	0	43,808	63,024	79,480	83,912	83,200	81,600	81,600	5	0.6
Digital Cordless Phones	Communication	21	130	1,459	6,778	9,136	12,930	16,659	22,703	25,804	31	0.2
Midrange Computers	Data Processing	0	0	2,530	3,360	5,065	7,597	12,642	18,922	23,918	48	0.2
DVD Players	Consumer	0	0	0	65	1,720	4,469	10,322	15,425	21,000	NA	0.2
Modems	Communication	1,132	1,747	2,660	3,224	4,345	5,258	6,279	7,352	8,481	21	0.1
Digital Camcorders	Consumer	0	59	208	956	1,712	3,124	4,808	6,062	7,673	52	0.1
LAN Cards	Communication	332	798	1,132	1,835	2,665	3,647	4,750	6,022	7,336	32	0.1
CO Line Cards	Communication	3,737	4,247	4,715	5,156	5,584	6,026	6,469	6,904	7,152	7	0.1
Workstations	Data Processing	620	735	841	925	1,283	1,845	2,984	4,277	5,176	41	0
Removable Magnetic Storage	Data Processing	0	0	740	1,747	2,312	2,735	3,125	3,570	4,027	18	0
Optical Disc Drives	Data Processing	73	183	397	513	641	701	730	767	807	10	0
Mainframes and Supercomputers	Data Processing	0	0	90	113	157	213	296	378	557	38	0
Motherboards	Data Processing	0	0	0	0	0	0	0	0	0	NA	0
Page Printers	Data Processing	0	0	0	0	0	0	0	0	0	NA	0
Serial Printers	Data Processing	0	0	0	0	0	0	0	0	0	NA	0
Monitors	Data Processing	0	0	0	0	0	0	0	0	0	NA	0
Premise Line Cards	Communication	0	0	0	0	0	0	0	0	0	NA	0

Table A-2 (Continued)
Flash Memory Bit Forecast by Application (Trillions of Bits)

	Industry	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001	Market Share (%) 2001
Corded Telephones	Communication	0	0	0	0	0	0	0	0	0	NA	0
Analog Cellular Phones	Communication	0	0	0	0	0	0	0	0	0	NA	0
Analog Cordless Phones	Communication	0	0	0	0	0	0	0	0	0	NA	0
Other Mobile Communications	Communication	0	0	0	0	0	0	0	0	0	NA	0
Color TVs	Consumer	0	0	0	0	0	0	0	0	0	NA	0
VCRs	Consumer	0	0	0	0	0	0	0	0	0	NA	0
Analog Camcorders	Consumer	0	0	0	0	0	0	0	0	0	NA	0
Personal/Portable Stereos	Consumer	0	0	0	0	0	0	0	0	0	NA	0
Analog Set-Top Boxes	Consumer	0	0	0	0	0	0	0	0	0	NA	0
Game Consoles	Consumer	0	0	0	0	0	0	0	0	0	NA	0
Game Cartridges	Consumer	0	0	0	0	0	0	0	0	0	NA	0
Auto Stereos	Transportation	0	0	0	0	0	0	0	0	0	NA	0
Antilock Brakes	Transportation	0	0	0	0	0	0	0	0	0	NA	0
Air Bags	Transportation	0	0	0	0	0	0	0	0	0	NA	0
Others	-	27,547	57,422	179,721	347,556	662,649	1,208,123	2,186,949	3,875,133	6,417,538	79	48.6

NA = Not applicable
Source: Dataquest (April 1997)

Table A-3
System Unit Shipment Assumptions (Thousands of Units)

	Industry	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
RDDs	Data processing	51,427	69,334	90,108	107,422	134,106	159,860	187,410	214,950	246,537	18
Digital Cellular Phones	Communications	2,467	6,951	17,791	48,764	75,734	97,321	122,334	144,182	174,651	29
Corded Telephones	Communications	142,150	145,330	149,605	153,699	157,499	161,149	165,160	169,600	173,901	3
Motherboards	Data processing	41,847	52,212	65,721	82,429	95,738	109,857	127,282	146,667	169,005	15
Personal/Portable Stereos	Consumer	129,044	129,237	132,861	133,445	138,009	143,120	148,264	154,025	159,724	4
PCs	Data processing	39,088	47,894	60,171	72,021	84,793	98,460	114,110	131,495	151,529	19
CO Line Cards	Communications	74,740	84,940	94,290	103,115	111,688	120,520	129,374	138,071	143,033	7
Color TVs	Consumer	102,861	105,748	110,527	113,671	117,885	123,243	128,972	135,208	141,563	4
Monitors	Data processing	-	-	51,680	64,323	76,358	90,301	103,638	117,325	132,609	16
Optical Disc Drives	Data processing	7,254	18,344	39,683	51,259	64,110	70,091	72,992	76,676	80,709	10
LAN Cards	Communications	16,597	26,598	28,294	36,702	44,412	52,095	59,369	66,912	73,357	15
Pagers	Communications	21,064	30,838	39,214	45,061	48,899	51,800	54,580	61,150	65,950	8
Auto Stereos	Transportation	49,026	49,850	50,946	52,102	53,798	56,029	57,652	59,352	61,227	3
Game Cartridges	Consumer	133,185	115,737	103,349	73,781	49,814	58,951	62,330	64,911	60,133	-4
Serial Printers	Data processing	20,092	22,055	28,789	33,385	37,338	42,848	45,414	49,782	51,800	9
VCRs	Consumer	53,133	57,930	58,821	59,456	61,276	60,613	57,083	53,465	49,840	-3
Automotive ECU	Transportation	33,174	36,031	37,924	39,253	40,428	42,101	43,424	44,868	47,181	4
Digital Cordless Phones	Communications	190	632	3,617	12,084	15,562	21,614	27,867	37,489	43,006	29
Modem	Communications	11,321	17,471	26,598	32,239	36,211	37,559	39,243	40,842	42,406	6
Airbags	Transportation	13,215	18,493	21,618	26,542	29,050	31,949	34,944	38,493	41,565	9
Premise Line Cards	Communications	25,520	26,240	29,000	31,264	33,047	34,703	36,100	37,548	38,711	4
Digital Set-Top Boxes	Consumer	9	894	2,904	6,076	9,661	13,945	18,829	26,552	36,878	43
Answering Machines	Communications	23,470	26,273	28,194	27,884	28,300	29,266	29,464	30,074	31,065	2
Antilock Brakes	Transportation	12,910	16,173	18,154	21,084	23,389	25,217	27,101	29,039	30,954	8
Game Consoles	Consumer	22,045	12,900	14,411	18,401	18,786	21,970	18,574	20,500	22,000	4
DVD Players	Consumer	0	0	0	65	1,720	4,469	10,322	15,425	21,000	NA
Analog Cordless Phones	Communications	35,234	37,473	42,407	42,529	40,573	34,504	29,118	21,011	16,500	-17
Page Printers	Data processing	5,918	7,096	8,685	9,897	11,122	12,170	13,325	14,295	14,750	8
Hubs	Communications	1,982	3,241	5,084	6,848	9,026	10,459	11,726	12,977	14,000	15
Analog Cellular Phones	Communications	16,275	25,058	29,613	29,835	27,233	24,868	20,475	17,000	14,000	-14
Facsimile	Communications	7,642	8,710	9,784	10,299	10,573	10,777	11,321	12,024	12,835	5

Table A-3 (Continued)
System Unit Shipment Assumptions (Thousands of Units)

	Industry	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
Auto Navigation	Transportation	-	-	791	1,211	1,939	2,762	4,530	7,326	11,239	56
Mobile Communications Infrastructure	Communications	-	-	5,476	7,878	9,935	10,489	10,400	10,200	10,200	5
Digital Camcorders	Consumer	-	59	208	956	1,712	3,124	4,808	6,062	7,673	52
Digital Still Cameras	Consumer	-	30	254	1,100	1,914	4,154	4,984	5,981	7,100	45
Analog Camcorders	Consumer	8,833	9,510	10,249	10,473	10,254	9,310	8,648	7,718	6,460	-9
Analog Set-Top Boxes	Consumer	10,719	12,233	11,505	11,388	11,115	10,890	7,583	6,790	6,111	-12
Routers	Communications	140	296	559	842	1,216	1,646	2,132	2,631	3,100	30
Other Mobile Communications	Communications	-	-	2,265	2,325	2,381	2,385	2,366	2,348	2,300	0
Removable Magnetic Storage	Data processing	-	-	1,480	1,747	1,926	1,953	1,953	1,983	2,014	3
Midrange Computers	Data processing	-	-	632	753	844	950	1,053	1,183	1,329	12
Workstations	Data processing	620	735	841	829	855	923	995	1,069	1,150	7
Mainframes and Supercomputers	Data processing	-	-	11	13	13	13	12	12	12	-2

Source: Dataquest (April 1997)

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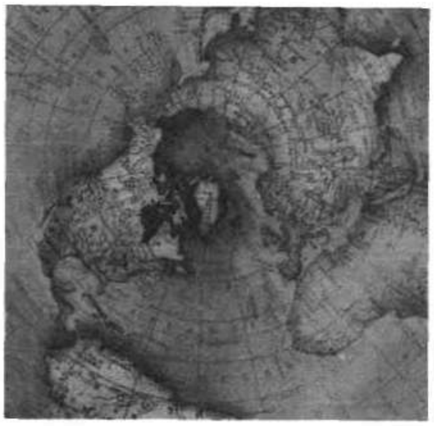
Errata

Tables 2-2 through 2-4 in Dataquest's *Worldwide MOS Memory Forecast, Fall 1997* (MMRY-WW-MS-9706, November 17, 1997) contained some incorrect data. Please discard the original document and replace it with this corrected one.

Dataquest regrets the error and apologizes for any inconvenience. For further information, contact Principal Analyst Bruce Bonner at (408) 468-8461 or at bruce.bonner@dataquest.com.



Dataquest

Worldwide MOS Memory Forecast, Fall 1997

Market Statistics

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Chapter 1

The Worldwide MOS Memory Forecast

This report details Dataquest's forecasts of six segments of the MOS memory market—DRAM, SRAM, EPROM, EEPROM, ROM, and flash memory. For each segment, Dataquest forecasts revenue, units shipped, average selling price, megabytes shipped, and price per megabyte. These forecasts are the result of detailed surveys of unit shipments for the 1996 calendar year.

Worldwide MOS memory revenue should total $32.8 billion for 1997, a decrease of almost 13 percent from 1996 revenue of $37.6 billion. This an extension of the 1996 cyclical decline in DRAM. By the second half of 1998, Dataquest expects to see a successful return to a normal market. Although much of the profit has evaporated in SRAM and flash memory, Dataquest still expects that 1997 will be a profitable year in these markets. On the other hand, 1997 is likely to be the least profitable year in DRAM since 1992, if not longer.

Dataquest sees long-term growth in most segments, including DRAM, SRAM, flash, and EEPROM, but flat performance in the EPROM and ROM markets. Dataquest has decreased its memory revenue growth outlook since the prior forecast (July 1997). Memory revenue should grow at a compound annual growth rate (CAGR) of 18 percent during the 1996-to-2001 period, with worldwide revenue reaching over $87 billion in 2000 and retreating slightly to just over $86 billion in 2001.

Forecast Assumptions

The following top-level assumptions guide Dataquest's forecast. The baseline assumptions associated with the six memory product forecasts—DRAM, SRAM, flash, EPROM, EEPROM, and ROM—appear in the sections that discuss those forecasts. This assessment highlights changes in assumptions since the prior forecast.

Dataquest's worldwide memory IC forecast assumes the following:

- The dramatic 1996 DRAM down cycle has bottomed out in 1997, and a more normal DRAM market remains, barring more of the simultaneous upsets of 1992 through 1995, such as the bursting of the Japanese stock bubble, the dollar-to-yen ratio slide, or difficulty in producing the x16 version of the mainstream density (such as a 4Mbx16 synchronous DRAM).
- Personal computer applications, including multimedia-type display applications, will continue to drive much of the growth of the worldwide memory market throughout the rest of this decade.
- New memory capacity and new memory market entrants should continue to be noticeable in the world.
- Communications applications ranging from low-voltage wireless systems to hubs and routers used for computer networking provide additional sources of growth for the worldwide memory market.

Dataquest continues to expect that Intel's x86 road map, along with more affordable DRAMs and SRAMs, will cause a near quadrupling of a PC's DRAM requirements from 1997 through 2001.

DRAM

DRAMs drive the memory market, and PCs drive the DRAM market. DRAMs will generate two-thirds of worldwide memory revenue in 1997. The DRAMs used in PCs alone now account for nearly half of the memory market's revenue.

Worldwide 1997 DRAM revenue should decline to $22.0 billion from $25.8 billion in 1996, a decrease of 14.6 percent. Worldwide DRAM revenue should total nearly $63 billion by 2001, but will peak in 2000 at over $68 billion.

This long-term forecast represents faster DRAM revenue growth than the prior long-term revenue forecast. Dataquest bases the change on the market's current position in the DRAM cycle. The industry should move from its trough position to a peak in 2000, with the next downturn taking effect in 2001.

DRAM Forecast Assumptions

The following summarizes the strategic assumptions that serve as the basis for the DRAM forecast:

- There is solid overcapacity in DRAMs, brought about through overinvestment in the highly profitable years of 1994 and 1995. This overcapacity is causing profit margins to disappear and, with them, investment in new plants and equipment. The consequence of the underinvestment in 1997 and 1998 will be an undercapacity in late 1999 and early 2000, fueling an industry cycle that Dataquest forecasts will be corrected late in 2000.
- Dataquest expects very strong PC demand throughout the forecast horizon.
- The 64Mb DRAM will have little market impact until after 1997, with the 64Mb price-per-bit crossover expected during 1999.

The explicit basis for Dataquest's high-growth DRAM outlook for both the near term and long term is as follows:

- Dataquest expects worldwide unit shipments of PCs to more than double from 1997 through 2001; PC shipments should expand from fewer than 71 million units in 1996 to nearly 152 million units in 2001.
- The amount of DRAM in each PC is likely to more than quadruple during this period. The amount of factory-installed DRAM had tripled from 8MB in 1995 to 24MB by the end of 1996. In 1997, PC buyers will demand even more memory—from 24MB to 32MB—for many applications.
- 16Mb DRAM unit shipments will peak during 1998; 4Mb units are in decline.

Intel's Pentium II ramp-up during the 1997-to-1999 period will have a dramatic impact on PC main memory. For example, Dataquest estimates conservatively that the combined Pentium II and Windows NT ramp-ups mean that 10 percent or more of PCs will ship from the PC factory with 64MB of DRAM by the end of 1997.

SRAM

Dataquest has adjusted the SRAM forecast downward for 1997, and we now expect 1997 worldwide SRAM revenue to total just under $4 billion, a 16 percent decrease from a disappointing 1996 total of $4.7 billion. This change was caused by continuing price slides that began with 1996's 32Kx32 crash.

Dataquest expects a strong rate of SRAM revenue growth in the long term. SRAM revenue will expand at a 19 percent rate from 1996 to 2001, led by the rapidly expanding cache segments.

SRAM Forecast Assumptions

The following assumptions provide the basis for the SRAM forecast:

- 1Mb slow SRAMs have suffered from a lack of market acceptance, although that scenario will change over the extended forecast. These parts have ramped extremely slowly when compared with the historical ramp rates of all prior SRAM densities. Dataquest attributes this phenomenon to the protracted recession Japan has suffered since the 1992 bubble burst and a resulting sluggishness in the market for high-end consumer electronics products. The 4Mb and 16Mb densities are also suffering from this phenomenon.
- The PC cache market is oversupplied in 1997 and in 1998 will become sourced through Intel, which will purchase these parts at aggressive prices. For this reason, the high-speed 1Mb market continues to suffer from low prices. Dataquest no longer believes that Intel's bundling of the 32Kx32 will cause prices for cache SRAMs to increase substantially. Dataquest sees continuing demand for 256K in the speed ranges from 10ns through 44ns in spite of this part's discontinuance in PC caches because of the use of inexpensive 32Kx32s.
- Total SRAM unit shipments declined in 1996 as the 1Mb density displaced the 256K density. The use of lower-density parts caused unusually high unit shipments of SRAMs as a whole in 1995. Unit shipments will hover near 1 billion units through the term of this forecast now that the conversion has taken its toll.
- Telecommunications continues to increase in importance to the SRAM market, consuming growing quantities of all densities of SRAMs at all speed ranges.

Slow SRAM

The slower-speed versions of the 1Mb SRAM have been available for several years yet continue to fail to win market acceptance. The high-end consumer electronics market has a dramatic effect on slow SRAMs, and today's protracted economic slump in Japan is postponing acceptance of the 1Mb SRAM density.

The delayed acceptance of the 1Mb SRAM and the technical difficulties of manufacturing a mass-produced thin-film transistor (TFT) have caused manufacturers to delay ramp-up of the 4Mb SRAM and development of the 16Mb density. Like the 1Mb density, the 4Mb density is behind normal life cycles and is expected to continue to suffer as long as the 1Mb density does. In the event of a recovery in Japan, it appears that, at this point in its life cycle, the 1Mb density will have lost its opportunity to gain acceptance and that the 4Mb density will take its place. This forecast assumes that shipments of the 1Mb density will stay relatively flat while the 4Mb density ramps up and lower densities ramp down.

Fast SRAM

In this forecast, Dataquest has added the 512K and 2Mb densities to cover the cache SRAM parts that have not been included in prior forecasts. Because we do not see sales of these densities being large enough to warrant their own six rows of the forecast, we have included them in the next-higher density numbers. These parts will be built using the next-more-dense process, so this should fit with the needs of production planners.

Over the term of the forecast, Dataquest believes that the faster SRAMs used in cache memory and telecommunications applications will contribute slightly more to overall SRAM revenue than their slower counterparts. This will occur despite average selling prices (ASPs) for the faster parts often being lower than ASPs for the same density at a slower speed.

Nonvolatile Memories

The four nonvolatile memory technologies reflect differing market characteristics, although at times they compete head-on for applications. Flash memory—the newly emerging nonvolatile technology—is enjoying rapid bit and unit growth in 1997. However, prices have come down faster than this growth, creating a flat revenue trend, compared to last year. A wide range of applications use EEPROMs, including industrial, telecommunications, and consumer systems. Diversified applications mean a bright long-term outlook for the EEPROM market. By contrast, the mask ROM market has depended heavily on video game demand. ROM suppliers, however, are shifting focus to other applications, such as laser printers. EPROMs are losing designs to flash memory, with units and revenue expected to be down from 1996.

Dataquest expects each to perform differently in the forecast window. Flash should continue to expand and benefit over the forecast horizon from the continued emergence of low-voltage handheld systems for telecom and computing applications. The outlook for EPROM shows a relatively flat market despite the advent of more flash capacity coming on line. This is because EPROM manufacturing costs should remain below those of flash memory, and the product will simply move into a niche as long as it is supplied, which suppliers guarantee Dataquest will be a very long time. EEPROM market revenue quietly surged during 1996, and we expect impressive growth for the next several years. EEPROM market revenue will exceed both ROM and EPROM revenue in 1997, a reversal of history. The mask ROM market should be down but should bounce back through the forecast period.

Worldwide flash memory revenue should approach $3 billion for 1997, for a diminutive 6 percent growth rate over 1996, especially in light of the segment's five-year CAGR of 17 percent.

Flash Memory

Dataquest foresees strong flash demand for both units and bits, but because of increased competition, pricing is likely to be depressed for the forecast period. Revenue in 1997 is expected to be almost $3 billion, a very small increase from the $2.8 billion of 1996—only 6 percent. New vendors, such as Sharp Electronics Corporation and Samsung Electronics Company Ltd., will continue to enter the market and offset increasing demand. This will yield a 1996-to-2001 CAGR of only 17 percent, lower that the other mainstream memories of DRAM, SRAM, and EEPROM. This is a significant reversal from years past, when flash lead the pack.

Dataquest sees the flash market as three distinct segments: low-voltage code store, mass data storage, and a generic "vanilla" segment for the broad range of smaller applications. All will see pricing pressure for different reasons. The generic style of flash will be lower density, with many vendors competing with standardized products. Mass-storage flash vendors are companies such as Samsung that are using excess DRAM capacity to produce parts and see a need for aggressive pricing to jump-start the digital film industry for computer photography. Low-voltage code store devices would have healthy premiums in normal times, but brawling for a limited number of sockets at leading cellular telephone handset manufacturers shatters this dream. Also, these are the leading-edge parts, going to 1.8V starting in 1998, and built with advanced lithography that lowers the cost of construction.

Flash Memory Forecast Assumptions

Dataquest bases the flash memory forecast on these assumptions:

- Flash remains a key enabling technology for a profusion of low-power handheld systems and peripherals; flash will enable the emergence of a host of other applications, such as digital cameras, Web TV and NetPC terminals, and automotive navigation systems.
- Current applications will continue to drive near-term growth very hard. Such applications are mainly in handheld cellular telephones and a variety of other telecommunications, data processing, and automotive areas.
- Embedded use of flash memory will accelerate, but not affect the flash device market significantly because of the steep price premium for useful densities. Embedded flash is seen as a development tool for prototypes and early production, with ROM versions used when the code is stable.

Flash technology remains inherently attractive because of its ruggedness, nonvolatility, low power requirement, and rewrite capability. The technology effectively performs a host of roles, including code storage, mass data storage and manipulation, and system configuration setting. From Dataquest's perspective, the continued lowering of the flash price-per-bit curve—combined with attractive functionality—means that flash remains positioned as a fast-growing semiconductor memory market during the forecast horizon.

EPROM

Although EPROM has continually defied the predictions of ill health made by proponents of flash until now, this fate seems to have arrived in 1997. Worldwide EPROM revenue is expected to drop to $713 million in 1997 from $1.2 billion in 1996, a 43 percent decline. Long-term EPROM revenue will be flat, contracting at a compound annual rate of -11 percent between 1996 and 2001.

EPROM Forecast Assumptions

The following assumptions serve as the basis for the EPROM forecast:

- EPROM's price per bit must remain below that of flash because of its lower comparative functionality.
- There will be no major growth in total EPROM revenue. It will be used mainly in legacy applications, not new designs.
- Despite competitive challenges, the EPROM market will exist well beyond the end of the 2001 forecast horizon, with SGS-Thomson Microelectronics B.V. leading in terms of long-term supplier commitment. Its primary value will be for cost-conscious applications not requiring the in-system update capability of flash.

EEPROM

Worldwide EEPROM revenue should reach $1.3 billion in 1997, up from $1 billion in 1996, a 28 percent increase. This represents no significant change compared with the prior forecast. The EEPROM market is now moving through an especially impressive growth phase because of its widespread acceptance for transaction processing in Europe and its suitability for a host of low-power telecom, industrial, automotive, consumer, and other applications. Smart cards are a large portion of the 1996 and 1997 growth. Dataquest forecasts continued long-term growth of the EEPROM market worldwide, with a 1996-to-2001 CAGR of 24 percent expected.

EEPROM Forecast Assumptions

Dataquest bases the EEPROM forecast on the following set of assumptions:

- EEPROM demand will continue to be driven by high demand for microcontrollers for a host of industrial, telecom, and consumer embedded applications. This is great news for the limited number of volume suppliers because it reduces competition (as opposed to the intense level of direct competition in segments of the DRAM, cache RAM, and flash markets).
- The EEPROM market will continue to enjoy a window of opportunity over the flash market in low-power applications because EEPROM's power consumption requirements are vastly lower than those of flash memory technology.

Mask ROM

Printers now account for a large share of ROM demand, as opposed to the past when video game cartridges were the No. 1 application.

Worldwide ROM revenue should total just under $1.1 billion for 1997, compared to nearly $1.4 billion in 1996, a 27.5 percent decline. Dataquest expects a mild decline in this mature technology over the long term. Unit shipments will be essentially flat, however, because a market move to higher densities should be offset by a decline in the ROM market average selling price. ROM revenue should decline at a compound annual rate of negative 5.6 percent from 1996 to 2001 and should hold at nearly $1 billion.

Mask ROM Forecast Assumptions

The following assumptions guide Dataquest's mask ROM forecast:

- ROM density shifts, which during the peak of ROM use in video games moved faster than introductions of new densities, are now compensating for this trend and will move more slowly than in the past.
- The stabilization of the market will lead to a leveling off in overall units and average selling price.
- The eventual demise of the ROM-based video cartridge business will cause ROM suppliers to migrate to other applications—or to de-emphasize this product technology.

ROM price per bit will remain about one-sixth that of flash memory through the forecast period. Although multilevel cell flash technology could alter this scenario, current trends signal that flash is likely to be unable to displace ROM if price per bit is the major consideration.

Chapter 2

Market Statistics Tables

Tables 2-1 through 2-35 show the worldwide MOS memory forecast.

Table 2-1
Worldwide MOS Memory Revenue Forecast, 1993 to 2001 (Millions of U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
DRAM	14,411.3	22,863.7	41,755.0	25,842.8	22,059.5	26,643.4	40,088.5	68,657.0	62,591.0	19.4
SRAM	3,484.9	4,066.7	6,131.8	4,709.2	3,987.8	4,840.1	6,045.9	8,479.1	11,308.8	19.2
EPROM	1,417.3	1,444.0	1,336.6	1,271.0	713.4	634.4	642.4	658.9	703.6	-11.2
Flash	725.5	992.0	1,845.7	2,828.4	2,993.9	3,417.1	4,162.8	5,192.5	6,280.1	17.3
ROM	1,730.6	2,172.4	2,134.6	1,368.0	1,085.2	911.4	989.9	1,027.8	1,025.3	-5.6
EEPROM	491.9	557.8	680.0	1,062.6	1,364.4	1,725.1	2,147.1	2,600.6	3,149.8	24.3
Other MOS Memory	266.0	318.0	534.0	577.0	642.0	834.5	956.2	1,020.1	1,070.7	13.2
All MOS Memory	**22,527.6**	**32,414.5**	**54,417.7**	**37,659.0**	**32,846.2**	**39,006.0**	**55,032.8**	**87,635.9**	**86,129.4**	**18.0**
Growth (%)	**50.1**	**43.9**	**67.9**	**-30.8**	**-12.8**	**18.8**	**41.1**	**59.2**	**-1.7**	**-**

Source: Dataquest (October 1997)

Table 2-2
Worldwide MOS Memory Average Selling Price Forecast, 1993 to 2001 (U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
DRAM	8.95	12.66	16.61	9.69	6.96	7.69	11.85	20.48	18.45	13.7
SRAM	3.85 (3.93)	4.64	4.80	4.45	3.97	5.07	6.39	7.92	9.77	17.0
EPROM	2.98	3.16	2.68	2.81	2.26	2.29	2.37	2.49	2.61	-1.4
Flash	9.81 (9.50)	8.02	7.94	7.68	5.26	4.68	4.90	5.32	5.75	-5.6
ROM	3.89	4.76	5.02	4.29	3.47	3.08	3.45	3.58	3.51	-3.9
EEPROM	1.07	0.96	0.86	0.82	0.76	0.74	0.76	0.82	0.93	2.4
All MOS Memory	**5.67 (5.60)**	**7.54**	**9.48**	**6.12**	**4.59**	**4.85**	**6.44**	**9.61**	**8.97**	**8.0**
Growth (%)	**33.4**	**32.9**	**25.8**	**-35.5**	**-25.0**	**5.8**	**32.7**	**49.3**	**-6.6**	**-**

Source: Dataquest (October 1997)

Table 2-3
Worldwide MOS Memory Unit Shipment Forecast, 1993 to 2001 (Millions of Units Shipped)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
DRAM	1,610.2	1,805.7	2,514.3	2,666.3	3,171.8	3,463.6	3,383.3	3,352.4	3,392.5	4.9
SRAM	906.4	876.1	1,277.0	1,058.2	1,004.6	954.2	946.3	1,071.2	1,157.1	1.8
EPROM	475.9	457.7	498.8	452.5	316.2	277.7	270.7	264.9	269.3	-9.9
Flash	74.0	123.7	232.5	368.5	569.4	730.9	848.8	975.3	1,092.9	24.3
ROM	444.7	456.3	425.5	319.0	312.6	295.8	286.6	287.2	292.3	-1.7
EEPROM	459.8	580.6	789.9	1,291.2	1,788.1	2,319.2	2,813.9	3,170.6	3,397.2	21.3
All MOS Memory	3,971.0	4,300.0	5,737.9	6,155.7	7,162.8	8,041.3	8,549.6	9,121.6	9,601.2	9.3
Growth (%)	13.9	8.3	33.4	7.3	16.4	12.3	6.3	6.7	5.3	-

Source: Dataquest (October 1997)

Table 2-4
Worldwide MOS Memory Megabyte Shipment Forecast, 1993 to 2001 (Millions of Megabytes Shipped)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
DRAM	555.8	853.2	1,560.8	2,767.3	5,042.7	7,920.9	12,520.7	22,716.2	38,736.8	69.5
SRAM	32.2	36.6	58.5	66.3	103.2	155.5	229.6	375.0	586.5	54.7
EPROM	46.0	48.0	54.9	61.4	56.3	66.6	80.5	94.8	113.5	13.1
Flash	12.1	27.6	85.9	156.7	317.5	515.5	825.2	1,310.6	1,949.5	65.6
ROM	341.6	405.4	451.7	407.1	475.1	589.6	804.2	1,147.6	1,578.1	31.1
EEPROM	0.4	0.7	0.9	1.4	2.5	4.3	7.4	13.9	24.2	75.9
All MOS Memory	**988.1**	**1,371.4**	**2,212.6**	**3,460.2**	**5,997.4**	**9,252.5**	**14,467.6**	**25,658.1**	**42,988.7**	**65.5**
Growth (%)	**69.4**	**38.8**	**61.3**	**56.4**	**73.3**	**54.3**	**56.4**	**77.3**	**67.5**	**-**

Source: Dataquest (October 1997)

Table 2-5
Worldwide MOS Memory Price-per-Megabyte Forecast, 1993 to 2001 (U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
DRAM	25.93	26.80	26.75	9.34	4.38	3.36	3.20	3.02	1.62	-29.6
SRAM	108.20	111.21	104.83	71.06	38.63	31.13	26.33	22.61	19.28	-23.0
EPROM	30.81	30.05	24.37	20.71	12.67	9.52	7.98	6.95	6.20	-21.4
Flash	59.96	36.00	21.49	18.05	9.43	6.63	5.05	3.96	3.22	-29.2
ROM	5.07	5.36	4.73	3.36	2.28	1.55	1.23	0.90	0.65	-28.0
EEPROM	1,113.51	783.01	741.08	739.22	545.26	401.56	288.98	186.69	129.95	-29.4
All MOS Memory	**22.80**	**23.64**	**24.59**	**10.88**	**5.48**	**4.22**	**3.80**	**3.42**	**2.00**	-28.7
Growth (%)	**-10.3**	**3.7**	**4.1**	**-55.7**	**-49.7**	**-23.0**	**-9.8**	**-10.2**	**-41.3**	-

Source: Dataquest (October 1997)

Table 2-6
Worldwide DRAM Revenue Forecast, 1993 to 2001 (Millions of U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
64K Standard	5.3	3.3	-	0	0	0	0	0	0	-
256K Standard	109.5	53.7	54.9	20.3	1.3	-	-	-	-	-100.0
256K Display	102.9	63.1	49.3	14.3	15.4	5.8	5.3	2.6	2.6	-28.7
1Mb Standard	1,618.2	1,541.5	1,850.6	670.1	290.9	213.3	171.2	81.4	16.7	-52.2
1Mb Display	774.8	566.1	10.1	250.3	149.5	92.1	58.5	34.7	29.3	-34.9
2Mb DRAM	236.7	409.8	581.2	247.3	494.0	381.3	223.7	146.3	103.1	-16.1
4Mb Standard	9,948.7	14,402.4	21,041.4	8,062.9	1,944.1	798.8	160.2	208.2	82.9	-60.0
4Mb Display	14.5	110.9	521.7	514.5	735.2	880.9	870.6	522.4	157.9	-21.0
8Mb Display	-	-	-	302.9	494.8	693.6	460.6	13.6	3.0	-60.3
16Mb Standard	1,600.8	5,712.9	17,641.4	15,091.6	14,212.6	12,775.7	10,313.3	4,376.2	445.3	-50.6
16Mb Display	-	-	-	-	-	811.9	1,311.0	1,956.5	480.4	-
64Mb Standard	-	-	4.3	668.6	3,721.6	9,679.9	20,688.8	38,697.1	29,595.6	113.4
128Mb Standard	-	-	-	-	-	-	46.6	387.0	591.9	-
256Mb Standard	-	-	-	-	-	310.1	5,778.8	22,231.1	31,082.2	-
Total	14,411.3	22,863.7	41,755.0	25,842.8	22,059.5	26,643.4	40,088.5	68,657.0	62,591.0	19.4
Growth (%)	68.8	58.7	82.6	-38.1	-14.6	20.8	50.5	71.3	-8.8	-

Source: Dataquest (October 1997)

Table 2-7
Worldwide DRAM Average Selling Price Forecast, 1993 to 2001 (U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
64K Standard	1.12	1.20	-	-	-	-	-	-	-	-
256K Standard	1.54	1.61	1.73	1.81	1.56	-	-	-	-	-100.0
256K Display	3.04	2.92	2.96	1.84	2.56	2.56	2.56	2.56	2.56	6.9
1Mb Standard	3.38	4.10	4.07	3.09	1.99	1.76	1.74	1.69	1.57	-12.6
1Mb Display	6.31	6.10	5.97	5.91	5.24	4.60	4.15	3.47	3.25	-11.3
2Mb DRAM	12.88	11.40	11.19	4.06	9.68	9.08	7.06	6.09	5.00	4.3
4Mb Standard	11.59	12.73	13.21	6.34	2.38	2.12	2.07	2.05	1.85	-21.9
4Mb Display	33.88	28.38	23.45	16.02	9.70	9.14	9.05	8.69	8.00	-13.0
8Mb Display	-	-	-	14.38	8.00	5.81	5.00	4.00	3.00	-26.9
16Mb Standard	74.27	52.84	51.77	15.15	7.50	5.59	5.50	5.25	3.00	-27.7
16Mb Display	-	-	-	-	-	19.38	10.00	8.00	6.00	-
64Mb Standard	-	-	483.82	99.42	42.00	27.06	22.00	21.00	12.00	-34.5
128Mb Standard	-	-	-	-	-	-	77.63	42.00	24.00	-
256Mb Standard	-	-	-	-	-	496.36	238.78	127.64	54.91	-
Total	8.95	12.66	16.61	9.69	6.96	7.69	11.85	20.48	18.45	13.7
Growth (%)	54.6	41.5	31.2	-41.6	-28.2	10.6	54.0	72.8	-9.9	-

Source: Dataquest (October 1997)

Table 2-8
Worldwide DRAM Unit Shipment Forecast, 1993 to 2001 (Millions of Units Shipped)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
64K Standard	4.7	2.7	1.2	-	-	-	-	-	-	-
256K Standard	71.0	33.3	31.8	11.2	0.9	-	-	-	-	-100.0
256K Display	33.8	21.6	16.7	7.8	6.0	2.3	2.1	1.0	1.0	-33.3
1Mb Standard	478.6	376.0	455.2	216.7	146.5	121.0	98.3	48.1	10.6	-45.3
1Mb Display	122.9	92.8	1.7	42.4	28.5	20.0	14.1	10.0	9.0	-26.6
2Mb DRAM	18.4	35.9	51.9	61.0	51.0	42.0	31.7	24.0	20.6	-19.5
4Mb Standard	858.8	1,131.4	1,592.8	1,271.1	817.4	376.7	77.4	101.6	44.9	-48.8
4Mb Display	0.4	3.9	22.3	32.1	75.8	96.4	96.2	60.1	19.7	-9.3
8Mb Display	-	-	-	21.1	61.9	119.3	92.1	3.4	1.0	-45.6
16Mb Standard	21.6	108.1	340.8	996.3	1,895.3	2,285.8	1,875.1	833.6	148.4	-31.7
16Mb Display	-	-	-	-	-	41.9	131.1	244.6	80.1	-
64Mb Standard	-	-	0	6.7	88.6	357.7	940.4	1,842.7	2,466.3	225.7
128Mb Standard	-	-	-	-	-	-	0.6	9.2	24.7	-
256Mb Standard	-	-	-	-	-	0.6	24.2	174.2	566.1	-
Total	**1,610.2**	**1,805.7**	**2,514.3**	**2,666.3**	**3,171.8**	**3,463.6**	**3,383.3**	**3,352.4**	**3,392.5**	**4.9**
Growth (%)	**9.2**	**12.1**	**39.2**	**6.0**	**19.0**	**9.2**	**-2.3**	**-0.9**	**1.2**	**-**

Source: Dataquest (October 1997)

Table 2-9
Worldwide DRAM Megabyte Shipment Forecast, 1993 to 2001 (Millions of Megabytes Shipped)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
64K Standard	0	0	0	-	-	-	-	-	-	-
256K Standard	2.2	1.0	1.0	0.4	0	-	-	-	-	-100.0
256K Display	1.1	0.7	0.5	0.2	0.2	0.1	0.1	0	0	-33.3
1Mb Standard	59.8	47.0	56.9	27.1	18.3	15.1	12.3	6.0	1.3	-45.3
1Mb Display	15.4	11.6	0.2	5.3	3.6	2.5	1.8	1.3	1.1	-26.6
2Mb DRAM	4.6	9.0	13.0	15.2	12.8	10.5	7.9	6.0	5.2	-19.5
4Mb Standard	429.4	565.7	796.4	635.5	408.7	188.3	38.7	50.8	22.5	-48.8
4Mb Display	0.2	2.0	11.1	16.1	37.9	48.2	48.1	30.1	9.9	-9.3
8Mb Display	-	-	-	21.1	61.9	119.3	92.1	3.4	1.0	-45.6
16Mb Standard	43.1	216.2	681.5	1,992.6	3,790.6	4,571.5	3,750.3	1,667.1	296.9	-31.7
16Mb Display	-	-	-	-	-	83.8	262.2	489.1	160.1	-
64Mb Standard	-	-	0.1	53.8	708.9	2,861.6	7,523.2	14,741.8	19,730.4	225.7
128Mb Standard	-	-	-	-	-	-	9.6	147.4	394.6	-
256Mb Standard	-	-	-	-	-	20.0	774.4	5,573.3	18,113.7	-
Total	555.8	853.2	1,560.8	2,767.3	5,042.7	7,920.9	12,520.7	22,716.2	38,736.8	69.5
Growth (%)	64.7	53.5	82.9	77.3	82.2	57.1	58.1	81.4	70.5	-

Source: Dataquest (October 1997)

Table 2-10
Worldwide DRAM Price-per-Megabyte Forecast, 1993 to 2001 (U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
64K Standard	143.76	153.60	-	-	-	-	-	-	-	-
256K Standard	49.31	51.62	55.26	58.06	50.05	-	-	-	-	-100.0
256K Display	97.28	93.56	94.74	58.79	81.88	81.88	81.88	81.88	81.88	6.9
1Mb Standard	27.05	32.80	32.53	24.73	15.89	14.11	13.93	13.55	12.59	-12.6
1Mb Display	50.44	48.80	47.76	47.28	41.95	36.83	33.20	27.74	26.00	-11.3
2Mb DRAM	51.52	45.60	44.78	16.23	38.73	36.32	28.23	24.37	20.00	4.3
4Mb Standard	23.17	25.46	26.42	12.69	4.76	4.24	4.14	4.10	3.69	-21.9
4Mb Display	67.76	56.76	46.89	32.04	19.40	18.28	18.10	17.39	16.00	-13.0
8Mb Display	-	-	-	14.38	8.00	5.81	5.00	4.00	3.00	-26.9
16Mb Standard	37.13	26.42	25.89	7.57	3.75	2.80	2.75	2.63	1.50	-27.7
16Mb Display	-	-	-	-	-	9.69	5.00	4.00	3.00	-
64Mb Standard	-	-	60.48	12.43	5.25	3.38	2.75	2.63	1.50	-34.5
128Mb Standard	-	-	-	-	-	-	4.85	2.63	1.50	-
256Mb Standard	-	-	-	-	-	15.51	7.46	3.99	1.72	-
Total	25.93	26.80	26.75	9.34	4.38	3.36	3.20	3.02	1.62	-29.6
Growth (%)	2.5	3.4	-0.2	-65.1	-53.2	-23.1	-4.8	-5.6	-46.5	-

Source: Dataquest (October 1997)

Table 2-11
Worldwide SRAM Revenue Forecast, 1993 to 2001 (Millions of U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
16K										
0-9ns SRAM	-	-	-	-	-	-	-	-	-	-
10-19ns SRAM	3.3	4.3	4.7	0.5	0.8	0.5	0.3	0.2	0.2	-18.6
20-44ns SRAM	12.5	16.5	7.8	4.1	3.3	2.5	2.1	1.8	1.3	-21.3
45-70ns SRAM	3.6	4.6	1.4	1.5	0.7	0.4	0.1	0.1	0.1	-38.9
71ns+ SRAM	100.9	80.8	54.0	10.4	6.0	3.9	2.0	1.8	1.1	-36.2
Pseudo	-	-	-	-	-	-	-	-	-	-
16K Total	**120.3**	**106.2**	**67.8**	**16.5**	**10.8**	**7.3**	**4.6**	**3.8**	**2.6**	**-30.6**
64K										
0-9ns SRAM	25.5	8.6	-	1.0	3.7	9.7	11.5	10.4	6.6	46.0
10-19ns SRAM	23.6	46.7	94.0	62.6	4.9	4.3	3.1	2.3	2.4	-47.7
20-44ns SRAM	119.1	98.4	79.2	52.6	7.5	4.5	4.4	4.9	4.6	-38.6
45-70ns SRAM	27.6	24.1	72.6	25.2	11.5	7.9	6.1	5.9	4.7	-28.5
71ns+ SRAM	437.9	273.3	226.4	183.5	88.6	57.6	41.9	37.8	29.6	-30.6
Pseudo	7.0	7.9	10.2	5.2	-	-	-	-	-	-100.0
64K Total	**640.8**	**459.1**	**482.3**	**330.1**	**116.3**	**84.0**	**67.0**	**61.3**	**47.9**	**-32.0**
256K										
0-9ns SRAM	8.9	11.1	134.8	29.2	14.8	10.8	6.0	5.2	4.1	-32.6
10-19ns SRAM	65.7	302.5	969.0	390.6	82.4	45.8	25.4	17.7	10.9	-51.1
20-44ns SRAM	394.4	429.3	349.0	142.4	35.7	21.4	15.5	12.8	11.3	-39.8
45-70ns SRAM	90.6	157.1	234.9	105.2	78.7	50.9	38.8	30.2	24.1	-25.5
71ns+ SRAM	813.1	675.5	511.2	533.1	366.4	292.4	224.7	183.6	132.6	-24.3
Pseudo	140.8	118.9	89.5	28.2	23.3	20.2	11.7	3.2	2.2	-40.0
256K Total	**1,513.4**	**1,694.4**	**2,288.4**	**1,228.7**	**601.4**	**441.5**	**322.0**	**252.6**	**185.1**	**-31.5**

Table 2-11 (Continued)
Worldwide SRAM Revenue Forecast, 1993 to 2001 (Millions of U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
512K and 1Mb										
0-9ns SRAM	33.5	105.6	185.7	307.2	268.4	239.8	237.9	179.4	138.4	-14.7
10-19ns SRAM	197.3	327.9	1,291.2	1,072.7	313.0	295.1	331.9	348.3	428.7	-16.8
20-44ns SRAM	124.1	226.3	264.7	481.8	246.4	199.4	160.9	127.0	73.3	-31.4
45-70ns SRAM	100.3	81.1	494.8	79.5	28.1	17.1	11.6	8.6	7.1	-38.4
71ns+ SRAM	496.6	550.2	627.3	736.6	742.9	657.3	622.8	669.2	550.7	-5.7
Pseudo	72.9	72.0	85.5	87.2	66.6	42.6	31.0	26.4	23.7	-22.9
512K and 1Mb Total	**1,024.7**	**1,363.0**	**2,949.3**	**2,765.0**	**1,665.5**	**1,451.3**	**1,396.1**	**1,358.8**	**1,221.9**	**-15.1**
2Mb and 4Mb										
0-9ns SRAM	-	-	-	10.2	400.1	397.6	387.7	435.5	477.5	115.6
10-19ns SRAM	12.0	5.1	23.8	62.1	366.5	616.8	701.9	946.6	1,330.9	84.6
20-44ns SRAM	3.8	124.6	48.3	77.1	359.2	696.0	922.9	1,368.2	1,806.7	87.9
45-70ns SRAM	15.5	-	62.8	9.5	23.7	28.8	44.9	66.5	89.3	56.7
71ns+ SRAM	50.5	190.4	77.1	183.4	440.8	708.5	1,191.5	1,745.0	2,250.9	65.1
Pseudo	104.1	123.9	132.0	26.6	3.6	1.5	1.1	1.1	0.9	-48.7
2Mb and 4Mb Total	**185.7**	**444.0**	**343.9**	**368.9**	**1,593.9**	**2,449.2**	**3,250.0**	**4,563.0**	**5,956.2**	**74.4**
16Mb										
0-9ns SRAM	-	-	-	-	-	28.9	79.5	134.2	210.9	-
10-19ns SRAM	-	-	-	-	-	77.4	147.5	453.9	776.2	-
20-44ns SRAM	-	-	-	-	-	75.1	147.1	516.6	756.6	-
45-70ns SRAM	-	-	-	-	-	53.2	252.9	471.3	731.2	-
71ns+ SRAM	-	-	-	-	-	172.1	379.1	663.5	1,419.9	-
Pseudo	-	-	-	-	-	-	-	-	-	-
16Mb Total	-	-	-	-	-	**406.7**	**1,006.2**	**2,239.5**	**3,894.9**	-
Grand Total	**3,484.9**	**4,066.7**	**6,131.8**	**4,709.2**	**3,987.8**	**4,840.1**	**6,045.9**	**8,479.1**	**11,308.8**	**19.2**
Growth (%)	**16.5**	**16.7**	**50.8**	**-23.2**	**-15.3**	**21.4**	**24.9**	**40.2**	**33.4**	-

Source: Dataquest (October 1997)

Table 2-12
Worldwide SRAM Average Selling Price Forecast, 1993 to 2001 (U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
16K										
0-9ns SRAM	-	-	-	-	-	-	-	-	-	-
10-19ns SRAM	2.59	2.49	2.72	1.38	2.76	3.00	3.00	3.00	3.00	16.7
20-44ns SRAM	1.82	2.35	2.62	0.82	2.35	2.46	2.50	2.50	2.50	25.0
45-70ns SRAM	1.25	1.90	1.10	0.92	0.96	1.04	1.10	1.10	1.10	3.6
71ns+ SRAM	2.14	2.25	1.88	0.81	0.96	1.04	1.10	1.10	1.10	6.3
Pseudo	-	-	-	-	-	-	-	-	-	-
16K Total	**2.07**	**2.26**	**1.95**	**0.83**	**1.24**	**1.38**	**1.58**	**1.55**	**1.58**	13.8
64K										
0-9ns SRAM	14.78	13.10	-	2.18	4.67	4.70	4.89	4.92	5.03	18.2
10-19ns SRAM	2.56	2.80	2.12	2.08	1.02	1.09	1.23	1.30	1.35	-8.2
20-44ns SRAM	2.07	1.95	2.11	1.79	1.28	1.02	1.17	1.31	1.31	-6.1
45-70ns SRAM	1.70	1.60	1.35	2.20	1.31	1.25	1.23	1.31	1.31	-9.8
71ns+ SRAM	2.00	1.80	1.45	1.73	1.31	1.25	1.23	1.31	1.31	-5.4
Pseudo	1.49	1.65	2.54	2.10	-	-	-	-	-	-100.0
64K Total	**2.08**	**1.92**	**1.63**	**1.83**	**1.30**	**1.33**	**1.40**	**1.50**	**1.46**	-4.4
256K										
0-9ns SRAM	13.52	16.60	21.01	7.09	4.55	4.29	2.65	2.30	2.05	-22.0
10-19ns SRAM	6.73	7.29	3.28	2.10	1.07	1.12	1.32	1.54	1.70	-4.1
20-44ns SRAM	4.29	3.86	3.14	2.54	1.07	1.12	1.32	1.54	1.70	-7.7
45-70ns SRAM	3.15	3.23	2.79	2.37	1.25	1.11	1.27	1.33	1.54	-8.3
71ns+ SRAM	3.33	3.19	2.86	2.32	1.52	1.52	1.52	1.52	1.52	-8.2
Pseudo	2.25	2.29	2.46	2.21	2.04	2.00	2.00	2.00	2.00	-2.0
256K Total	**3.46**	**3.64**	**3.21**	**2.31**	**1.40**	**1.42**	**1.48**	**1.51**	**1.56**	-7.6

Table 2-12 (Continued)
Worldwide SRAM Average Selling Price Forecast, 1993 to 2001 (U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
512K and 1Mb										
0-9ns SRAM	186.11	162.66	72.17	18.66	11.60	7.89	6.78	5.97	4.84	-23.6
10-19ns SRAM	73.50	61.42	30.84	14.12	3.11	2.75	2.84	2.81	3.45	-24.6
20-44ns SRAM	16.42	14.27	11.30	8.74	3.89	3.39	3.26	3.23	3.41	-17.2
45-70ns SRAM	8.74	8.89	10.10	8.17	3.89	3.36	3.21	3.13	3.30	-16.6
71ns+ SRAM	9.11	8.83	7.36	5.77	3.97	3.36	3.21	3.13	3.30	-10.6
Pseudo	4.15	3.95	4.42	4.20	3.80	3.69	3.78	3.69	3.69	-2.6
512K and 1Mb Total	**10.90**	**12.22**	**13.32**	**9.05**	**4.17**	**3.55**	**3.43**	**3.26**	**3.49**	**-17.3**
2Mb and 4Mb										
0-9ns SRAM	-	-	-	48.21	38.84	19.55	16.36	15.52	13.93	-22.0
10-19ns SRAM	500.00	189.44	193.17	62.98	19.53	16.91	13.42	12.55	12.30	-27.9
20-44ns SRAM	250.00	160.74	98.21	34.63	17.76	15.63	12.70	11.55	11.33	-20.0
45-70ns SRAM	150.00	-	68.36	21.89	16.27	13.45	12.64	11.45	11.13	-12.7
71ns+ SRAM	103.87	98.92	72.35	11.99	16.27	13.07	12.64	11.45	11.13	-1.5
Pseudo	13.16	13.05	13.52	34.13	6.53	5.45	5.40	5.38	5.38	-30.9
2Mb and 4Mb Total	**21.77**	**36.34**	**27.83**	**18.51**	**20.33**	**15.51**	**13.18**	**12.00**	**11.62**	**-8.9**
16Mb										
0-9ns SRAM	-	-	-	-	-	532.88	298.49	174.80	110.00	-
10-19ns SRAM	-	-	-	-	-	126.88	71.07	62.37	45.00	-
20-44ns SRAM	-	-	-	-	-	88.15	73.91	59.37	35.00	-
45-70ns SRAM	-	-	-	-	-	38.06	36.75	27.75	20.00	-
71ns+ SRAM	-	-	-	-	-	36.92	29.40	22.20	22.20	-
Pseudo	-	-	-	-	-	-	-	-	-	-
16Mb Total	-	-	-	-	-	**53.69**	**41.73**	**35.20**	**27.56**	-
Grand Total	**3.85**	**4.64**	**4.80**	**4.45**	**3.97**	**5.07**	**6.39**	**7.92**	**9.77**	**17.0**
Growth (%)	**8.2**	**20.7**	**3.4**	**-7.3**	**-10.8**	**27.8**	**26.0**	**23.9**	**23.5**	-

Source: Dataquest (October 1997)

Table 2-13
Worldwide SRAM Unit Shipment Forecast, 1993 to 2001 (Millions of Units Shipped)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
16K										
0-9ns SRAM	-	-	-	-	-	-	-	-	-	-
10-19ns SRAM	1.3	1.7	1.7	0.3	0.3	0.2	0.1	0.1	0.1	-30.2
20-44ns SRAM	6.9	7.0	3.0	5.1	1.4	1.0	0.9	0.7	0.5	-37.1
45-70ns SRAM	2.9	2.4	1.3	1.6	0.8	0.3	0.1	0.1	0.1	-41.0
71ns+ SRAM	47.2	35.9	28.8	12.8	6.3	3.8	1.8	1.6	1.0	-40.0
Pseudo	-	-	-	-	-	-	-	-	-	-
16K Total	**58.2**	**47.1**	**34.8**	**19.8**	**8.7**	**5.3**	**2.9**	**2.5**	**1.7**	**-39.0**
64K										
0-9ns SRAM	1.7	0.7	-	0.5	0.8	2.1	2.3	2.1	1.3	23.5
10-19ns SRAM	9.2	16.7	44.3	30.1	4.9	3.9	2.5	1.8	1.8	-43.1
20-44ns SRAM	57.4	50.4	37.5	29.3	5.9	4.4	3.8	3.7	3.5	-34.6
45-70ns SRAM	16.2	15.1	53.8	11.5	8.8	6.3	5.0	4.5	3.6	-20.7
71ns+ SRAM	218.7	151.8	156.6	106.2	67.7	46.1	34.1	28.8	22.5	-26.6
Pseudo	4.7	4.8	4.0	2.5	1.2	0.5	0.2	-	-	-100.0
64K Total	**308.1**	**239.5**	**296.2**	**180.0**	**89.2**	**63.3**	**47.9**	**40.9**	**32.8**	**-28.9**
256K										
0-9ns SRAM	0.7	0.7	6.4	4.1	3.2	2.5	2.2	2.3	2.0	-13.5
10-19ns SRAM	9.8	41.5	295.4	186.0	77.0	40.9	19.2	11.5	6.4	-49.0
20-44ns SRAM	91.9	111.3	111.1	56.1	33.4	19.1	11.7	8.3	6.6	-34.8
45-70ns SRAM	28.7	48.7	84.2	44.4	62.9	45.8	30.6	22.7	15.7	-18.8
71ns+ SRAM	243.9	211.6	178.6	229.4	241.3	192.5	147.9	120.9	87.3	-17.6
Pseudo	62.6	52.0	36.4	12.8	11.4	10.1	5.9	1.6	1.1	-38.7
256K Total	437.6	465.7	712.2	532.7	429.2	311.0	217.6	167.2	119.1	-25.9

Table 2-13 (Continued)
Worldwide SRAM Unit Shipment Forecast, 1993 to 2001 (Millions of Units Shipped)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
512K and 1Mb										
0-9ns SRAM	0.2	0.6	2.6	16.5	23.1	30.4	35.1	30.1	28.6	11.7
10-19ns SRAM	2.7	5.3	41.9	76.0	100.7	107.3	117.0	123.9	124.3	10.3
20-44ns SRAM	7.6	15.9	23.4	55.1	63.3	58.8	49.3	39.3	21.5	-17.2
45-70ns SRAM	11.5	9.1	49.0	9.7	7.2	5.1	3.6	2.7	2.1	-26.2
71ns+ SRAM	54.5	62.3	85.2	127.6	187.3	195.9	194.0	213.5	166.9	5.5
Pseudo	17.6	18.2	19.4	20.8	17.5	11.5	8.2	7.1	6.4	-20.9
512K and 1Mb Total	**94.0**	**111.5**	**221.4**	**305.7**	**399.1**	**409.1**	**407.2**	**416.7**	**349.8**	**2.7**
2Mb and 4Mb										
0-9ns SRAM	-	-	-	0.2	10.3	20.3	23.7	28.1	34.3	176.4
10-19ns SRAM	0	0	0.1	1.0	18.8	36.5	52.3	75.4	108.2	155.9
20-44ns SRAM	0	0.8	0.5	2.2	20.2	44.5	72.6	118.4	159.5	135.0
45-70ns SRAM	0.1	-	0.9	0.4	1.5	2.1	3.6	5.8	8.0	79.4
71ns+ SRAM	0.5	1.9	1.1	15.3	27.1	54.2	94.3	152.3	202.3	67.6
Pseudo	7.9	9.5	9.8	0.8	0.6	0.3	0.2	0.2	0.2	-25.7
2Mb and 4Mb Total	**8.5**	**12.2**	**12.4**	**19.9**	**78.4**	**158.0**	**246.7**	**380.3**	**512.4**	**91.4**
16Mb										
0-9ns SRAM	-	-	-	-	-	0.1	0.3	0.8	1.9	-
10-19ns SRAM	-	-	-	-	-	0.6	2.1	7.3	17.2	-
20-44ns SRAM	-	-	-	-	-	0.9	2.0	8.7	21.6	-
45-70ns SRAM	-	-	-	-	-	1.4	6.9	17.0	36.6	-
71ns+ SRAM	-	-	-	-	-	4.7	12.9	29.9	64.0	-
Pseudo	-	-	-	-	-	-	-	-	-	-
16Mb Total	-	-	-	-	-	**7.6**	**24.1**	**63.6**	**141.3**	-
Grand Total	**906.4**	**876.1**	**1,277.0**	**1,058.2**	**1,004.6**	**954.2**	**946.3**	**1,071.2**	**1,157.1**	**1.8**
Growth (%)	**7.6**	**-3.3**	**45.8**	**-17.1**	**-5.1**	**-5.0**	**-0.8**	**13.2**	**8.0**	-

Source: Dataquest (October 1997)

Table 2-14
Worldwide SRAM Megabyte Shipment Forecast, 1993 to 2001 (Millions of Megabytes Shipped)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
16K										
0-9ns SRAM	-	-	-	-	-	-	-	-	-	-
10-19ns SRAM	0	0	0	0	0	0	0	0	0	-30.2
20-44ns SRAM	0	0	0	0	0	0	0	0	0	-37.1
45-70ns SRAM	0	0	0	0	0	0	0	0	0	-41.0
71ns+ SRAM	0.1	0.1	0.1	0	0	0	0	0	0	-40.0
Pseudo	-	-	-	-	-	-	-	-	-	-
16K Total	0.1	0.1	0.1	0	0	0	0	0	0	-39.0
64K										
0-9ns SRAM	0	0	-	0	0	0	0	0	0	23.5
10-19ns SRAM	0.1	0.1	0.3	0.2	0	0	0	0	0	-43.1
20-44ns SRAM	0.4	0.4	0.3	0.2	0	0	0	0	0	-34.6
45-70ns SRAM	0.1	0.1	0.4	0.1	0.1	0	0	0	0	-20.7
71ns+ SRAM	1.7	1.2	1.2	0.8	0.5	0.4	0.3	0.2	0.2	-26.6
Pseudo	0	0	0	0	0	0	0	-	-	-100.0
64K Total	2.4	1.9	2.3	1.4	0.7	0.5	0.4	0.3	0.3	-28.9
256K										
0-9ns SRAM	0	0	0.2	0.1	0.1	0.1	0.1	0.1	0.1	-13.5
10-19ns SRAM	0.3	1.3	9.2	5.8	2.4	1.3	0.6	0.4	0.2	-49.0
20-44ns SRAM	2.9	3.5	3.5	1.8	1.0	0.6	0.4	0.3	0.2	-34.8
45-70ns SRAM	0.9	1.5	2.6	1.4	2.0	1.4	1.0	0.7	0.5	-18.8
71ns+ SRAM	7.6	6.6	5.6	7.2	7.5	6.0	4.6	3.8	2.7	-17.6
Pseudo	2.0	1.6	1.1	0.4	0.4	0.3	0.2	0	0	-38.7
256K Total	13.7	14.6	22.3	16.6	13.4	9.7	6.8	5.2	3.7	-25.9

Table 2-14 (Continued)
Worldwide SRAM Megabyte Shipment Forecast, 1993 to 2001 (Millions of Megabytes Shipped)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
512K and 1Mb										
0-9ns SRAM	0	0.1	0.3	2.1	2.9	3.8	4.4	3.8	3.6	11.7
10-19ns SRAM	0.3	0.7	5.2	9.5	12.6	13.4	14.6	15.5	15.5	10.3
20-44ns SRAM	0.9	2.0	2.9	6.9	7.9	7.4	6.2	4.9	2.7	-17.2
45-70ns SRAM	1.4	1.1	6.1	1.2	0.9	0.6	0.5	0.3	0.3	-26.2
71ns+ SRAM	6.8	7.8	10.7	15.9	23.4	24.5	24.2	26.7	20.9	5.5
Pseudo	2.2	2.3	2.4	2.6	2.2	1.4	1.0	0.9	0.8	-20.9
512K and 1Mb Total	**11.7**	**13.9**	**27.7**	**38.2**	**49.9**	**51.1**	**50.9**	**52.1**	**43.7**	**2.7**
2Mb and 4Mb										
0-9ns SRAM	-	-	-	0.1	5.2	10.2	11.8	14.0	17.1	176.4
10-19ns SRAM	0	0	0.1	0.5	9.4	18.2	26.1	37.7	54.1	155.9
20-44ns SRAM	0	0.4	0.2	1.1	10.1	22.3	36.3	59.2	79.7	135.0
45-70ns SRAM	0.1	-	0.5	0.2	0.7	1.1	1.8	2.9	4.0	79.4
71ns+ SRAM	0.2	1.0	0.5	7.6	13.5	27.1	47.1	76.2	101.1	67.6
Pseudo	4.0	4.7	4.9	0.4	0.3	0.1	0.1	0.1	0.1	-25.7
2Mb and 4Mb Total	**4.3**	**6.1**	**6.2**	**10.0**	**39.2**	**79.0**	**123.3**	**190.1**	**256.2**	**91.4**
16Mb										
0-9ns SRAM	-	-	-	-	-	0.1	0.5	1.5	3.8	-
10-19ns SRAM	-	-	-	-	-	1.2	4.2	14.6	34.5	-
20-44ns SRAM	-	-	-	-	-	1.7	4.0	17.4	43.2	-
45-70ns SRAM	-	-	-	-	-	2.8	13.8	34.0	73.1	-
71ns+ SRAM	-	-	-	-	-	9.3	25.8	59.8	127.9	-
Pseudo	-	-	-	-	-	-	-	-	-	-
16Mb Total	-	-	-	-	-	**15.2**	**48.2**	**127.2**	**282.6**	-
Grand Total	**32.2**	**36.6**	**58.5**	**66.3**	**103.2**	**155.5**	**229.6**	**375.0**	**586.5**	**54.7**
Growth (%)	**44.9**	**13.5**	**60.0**	**13.3**	**55.8**	**50.6**	**47.7**	**63.3**	**56.4**	-

Source: Dataquest (October 1997)

Table 2-15
Worldwide SRAM Price-per-Megabyte Forecast, 1993 to 2001 (U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
16K										
0-9ns SRAM	-	-	-	-	-	-	-	-	-	-
10-19ns SRAM	1,326.77	1,273.09	1,392.64	708.81	1,411.98	1,536.00	1,536.00	1,536.00	1,536.00	16.7
20-44ns SRAM	929.09	1,203.20	1,341.44	419.53	1,201.15	1,259.52	1,280.00	1,280.00	1,280.00	25.0
45-70ns SRAM	640.00	972.80	563.20	471.84	490.95	532.58	563.20	563.20	563.20	3.6
71ns+ SRAM	1,093.96	1,152.00	960.00	414.28	490.95	532.58	563.20	563.20	563.20	6.3
Pseudo	-	-	-	-	-	-	-	-	-	-
16K Total	**1,057.27**	**1,154.92**	**999.47**	**425.31**	**635.57**	**707.48**	**809.64**	**792.74**	**811.05**	**13.8**
64K										
0-9ns SRAM	1,891.65	1,677.13	-	279.19	597.14	601.58	626.49	629.76	643.84	18.2
10-19ns SRAM	327.13	358.40	271.36	266.04	130.15	139.63	157.35	165.95	173.24	-8.2
20-44ns SRAM	265.33	249.70	270.08	229.53	163.97	130.70	150.28	167.80	167.80	-6.1
45-70ns SRAM	217.93	204.83	172.80	281.51	167.68	160.00	157.35	167.80	167.80	-9.8
71ns+ SRAM	256.28	230.40	185.04	221.20	167.68	160.00	157.35	167.80	167.80	-5.4
Pseudo	190.78	211.20	325.12	268.33	-	-	-	-	-	-100.0
64K Total	**266.23**	**245.34**	**208.41**	**234.70**	**166.89**	**169.87**	**179.17**	**191.62**	**187.16**	**-4.4**
256K										
0-9ns SRAM	432.73	531.29	672.32	226.84	145.52	137.38	84.73	73.58	65.47	-22.0
10-19ns SRAM	215.48	233.26	104.96	67.22	34.24	35.84	42.24	49.28	54.54	-4.1
20-44ns SRAM	137.25	123.44	100.48	81.29	34.24	35.84	42.24	49.28	54.54	-7.7
45-70ns SRAM	100.90	103.24	89.28	75.76	40.06	35.52	40.64	42.56	49.15	-8.3
71ns+ SRAM	106.67	102.16	91.57	74.37	48.60	48.60	48.60	48.60	48.60	-8.2
Pseudo	72.00	73.22	78.72	70.71	65.38	64.00	64.00	64.00	64.00	-2.0
256K Total	**110.68**	**116.43**	**102.82**	**73.81**	**44.84**	**45.43**	**47.36**	**48.35**	**49.75**	**-7.6**

Table 2-15 (Continued)
Worldwide SRAM Price-per-Megabyte Forecast, 1993 to 2001 (U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
512K and 1Mb										
0-9ns SRAM	1,488.89	1,301.31	577.36	149.24	92.79	63.14	54.28	47.75	38.74	-23.6
10-19ns SRAM	588.00	491.36	246.72	112.94	24.88	22.00	22.70	22.49	27.60	-24.6
20-44ns SRAM	131.36	114.20	90.40	69.92	31.12	27.12	26.08	25.84	27.28	-17.2
45-70ns SRAM	69.95	71.12	80.80	65.38	31.12	26.84	25.69	25.07	26.40	-16.6
71ns+ SRAM	72.87	70.60	58.90	46.18	31.74	26.84	25.69	25.07	26.40	-10.6
Pseudo	33.20	31.59	35.36	33.61	30.41	29.54	30.22	29.52	29.52	-2.6
512K and 1Mb Total	**87.23**	**97.76**	**106.56**	**72.37**	**33.38**	**28.38**	**27.43**	**26.09**	**27.95**	**-17.3**
2Mb and 4Mb										
0-9ns SRAM	-	-	-	96.43	77.68	39.10	32.72	31.05	27.85	-22.0
10-19ns SRAM	1,000.00	378.89	386.34	125.96	39.05	33.81	26.85	25.10	24.61	-27.9
20-44ns SRAM	500.00	321.48	196.42	69.26	35.51	31.26	25.41	23.11	22.66	-20.0
45-70ns SRAM	300.00	-	136.72	43.77	32.54	26.89	25.28	22.91	22.26	-12.7
71ns+ SRAM	207.75	197.84	144.70	23.98	32.54	26.15	25.28	22.91	22.26	-1.5
Pseudo	26.33	26.11	27.04	68.26	13.07	10.89	10.80	10.76	10.76	-30.9
2Mb and 4Mb Total	**43.54**	**72.68**	**55.65**	**37.01**	**40.66**	**31.01**	**26.35**	**24.00**	**23.25**	**-8.9**
16Mb										
0-9ns SRAM	-	-	-	-	-	266.44	149.25	87.40	55.00	-
10-19ns SRAM	-	-	-	-	-	63.44	35.54	31.18	22.50	-
20-44ns SRAM	-	-	-	-	-	44.08	36.96	29.68	17.50	-
45-70ns SRAM	-	-	-	-	-	19.03	18.38	13.88	10.00	-
71ns+ SRAM	-	-	-	-	-	18.46	14.70	11.10	11.10	-
Pseudo	-	-	-	-	-	-	-	-	-	-
16Mb Total	-	-	-	-	-	**26.85**	**20.87**	**17.60**	**13.78**	-
Grand Total	108.20	111.21	104.83	71.06	38.63	31.13	26.33	22.61	19.28	-23.0
Growth (%)	-19.6	2.8	-5.7	-32.2	-45.6	-19.4	-15.4	-14.1	-14.7	-

Source: Dataquest (October 1997)

Table 2-16
Worldwide EPROM Revenue Forecast, 1993 to 2001 (Millions of U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
16K	11.8	10.2	9.0	5.1	3.6	3.3	2.8	2.7	2.4	-13.7
32K	17.1	8.4	8.2	4.0	2.3	1.7	1.6	1.5	1.4	-18.9
64K	49.8	41.1	43.7	32.2	20.6	13.1	11.9	11.1	8.8	-22.8
128K	37.0	26.0	24.2	11.7	7.0	6.0	5.6	5.6	5.2	-15.0
256K	258.4	276.2	230.0	211.1	115.3	88.4	72.7	63.7	59.9	-22.3
512K	293.4	284.5	258.3	227.3	99.3	71.2	57.5	48.5	44.9	-27.7
1Mb	303.6	276.2	211.6	253.6	85.6	56.2	46.5	39.1	36.3	-32.2
2Mb	117.9	131.6	179.0	154.0	84.9	55.4	47.1	38.8	32.6	-26.7
4Mb	328.3	389.0	345.7	345.3	251.7	267.3	289.2	293.6	289.7	-3.5
8Mb	-	0.8	26.8	23.6	25.9	42.0	61.5	82.8	111.9	36.5
16Mb	-	-	-	3.0	17.2	29.8	46.0	71.6	110.5	105.1
Total	**1,417.3**	**1,444.0**	**1,336.6**	**1,271.0**	**713.4**	**634.4**	**642.4**	**658.9**	**703.6**	**-11.2**
Growth (%)	**15.7**	**1.9**	**-7.4**	**-4.9**	**-43.9**	**-11.1**	**1.3**	**2.6**	**6.8**	**-**

Source: Dataquest (October 1997)

Table 2-17
Worldwide EPROM Average Selling Price Forecast, 1993 to 2001 (U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
16K	2.16	2.37	2.04	2.00	1.99	2.32	2.46	2.71	2.71	6.3
32K	2.26	2.52	2.28	2.32	2.32	2.51	2.66	2.93	2.93	4.8
64K	1.60	1.51	1.55	1.65	1.72	1.90	2.01	2.21	2.21	6.1
128K	1.74	1.60	1.55	1.42	1.42	1.61	1.71	1.88	1.88	5.8
256K	1.81	1.95	1.59	1.83	1.35	1.29	1.22	1.20	1.20	-8.1
512K	2.54	2.43	1.85	1.97	1.41	1.34	1.29	1.26	1.25	-8.7
1Mb	3.09	3.25	2.52	2.60	1.87	1.72	1.68	1.63	1.60	-9.3
2Mb	5.31	5.25	4.72	4.10	2.83	2.38	2.36	2.31	2.31	-10.8
4Mb	10.34	10.30	9.01	6.60	4.19	3.48	3.21	3.09	3.01	-14.5
8Mb	-	19.75	14.42	10.37	6.81	5.19	4.52	4.06	3.84	-18.0
16Mb	-	-	-	25.25	17.18	12.94	10.64	9.20	8.51	-19.5
Total	**2.98**	**3.16**	**2.68**	**2.81**	**2.26**	**2.29**	**2.37**	**2.49**	**2.61**	-1.4
Growth (%)	2.9	5.9	-15.1	4.8	-19.7	1.3	3.9	4.8	5.1	-

Source: Dataquest (October 1997)

Table 2-18
Worldwide EPROM Unit Shipment Forecast, 1993 to 2001 (Millions of Units Shipped)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
16K	5.5	4.3	4.4	2.5	1.8	1.4	1.1	1.0	0.9	-18.8
32K	7.6	3.3	3.6	1.7	1.0	0.7	0.6	0.5	0.5	-22.6
64K	31.1	27.2	28.1	19.5	12.0	6.9	5.9	5.0	4.0	-27.2
128K	21.3	16.3	15.7	8.3	4.9	3.8	3.3	3.0	2.8	-19.6
256K	142.8	141.6	145.0	115.2	85.4	68.5	59.6	53.1	49.9	-15.4
512K	115.5	117.1	139.9	115.4	70.4	53.1	44.6	38.5	35.9	-20.8
1Mb	98.3	85.0	84.0	97.5	45.8	32.7	27.7	24.0	22.7	-25.3
2Mb	22.2	25.1	38.0	37.6	30.0	23.3	20.0	16.8	14.1	-17.8
4Mb	31.7	37.8	38.4	52.3	60.1	76.9	90.0	95.0	96.4	13.0
8Mb	-	0	1.9	2.3	3.8	8.1	13.6	20.4	29.2	66.5
16Mb	-	0	0	0.1	1.0	2.3	4.3	7.8	13.0	154.9
Total	475.9	457.7	498.8	452.5	316.2	277.7	270.7	264.9	269.3	-9.9
Growth (%)	12.4	-3.8	9.0	-9.3	-30.1	-12.2	-2.5	-2.1	1.6	-

Source: Dataquest (October 1997)

Table 2-19
Worldwide EPROM Megabyte Shipment Forecast, 1993 to 2001 (Millions of Megabytes Shipped)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
16K	0	0	0	0	0	0	0	0	0	-18.8
32K	0	0	0	0	0	0	0	0	0	-22.6
64K	0.2	0.2	0.2	0.2	0.1	0.1	0	0	0	-27.2
128K	0.3	0.3	0.2	0.1	0.1	0.1	0.1	0	0	-19.6
256K	4.5	4.4	4.5	3.6	2.7	2.1	1.9	1.7	1.6	-15.4
512K	7.2	7.3	8.7	7.2	4.4	3.3	2.8	2.4	2.2	-20.8
1Mb	12.3	10.6	10.5	12.2	5.7	4.1	3.5	3.0	2.8	-25.3
2Mb	5.6	6.3	9.5	9.4	7.5	5.8	5.0	4.2	3.5	-17.8
4Mb	15.9	18.9	19.2	26.2	30.1	38.5	45.0	47.5	48.2	13.0
8Mb	-	0	1.9	2.3	3.8	8.1	13.6	20.4	29.2	66.5
16Mb	-	0	0.1	0.2	2.0	4.6	8.6	15.5	26.0	154.9
Total	**46.0**	**48.0**	**54.9**	**61.4**	**56.3**	**66.6**	**80.5**	**94.8**	**113.5**	**13.1**
Growth (%)	**52.9**	**4.4**	**14.2**	**11.9**	**-8.2**	**18.3**	**20.7**	**17.8**	**19.8**	**-**

Source: Dataquest (October 1997)

Table 2-20
Worldwide EPROM Price-per-Megabyte Forecast, 1993 to 2001 (U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
16K	1,105.92	1,212.99	1,044.60	1,024.00	1,016.73	1,188.56	1,260.74	1,386.79	1,386.79	6.3
32K	578.56	645.21	583.95	592.65	594.36	642.85	681.89	750.07	750.07	4.8
64K	204.80	193.28	198.85	211.20	220.04	242.86	257.60	283.36	283.36	6.1
128K	111.36	102.40	98.87	90.58	91.05	102.86	109.10	120.01	120.01	5.8
256K	57.92	62.40	50.78	58.64	43.20	41.28	39.04	38.40	38.40	-8.1
512K	40.64	38.88	29.56	31.52	22.56	21.44	20.64	20.16	20.00	-8.7
1Mb	24.72	26.00	20.16	20.80	14.96	13.76	13.44	13.04	12.80	-9.3
2Mb	21.24	21.00	18.87	16.40	11.33	9.51	9.42	9.25	9.25	-10.8
4Mb	20.68	20.60	18.02	13.19	8.38	6.95	6.43	6.18	6.01	-14.5
8Mb	-	19.75	14.42	10.37	6.81	5.19	4.52	4.06	3.84	-18.0
16Mb	-	-	-	12.63	8.59	6.47	5.32	4.60	4.26	-19.5
Total	**30.81**	**30.05**	**24.37**	**20.71**	**12.67**	**9.52**	**7.98**	**6.95**	**6.20**	**-21.4**
Growth (%)	**-24.3**	**-2.4**	**-18.9**	**-15.0**	**-38.8**	**-24.9**	**-16.1**	**-12.9**	**-10.8**	**-**

Source: Dataquest (October 1997)

Table 2-21
Worldwide Flash Revenue Forecast, 1993 to 2001 (Millions of U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
256K	50.3	49.7	22.5	20.4	12.2	10.2	7.8	6.0	3.8	-28.4
512K	39.3	42.0	24.1	72.4	96.4	97.2	101.3	89.9	70.0	-0.7
1Mb	279.1	337.2	344.6	491.0	413.2	394.2	358.2	315.1	250.6	-12.6
2Mb	208.5	182.8	223.1	239.8	192.4	175.6	164.8	165.1	167.6	-7.5
4Mb	109.7	131.6	565.2	904.5	819.8	741.8	720.4	712.0	721.8	-4.4
8Mb	37.7	158.5	181.1	635.0	941.9	1,021.5	1,013.1	1,018.1	1,006.1	9.6
16Mb	0.9	90.1	485.1	453.8	453.5	611.3	826.0	1,037.9	1,186.2	21.2
32Mb	-	-	-	11.4	56.2	292.8	480.4	775.2	1,125.2	150.4
64Mb	-	-	-	-	8.3	72.5	419.1	839.3	1,197.2	-
128Mb	-	-	-	-	-	-	71.8	234.0	551.7	-
Total	**725.5**	**992.0**	**1,845.7**	**2,828.4**	**2,993.9**	**3,417.1**	**4,162.8**	**5,192.5**	**6,280.1**	**17.3**
Growth (%)	**182.6**	**36.7**	**86.1**	**53.2**	**5.9**	**14.1**	**21.8**	**24.7**	**20.9**	**-**

Source: Dataquest (October 1997)

Table 2-22
Worldwide Flash Average Selling Price Forecast, 1993 to 2001 (U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
256K	4.67	4.34	2.97	2.60	2.37	3.01	3.32	3.91	3.91	8.5
512K	5.76	4.52	3.13	3.10	2.53	2.16	2.15	2.14	2.14	-7.1
1Mb	7.43	4.93	3.32	3.43	2.58	2.19	2.18	2.17	2.16	-8.9
2Mb	15.39	9.91	6.69	6.60	4.01	3.17	2.78	2.62	2.58	-17.1
4Mb	26.89	15.89	10.09	9.72	5.52	4.12	3.57	3.27	3.13	-20.3
8Mb	31.58	24.85	15.01	12.89	6.98	5.45	4.63	4.19	3.89	-21.3
16Mb	85.00	61.41	40.82	29.68	13.87	9.75	7.73	6.68	5.94	-27.5
32Mb	-	-	-	51.99	29.58	19.10	13.87	11.14	9.62	-28.6
64Mb	-	-	-	-	81.10	48.64	32.81	24.83	19.95	-
128Mb	-	-	-	-	-	-	91.20	59.70	45.19	-
Total	9.81	8.02	7.94	7.68	5.26	4.68	4.90	5.32	5.75	-5.6
Growth (%)	7.1	-18.2	-1.0	-3.3	-31.5	-11.1	4.9	8.6	7.9	-

Source: Dataquest (October 1997)

Table 2-23
Worldwide Flash Unit Shipment Forecast, 1993 to 2001 (Millions of Units Shipped)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
256K	10.8	11.4	7.6	7.8	5.1	3.4	2.3	1.5	1.0	-34.0
512K	6.8	9.3	7.7	23.4	38.1	45.0	47.1	42.0	32.7	7.0
1Mb	37.6	68.4	103.9	143.0	160.0	180.0	164.3	145.2	116.0	-4.1
2Mb	13.6	18.4	33.3	36.3	48.0	55.4	59.3	62.9	64.9	12.3
4Mb	4.1	8.3	56.0	93.1	148.5	180.0	202.1	218.0	230.9	19.9
8Mb	1.2	6.4	12.1	49.3	134.9	187.6	218.6	243.1	258.6	39.3
16Mb	0	1.5	11.9	15.3	32.7	62.7	106.9	155.3	199.6	67.2
32Mb	-	-	-	0.2	1.9	15.3	34.6	69.6	117.0	250.9
64Mb	-	-	-	0.1	0.1	1.5	12.8	33.8	60.0	266.8
128Mb	-	-	-	-	-	-	0.8	3.9	12.2	-
Total	**74.0**	**123.7**	**232.5**	**368.5**	**569.4**	**730.9**	**848.8**	**975.3**	**1,092.9**	**24.3**
Growth (%)	**163.8**	**67.2**	**87.9**	**58.5**	**54.5**	**28.4**	**16.1**	**14.9**	**12.1**	**-**

Source: Dataquest (October 1997)

Table 2-24
Worldwide Flash Megabyte Shipment Forecast, 1993 to 2001 (Millions of Megabytes Shipped)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
256K	0.3	0.4	0.2	0.2	0.2	0.1	0.1	0	0	34.0
512K	0.4	0.6	0.5	1.5	2.4	2.8	2.9	2.6	2.0	7.0
1Mb	4.7	8.5	13.0	17.9	20.0	22.5	20.5	18.2	14.5	-4.1
2Mb	3.4	4.6	8.3	9.1	12.0	13.9	14.8	15.7	16.2	12.3
4Mb	2.0	4.1	28.0	46.5	74.3	90.0	101.1	109.0	115.5	19.9
8Mb	1.2	6.4	12.1	49.3	134.9	187.6	218.6	243.1	258.6	39.3
16Mb	0	2.9	23.8	30.6	65.4	125.4	213.8	310.6	399.2	67.2
32Mb	-	-	-	0.9	7.6	61.3	138.6	278.3	468.0	250.9
64Mb	-	-	-	0.7	0.8	11.9	102.2	270.4	480.0	266.8
128Mb	-	-	-	-	-	-	12.6	62.7	195.4	-
Total	**12.1**	**27.6**	**85.9**	**156.7**	**317.5**	**515.5**	**825.2**	**1,310.6**	**1,949.5**	**65.6**
Growth (%)	**243.7**	**127.7**	**211.7**	**82.4**	**102.7**	**62.4**	**60.1**	**58.8**	**48.7**	**-**

Source: Dataquest (October 1997)

Table 2-25
Worldwide Flash Price-per-Megabyte Forecast, 1993 to 2001 (U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
256K	149.44	138.88	94.91	83.18	75.88	96.43	106.07	125.01	125.01	8.5
512K	92.16	72.32	50.03	49.60	40.48	34.56	34.40	34.24	34.24	-7.1
1Mb	59.44	39.44	26.55	27.41	20.66	17.52	17.44	17.36	17.28	-8.9
2Mb	61.56	39.64	26.77	26.46	16.04	12.68	11.12	10.50	10.33	-17.1
4Mb	53.78	31.78	20.17	19.44	11.04	8.24	7.13	6.53	6.25	-20.3
8Mb	31.58	24.85	15.01	12.89	6.98	5.45	4.63	4.19	3.89	-21.3
16Mb	42.50	30.71	20.41	14.84	6.93	4.88	3.86	3.34	2.97	-27.5
32Mb	-	-	-	13.00	7.40	4.78	3.47	2.79	2.40	-28.6
64Mb	-	-	-	-	10.14	6.08	4.10	3.10	2.49	-
128Mb	-	-	-	-	-	-	5.70	3.73	2.82	-
Total	59.96	36.00	21.49	18.05	9.43	6.63	5.05	3.96	3.22	-29.2
Growth (%)	-17.8	-40.0	-40.3	-16.0	-47.8	-29.7	-23.9	-21.5	-18.7	-

Source: Dataquest (October 1997)

Table 2-26
Worldwide ROM Revenue Forecast, 1993 to 2001 (Millions of U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
64K	0.9	0.3	0.2	0.1	0	0	0	0	0	-35.3
128K	1.5	0.4	0.3	0.3	0.1	0.1	0	0	0	-36.9
256K	17.6	12.2	8.0	4.5	2.6	1.9	1.3	0.9	0.4	-38.2
512K	14.4	8.1	6.5	3.9	1.1	0.7	0.5	0.3	0.2	-47.4
1Mb	82.5	79.7	49.5	25.4	13.5	7.6	5.2	2.7	1.1	-46.5
2Mb	99.2	130.3	123.4	57.9	40.8	29.8	19.9	11.3	3.1	-44.5
4Mb	357.4	439.7	412.1	234.9	243.5	210.5	191.2	169.3	163.5	-7.0
8Mb	592.5	587.0	423.5	284.7	161.9	109.2	71.2	44.3	24.8	-38.6
16Mb	564.7	792.2	840.4	456.8	219.0	130.5	87.1	59.5	40.1	-38.5
32Mb	-	122.5	270.7	204.9	177.5	162.3	144.3	140.1	135.1	-8.0
64Mb	-	-	-	94.6	153.9	153.7	145.9	146.9	142.8	-8.6
128Mb	-	-	-	-	71.1	105.3	158.6	181.8	197.4	-
256Mb	-	-	-	-	-	-	164.7	270.8	316.9	-
Total	**1,730.6**	**2,172.4**	**2,134.6**	**1,368.0**	**1,085.2**	**911.4**	**989.9**	**1,027.8**	**1,025.3**	**-5.6**
Growth (%)	**19.6**	**25.5**	**-1.7**	**-35.9**	**-20.7**	**-16.0**	**8.6**	**3.8**	**-0.2**	**-**

Source: Dataquest (October 1997)

Table 2-27
Worldwide ROM Average Selling Price Forecast, 1993 to 2001 (U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
64K	0.86	0.86	0.86	0.85	0.83	0.93	0.99	1.08	1.08	4.9
128K	0.95	0.96	0.96	0.95	0.93	1.04	1.10	1.20	1.20	4.6
256K	1.12	1.10	1.10	1.10	1.07	1.19	1.26	1.38	1.38	4.6
512K	1.23	1.40	1.25	1.22	1.21	1.36	1.44	1.57	1.57	5.1
1Mb	1.49	2.03	1.64	1.40	1.25	1.25	1.40	1.60	1.60	2.7
2Mb	2.33	2.55	2.53	1.93	1.63	1.49	1.51	1.51	1.54	-4.5
4Mb	2.85	3.39	3.35	2.70	2.09	1.85	1.71	1.57	1.57	-10.3
8Mb	4.83	4.74	4.95	3.85	2.70	2.27	1.98	1.74	1.60	-16.1
16Mb	8.22	8.77	7.92	6.20	4.14	3.01	2.50	2.09	1.80	-21.9
32Mb	-	27.83	14.25	8.35	5.82	4.35	3.20	2.59	2.18	-23.6
64Mb	-	-	-	25.32	12.82	7.96	5.45	4.14	3.21	-33.8
128Mb	-	-	-	-	51.05	21.48	13.21	9.12	7.15	-
256Mb	-	-	-	-	-	-	101.52	45.50	24.16	-
Total	3.89	4.76	5.02	4.29	3.47	3.08	3.45	3.58	3.51	-3.9
Growth (%)	12.5	22.4	5.4	-14.5	-19.1	-11.2	12.1	3.6	-2.0	-

Source: Dataquest (October 1997)

Table 2-28
Worldwide ROM Unit Shipment Forecast, 1993 to 2001 (Millions of Units Shipped)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
64K	1.1	0.3	0.2	0.2	0.1	0	0	0	0	-38.3
128K	1.6	0.5	0.4	0.3	0.1	0.1	0	0	0	-39.8
256K	15.7	11.0	7.3	4.1	2.5	1.6	1.1	0.6	0.3	-40.9
512K	11.7	5.8	5.2	3.2	0.9	0.5	0.3	0.2	0.1	-50.0
1Mb	55.3	39.3	30.1	18.2	10.8	6.1	3.7	1.7	0.7	-47.9
2Mb	42.6	51.1	48.7	29.9	25.1	20.0	13.2	7.5	2.0	-41.9
4Mb	125.4	129.7	122.9	87.0	116.3	114.1	111.8	107.9	104.3	3.7
8Mb	122.7	123.8	85.6	74.0	60.0	48.2	36.0	25.4	15.5	-26.8
16Mb	68.7	90.3	106.1	73.6	52.9	43.4	34.9	28.4	22.3	-21.3
32Mb	-	4.4	19.0	24.5	30.5	37.3	45.1	54.0	62.0	20.4
64Mb	-	-	-	3.7	12.0	19.3	26.8	35.5	44.4	64.1
128Mb	-	-	-	0.3	1.4	4.9	12.0	19.9	27.6	152.5
256Mb	-	-	-	-	0.1	0.3	1.6	6.0	13.1	-
Total	**444.7**	**456.3**	**425.5**	**319.0**	**312.6**	**295.8**	**286.6**	**287.2**	**292.3**	**-1.7**
Growth (%)	**6.4**	**2.6**	**-6.8**	**-25.0**	**2.0**	**-5.4**	**-3.1**	**0.2**	**1.8**	**-**

Source: Dataquest (October 1997)

Table 2-29
Worldwide ROM Megabyte Shipment Forecast, 1993 to 2001 (Millions of Megabytes Shipped)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
64K	0	0	0	0	0	0	0	0	0	-38.3
128K	0	0	0	0	0	0	0	0	0	-39.8
256K	0.5	0.3	0.2	0.1	0.1	0	0	0	0	-40.9
512K	0.7	0.4	0.3	0.2	0.1	0	0	0	0	-50.0
1Mb	6.9	4.9	3.8	2.3	1.4	0.8	0.5	0.2	0.1	-47.9
2Mb	10.6	12.8	12.2	7.5	6.3	5.0	3.3	1.9	0.5	-41.9
4Mb	62.7	64.9	61.4	43.5	58.2	57.1	55.9	54.0	52.1	3.7
8Mb	122.7	123.8	85.6	74.0	60.0	48.2	36.0	25.4	15.5	-26.8
16Mb	137.4	180.7	212.2	147.3	105.8	86.8	69.8	56.8	44.5	-21.3
32Mb	-	17.6	76.0	98.1	122.0	149.2	180.4	216.1	248.1	20.4
64Mb	-	-	-	29.9	96.0	154.4	214.4	283.8	355.4	64.1
128Mb	-	-	-	4.3	22.3	78.4	192.0	318.9	442.1	152.5
256Mb	-	-	-	-	3.1	9.7	51.9	190.4	419.8	-
Total	**341.6**	**405.4**	**451.7**	**407.1**	**475.1**	**589.6**	**804.2**	**1,147.6**	**1,578.1**	**31.1**
Growth (%)	**80.0**	**18.7**	**11.4**	**-9.9**	**16.7**	**24.1**	**36.4**	**42.7**	**37.5**	**-**

Source: Dataquest (October 1997)

Table 2-30
Worldwide ROM Price-per-Megabyte Forecast, 1993 to 2001 (U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
64K	110.08	110.08	110.08	108.80	106.74	119.34	126.54	138.04	138.04	4.9
128K	60.80	61.44	61.44	60.80	59.58	66.61	70.63	77.04	77.04	4.8
256K	35.84	35.20	35.20	35.20	34.13	38.16	40.46	44.14	44.14	4.6
512K	19.68	22.40	20.00	19.52	19.39	21.68	22.99	25.08	25.08	5.1
1Mb	11.92	16.24	13.13	11.19	10.03	10.03	11.20	12.80	12.80	2.7
2Mb	9.32	10.20	10.13	7.73	6.50	5.96	6.03	6.03	6.14	-4.5
4Mb	5.70	6.78	6.71	5.40	4.19	3.69	3.42	3.14	3.14	-10.3
8Mb	4.83	4.74	4.95	3.85	2.70	2.27	1.98	1.74	1.60	-16.1
16Mb	4.11	4.39	3.96	3.10	2.07	1.50	1.25	1.05	0.90	-21.9
32Mb	-	6.96	3.56	2.09	1.46	1.09	0.80	0.65	0.54	-23.6
64Mb	-	-	-	3.16	1.60	1.00	0.68	0.52	0.40	-33.8
128Mb	-	-	-	-	3.19	1.34	0.83	0.57	0.45	-
256Mb	-	-	-	-	-	-	3.17	1.42	0.76	-
Total	5.07	5.36	4.73	3.36	2.28	1.55	1.23	0.90	0.65	-28.0
Growth (%)	-33.5	5.8	-11.8	-28.9	-32.0	-32.3	-20.4	-27.2	-27.5	-

Source: Dataquest (October 1997)

Table 2-31
Worldwide EEPROM Revenue Forecast, 1993 to 2001 (Millions of U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
256-Bit	36.3	14.7	12.1	112.5	128.9	130.5	128.4	102.9	89.2	-4.5
512-Bit	4.1	5.1	8.5	10.9	13.8	17.8	20.3	16.9	11.4	0.8
1K	87.7	116.3	129.5	121.9	132.0	140.2	150.3	136.2	118.9	-0.5
2K	83.2	81.1	96.1	82.8	91.3	115.4	152.3	164.8	181.6	17.0
4K	67.1	66.8	77.5	158.1	186.2	224.1	252.8	300.6	341.6	16.7
8K	7.4	10.0	25.7	41.4	74.9	124.2	191.8	254.2	267.9	45.3
16K	44.1	55.0	90.9	165.0	236.7	309.4	357.0	401.1	444.7	21.9
32K	-	-	-	-	-	-	-	-	-	-
64K	101.7	121.5	133.0	210.6	231.9	256.7	274.0	297.2	334.8	9.7
128K	-	-	-	-	-	-	-	-	-	-
256K	48.0	54.0	42.4	70.9	148.2	196.1	241.5	276.5	355.8	38.1
512K	1.5	7.7	3.0	2.7	4.8	89.3	193.4	293.2	416.2	173.3
1Mb	10.7	25.6	13.9	82.2	77.6	79.4	127.9	292.5	420.3	38.6
2Mb	-	-	-	-	-	-	-	-	-	-
4Mb	-	-	47.5	3.7	37.9	41.9	57.5	64.6	167.5	113.9
Total	**491.9**	**557.8**	**680.0**	**1,062.6**	**1,364.4**	**1,725.1**	**2,147.1**	**2,600.6**	**3,149.8**	**24.3**
Growth (%)	33.3	13.4	21.9	56.3	28.4	26.4	24.5	21.1	21.1	-

Source: Dataquest (October 1997)

Table 2-32
Worldwide EEPROM Average Selling Price Forecast, 1993 to 2001 (U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
256-Bit	0.55	0.50	0.43	0.35	0.30	0.28	0.29	0.28	0.29	-3.4
512-Bit	0.66	0.58	0.45	0.42	0.32	0.28	0.29	0.28	0.29	-7.3
1K	0.45	0.45	0.43	0.33	0.28	0.25	0.24	0.23	0.24	-5.6
2K	0.82	0.61	0.53	0.42	0.39	0.35	0.34	0.32	0.34	-4.1
4K	1.71	1.00	0.74	0.99	0.72	0.61	0.53	0.52	0.52	-12.1
8K	2.11	1.15	0.76	1.08	1.01	0.96	0.91	0.88	0.81	-5.6
16K	1.99	1.63	1.47	1.94	1.66	1.47	1.28	1.08	0.98	-12.8
32K	-	-	-	-	-	-	-	-	-	-
64K	4.68	3.40	2.55	2.86	2.44	2.14	1.82	1.46	1.30	-14.6
128K	-	-	-	-	-	-	-	-	-	-
256K	11.17	10.05	8.42	8.47	5.93	4.36	3.35	2.39	2.03	-24.8
512K	38.53	33.09	25.36	22.75	16.12	10.90	7.74	5.19	4.11	-29.0
1Mb	73.10	66.22	55.64	50.56	38.81	29.39	19.98	13.12	9.55	-28.3
2Mb	-	-	-	-	-	-	-	-	-	-
4Mb	-	-	950.00	491.63	189.65	97.55	63.90	35.90	26.19	-44.4
Total	**1.07**	**0.96**	**0.86**	**0.82**	**0.76**	**0.74**	**0.76**	**0.82**	**0.93**	**2.4**
Growth (%)	**-13.0**	**-10.2**	**-10.4**	**-4.4**	**-7.3**	**-2.5**	**2.6**	**7.5**	**13.0**	**-**

Source: Dataquest (October 1997)

Table 2-33
Worldwide EEPROM Unit Shipment Forecast, 1993 to 2001 (Millions of Units Shipped)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
256-Bit	66.1	29.5	28.3	326.4	432.7	473.0	445.0	367.8	307.7	-1.2
512-Bit	6.2	8.7	18.9	25.8	43.2	64.5	70.4	60.4	39.2	8.7
1K	195.0	258.4	302.5	375.2	479.5	563.0	617.1	597.0	490.0	5.5
2K	101.4	132.9	182.2	197.1	233.0	332.0	455.0	508.0	534.0	22.1
4K	39.2	66.8	104.5	159.7	260.0	370.0	480.0	578.0	657.0	32.7
8K	3.5	8.7	33.7	38.2	74.3	129.3	211.7	288.9	330.7	54.0
16K	22.2	33.7	62.0	85.1	143.0	211.0	280.0	370.0	454.0	39.8
32K	-	-	-	-	-	-	-	-	-	-
64K	21.7	35.7	52.2	73.5	95.0	120.0	150.4	204.2	258.0	28.5
128K	-	-	-	-	-	-	-	-	-	-
256K	4.3	5.4	5.0	8.4	25.0	45.0	72.0	115.8	175.0	83.6
512K	0	0.2	0.1	0.1	0.3	8.2	25.0	56.5	101.2	284.8
1Mb	0.1	0.4	0.2	1.6	2.0	2.7	6.4	22.3	44.0	93.4
2Mb	-	-	-	-	-	-	-	-	-	-
4Mb	-	0.1	0.1	0	0.2	0.4	0.9	1.8	6.4	284.6
Total	459.8	580.6	789.9	1,291.2	1,788.1	2,319.2	2,813.9	3,170.6	3,397.2	21.3
Growth (%)	53.3	26.3	36.1	63.5	38.5	29.7	21.3	12.7	7.1	-

Source: Dataquest (October 1997)

Table 2-34
Worldwide EEPROM Megabyte Shipment Forecast, 1993 to 2001 (Millions of Megabytes Shipped)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
256-Bit	0	0	0	0	0	0	0	0	0	-1.2
512-Bit	0	0	0	0	0	0	0	0	0	8.7
1K	0	0	0	0	0.1	0.1	0.1	0.1	0.1	5.5
2K	0	0	0	0	0.1	0.1	0.1	0.1	0.1	22.1
4K	0	0	0.1	0.1	0.1	0.2	0.2	0.3	0.3	32.7
8K	0	0	0	0	0.1	0.1	0.2	0.3	0.3	54.0
16K	0	0.1	0.1	0.2	0.3	0.4	0.5	0.7	0.9	39.8
32K	-	-	-	-	-	-	-	-	-	-
64K	0.2	0.3	0.4	0.6	0.7	0.9	1.2	1.6	2.0	28.5
128K	-	-	-	-	-	-	-	-	-	-
256K	0.1	0.2	0.2	0.3	0.8	1.4	2.3	3.6	5.5	83.6
512K	0	0	0	0	0	0.5	1.6	3.5	6.3	284.8
1Mb	0	0	0	0.2	0.3	0.3	0.8	2.8	5.5	93.4
2Mb	-	-	-	-	-	-	-	-	-	-
4Mb	-	0	0	0	0.1	0.2	0.5	0.9	3.2	284.6
Total	**0.4**	**0.7**	**0.9**	**1.4**	**2.5**	**4.3**	**7.4**	**13.9**	**24.2**	75.9
Growth (%)	**26.3**	**61.3**	**28.8**	**56.7**	**74.1**	**71.7**	**72.9**	**87.5**	**74.0**	-

Source: Dataquest (October 1997)

Table 2-35
Worldwide EEPROM Price-per-Megabyte Forecast, 1993 to 2001 (U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
256-Bit	18,022.40	16,384.00	14,053.15	11,289.09	9,761.09	9,042.96	9,453.87	9,164.83	9,502.72	-3.4
512-Bit	10,813.44	9,502.72	7,372.80	6,934.73	5,240.41	4,521.48	4,726.94	4,582.41	4,751.36	-7.3
1K	3,686.40	3,686.40	3,505.96	2,661.00	2,255.98	2,039.96	1,994.90	1,868.25	1,988.42	-5.7
2K	3,358.72	2,498.56	2,159.79	1,720.32	1,604.37	1,424.27	1,370.81	1,328.90	1,392.64	-4.1
4K	3,502.08	2,048.00	1,519.11	2,027.52	1,466.48	1,240.40	1,078.60	1,064.96	1,064.96	-12.1
8K	2,160.64	1,177.60	779.65	1,108.75	1,033.18	983.42	927.59	901.12	829.44	-5.6
16K	1,018.88	834.56	750.20	992.84	847.65	750.76	652.83	554.97	501.50	-12.8
32K	-	-	-	-	-	-	-	-	-	-
64K	599.04	435.20	325.80	366.64	312.41	273.81	233.21	186.32	166.08	-14.6
128K	-	-	-	-	-	-	-	-	-	-
256K	357.44	321.60	269.32	270.89	189.72	139.44	107.32	76.42	65.05	-24.8
512K	616.48	529.44	405.83	363.97	257.99	174.32	123.78	83.02	65.80	-29.0
1Mb	584.80	529.76	445.13	404.44	310.48	235.14	159.82	104.99	76.42	-28.3
2Mb	-	-	-	-	-	-	-	-	-	-
4Mb	-	-	1,900.00	983.25	379.29	195.10	127.81	71.79	52.38	-44.4
Total	**1,113.51**	**783.01**	**741.08**	**739.22**	**545.26**	**401.56**	**288.98**	**186.69**	**129.95**	**-29.4**
Growth (%)	**5.59**	**29.68**	**5.36**	**0.25**	**26.24**	**26.35**	**28.03**	**35.40**	**30.39**	-

Source: Dataquest (October 1997)

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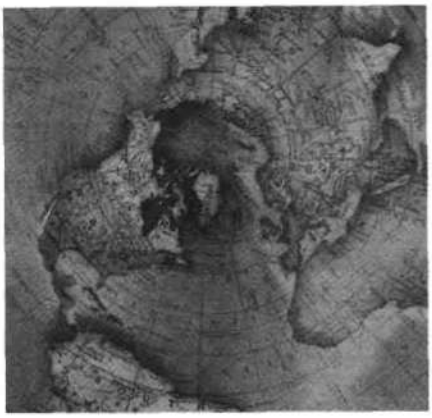

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Dataquest

Worldwide MOS Memory Forecast, Spring 1997

Market Statistics

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Chapter 1
Worldwide MOS Memory Forecast

This report details forecasts of six segments of the MOS memory market—DRAM, SRAM, EPROM, EEPROM, ROM, and flash memory. For each segment, Dataquest forecasts revenue, units shipped, average selling price, megabytes shipped, and price per megabyte. These forecasts are the result of detailed surveys of unit shipments for the 1996 calendar year. The forecasts present further detail gathered after publication of the worldwide semiconductor worldwide forecast (*Worldwide Semiconductor Forecast and Trends*, SCND-WW-MT-9701, May 1997) and thus supersede it.

Worldwide MOS memory revenue should total just over $38 billion for 1997, a rise of less than 1 percent from 1996. This is the outcome of a catastrophic 1996 memory market that went through a cyclical decline in DRAM. By the second half of 1998, Dataquest expects to see a successful return to a normal market. Although a lot of the profit has evaporated in DRAM, SRAM, and flash memory, Dataquest still expects that 1997 will have been a profitable year in these markets. Dataquest expects to see long-term growth in most segments, including DRAM, SRAM, flash, and EEPROM. Dataquest has increased its memory revenue growth outlook since the prior forecast (November 1996). Memory revenue should grow at a compound annual growth rate (CAGR) of 20.8 percent during the 1996-to-2001 period, with worldwide revenue reaching over $100 billion in 2000 and retreating to just under than $100 billion in 2001.

Forecast Assumptions

The following top-level assumptions guide Dataquest's forecast. The baseline assumptions associated with the six memory product forecasts—DRAM, SRAM, flash, EPROM, EEPROM, and ROM—appear in the sections that discuss those forecasts. This assessment highlights changes in assumptions since the prior forecast.

Dataquest's worldwide memory IC forecast assumes the following:

- The dramatic 1996 DRAM cycle has bottomed out, and a more normal DRAM market should stay in place, barring another set of the simultaneous upsets we saw in 1992 through 1995 (the bursting of the Japanese stock bubble, a dollar-to-yen ratio slide, or difficulty in producing 4Mx16 SDRAM).
- Personal computer applications, including multimedia-type display applications, will continue to drive much of the growth of the worldwide memory market throughout the rest of this decade.
- New memory capacity and new memory market entrants should continue to be noticeable in the world.
- Communications applications ranging from low-voltage wireless systems to hubs and routers used for computer networking provide additional sources of growth for the worldwide memory market.

Dataquest continues to expect that Intel's x86 road map, along with more affordable DRAMs and SRAMs, will cause a near quadrupling of a PC's DRAM requirements during the 1996-to-2001 period.

DRAM

DRAMs drive the memory market, and PCs drive the DRAM market. DRAMs will generate two-thirds of worldwide memory revenue in 1997. The DRAMs used in PCs alone now account for nearly half of the memory market's revenue.

Worldwide DRAM revenue should grow to $38 billion for 1997. This is up 0.6 percent from last year owing to slowing price drops. Worldwide DRAM revenue should total nearly $66 billion by 2001.

This long-term forecast represents much faster DRAM revenue growth in comparison with the prior long-term revenue forecast. We base the change on the market's current position in the DRAM cycle. The industry should move from its trough position to a peak in 2000, with the next downturn taking effect in 2001.

DRAM Forecast Assumptions

The following summarizes the strategic assumptions that serve as the basis for the DRAM forecast:

- Prices have slowed their descent, and spot prices have begun to modulate above and below contract prices. This indicates a bottoming out of the cyclical trough and a return to more normal price declines.
- Dataquest expects very strong PC demand throughout the forecast horizon.
- The 64Mb DRAM will have little market impact until after 1997, with the 64Mb price-per-bit crossover expected during 1999.

The explicit basis for Dataquest's high-growth DRAM outlook for both the near term and long term is as follows:

- Dataquest expects worldwide unit shipments of PCs to more than double during the 1996-to-2001 period; PC shipments should expand from fewer than 71 million units in 1996 to nearly 152 million units for 2001.
- The amount of DRAM in each PC likely will more than quadruple during this period. The amount of factory-installed DRAM had tripled from 8MB during 1995 to 24MB by the end of 1996. During 1997, PC buyers will demand even more memory—from 24MB to 48MB—for many applications.
- 16Mb DRAM unit shipments will peak during 1998; 4Mb units are in decline.

Intel's Pentium II ramp-up during the 1997-to-1999 period will have a dramatic impact in terms of PC main memory. For example, Dataquest conservatively estimates that the combined Pentium II and Windows NT ramp-ups mean that 10 percent or more of PCs will ship from the PC factory with 48MB of DRAM by the end of 1997.

SRAM

Worldwide SRAM revenue should total $5.4 billion in 1997, a 14 percent increase from a disappointing 1996. We expect no recovery from the 32Kx32 crash.

Dataquest expects a moderated rate of SRAM revenue growth in the long term. SRAM revenue will expand at a 25 percent rate during the 1996-to-2001 period, led by the rapidly expanding cache segments.

SRAM Forecast Assumptions

The following assumptions provide the basis for the SRAM forecast:

- 1Mb slow SRAMs have suffered from a lack of market acceptance, although that scenario will change.
- The PC cache market is again oversupplied, and is likely to remain in that position for the foreseeable future. Dataquest expects rapidly diminishing demand for 256K in the speed ranges from 10ns through 44ns because of the widespread availability of inexpensive 32Kx32s.
- Total SRAM unit shipments will decline in the near future as the 1Mb density displaces the 256K density. The use of lower-density parts caused unusually high unit shipments of SRAMs as a whole in 1995. Unit shipments will grow again after 1997, after the conversion has taken its toll.

Slow SRAM

The slower-speed versions of the 1Mb SRAM have been available for several years, yet continue to fail to win market acceptance. The high-end consumer electronics market has a dramatic effect on slow SRAMs, and today's protracted economic slump in Japan is postponing acceptance of the 1Mb SRAM density. This delayed conversion to 1Mb from 256K means SRAM unit shipments will decline in 1996 and 1997 but will rebound in 1998.

The delayed acceptance of the 1Mb SRAM and the technical difficulties of manufacturing a mass-produced thin-film transistor (TFT) have delayed production of the 4Mb SRAM. This density is also behind normal life cycles and is expected to continue to suffer as long as the 1Mb density does. If this situation continues for long enough, there is the possibility that the 1Mb density will never really gain acceptance and that the 4Mb density will be far enough along to take its place. However, this forecast assumes that the 1Mb density will regain lost ground in 1997.

Nonvolatile Memories

The four nonvolatile memory technologies reflect differing market characteristics, although at times they compete head-on for applications. Flash memory—the newly emerging nonvolatile technology—is enjoying growth during 1997; however, prices have come down since 1996, as previously constrained supply loosened. A wide range of applications use EEPROMs, including industrial, telecommunications, and consumer systems. Diversified applications means a bright long-term outlook for the EEPROM market. By contrast, the mask ROM market has depended heavily on video game demand. ROM suppliers, however, are starting to devote more resources to other applications, such as laser printers.

Dataquest expects each to perform differently in the forecast window. Flash should continue to expand and benefit over the forecast horizon from the continued emergence of low-voltage handheld systems for telecom and computing applications. Our outlook for EPROM shows a relatively flat market despite the advent of more flash capacity coming on line. This is because manufacturing costs of EPROM should remain below those of flash memory, and the product will simply move into a niche as long as it is supplied, which suppliers guarantee Dataquest will be a very long time. EEPROM market revenue quietly surged during 1994, and we expect impressive growth for the next several years. EEPROM market revenue will exceed EPROM revenue by 1997, a reversal of history. The mask ROM market should be down but should bounce back through the forecast period.

Worldwide flash memory revenue should approach $3.4 billion for 1997, for a diminutive 19 percent growth rate over 1996, especially in light of its five-year CAGR of 27.3 percent.

Flash Recaptures Market Attention

Dataquest foresees flash demand and supply continuing to vacillate for most of the forecast period.

As always, Dataquest expects flash to emerge as the fastest-growing worldwide memory market in the long term. Driven by newly emerging applications, flash memory revenue should have a 27.3 percent CAGR from 1996 to 2001. Worldwide flash revenue should approach $10 billion by 2001.

Flash Memory Forecast Assumptions

Dataquest bases the flash memory forecast on these assumptions:

- Flash remains a key enabling technology for a profusion of low-power handheld systems and peripherals; flash will enable the emergence of a host of other applications, such as digital cameras and automotive navigation systems.
- Current applications will continue to drive near-term growth very hard. Such applications are mainly in handheld cellular telephones and a variety of other telecommunications, data processing, and automotive areas.
- A major increase in flash capacity will occur during 1997, meaning tremendous growth in terms of bit shipments but also a steep drop in flash price per bit (PPB).

Flash technology remains inherently attractive because of its ruggedness, nonvolatility, low power requirement, and rewrite capability. In terms of flash's functionality, the technology effectively performs a host of roles, including code storage, mass data storage and manipulation, and system configuration setting. From Dataquest's perspective, the continued lowering of the flash PPB curve—combined with attractive functionality—means that flash remains positioned as the fastest-growing semiconductor memory market during the forecast horizon.

EPROM

Worldwide EPROM revenue should exceed $1.2 billion for 1997, a 2.5 percent decline from 1996. EPROM continually defies the predictions of ill health made by proponents of flash. Long-term EPROM revenue should increase at a 1 percent CAGR between 1996 and 2001. The EPROM market will hover around the $1.3 billion mark through the end of the forecast period.

EPROM Forecast Assumptions

The following assumptions serve as the basis for the EPROM forecast:

- EPROM's PPB will remain below that of flash, limiting flash's displacement of EPROM.
- There will be no major growth in total EPROM revenue.
- Despite competitive challenges, the EPROM market will exist well beyond the end of the 2001 forecast horizon, with SGS-Thomson leading in terms of long-term supplier commitment.

EEPROM

Worldwide EEPROM revenue should reach $1.4 billion in 1997. This represents significantly stronger growth compared with the prior forecast. The EEPROM market is now moving through an especially impressive growth phase because of its widespread acceptance for transaction processing in Europe and its suitability for a host of low-power telecom, industrial, automotive, consumer, and other applications. Dataquest expects continued long-term growth of the EEPROM market worldwide.

EEPROM Forecast Assumptions

Dataquest bases the EEPROM forecast on the following set of assumptions:

- EEPROM demand will continue to be driven by high demand for microcontrollers for a host of industrial, telecom, and consumer embedded applications. This is great news for the limited number of volume suppliers because it reduces competition (as opposed to the intense level of direct competition in segments of the DRAM, cache RAM, and flash markets).
- The EEPROM market will continue to enjoy a window of opportunity over the flash market in low-power applications because EEPROM's power consumption requirements are vastly lower than those of flash memory technology.

Mask ROM

Video games continue to account for a large share of ROM demand. A single major customer, Nintendo, commands considerable attention from ROM suppliers in terms of product strategies and fab capacity plans. Market forces, however, might cause ROM suppliers to be more responsive over time to the needs of other applications, such as laser printers. For example, some suppliers report supporting the ROM requirements of major customers (nonvideo game customers) in order to win the customer's business for other memory ICs.

Worldwide ROM revenue should total over $1.4 billion for 1997, a 9 percent decline from 1996. Dataquest expects mild growth in this mature technology over the long term. Unit shipments will be essentially flat, however, because a market move to higher densities should be offset by a decline in the ROM market average selling price. ROM revenue should grow at a CAGR of 7.8 percent from 1996 to 2001. ROM revenue should return to nearly $2.3 billion in 2001.

Mask ROM Forecast Assumptions

The following assumptions guide Dataquest's mask ROM forecast:

- ROM density shifts will continue to move faster than introductions of new densities, leading to a drop in overall units and a slower decline in the ROM average selling price.
- The eventual demise of the ROM-based video cartridge business will cause ROM suppliers to migrate to other applications—or to de-emphasize this product technology.

ROM PPB will remain about one-sixth that of flash memory through the forecast period. Although multilevel cell flash technology could alter this scenario, current trends signal that flash is likely to be unable to displace ROM if PPB is the major consideration.

Chapter 2

Market Statistics Tables

Table 2-1
Factory Revenue from Shipments of MOS Memory to the World, 1993-2001 (Millions of U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
DRAM	14,411.4	22,863.7	41,754.9	26,506.9	25,348.5	30,271.5	48,039.6	81,943.3	66,700.1	20.3
SRAM	3,485.1	4,132.2	6,131.9	4,718.4	5,383.7	7,555.4	9,761.3	12,899.6	14,268.8	24.8
EPROM	1,417.3	1,444.0	1,336.5	1,263.8	1,232.0	1,285.0	1,336.3	1,348.7	1,353.5	1.4
Flash	725.5	991.9	1,845.7	2,828.5	3,362.6	4,485.6	6,396.5	8,754.3	9,470.2	27.3
ROM	1,730.7	2,172.4	2,134.6	1,564.1	1,420.9	1,493.1	1,957.5	2,241.7	2,277.6	7.8
EEPROM	491.8	557.8	680.1	1,062.7	1,425.1	1,847.6	2,301.0	2,796.5	3,533.2	27.2
Total	**22,261.8**	**32,162.0**	**53,883.7**	**37,944.4**	**38,172.8**	**46,938.2**	**69,792.2**	**109,984.1**	**97,603.4**	**20.8**
Growth (%)	**-**	**44.5**	**67.5**	**-29.6**	**0.6**	**23.0**	**48.7**	**57.6**	**-11.3**	**-**

Source: Dataquest (June 1997)

Table 2-2
Shipments of MOS Memory to the World, 1993-2001 (Millions of Units)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
DRAM	1,610.2	1,805.7	2,514.4	2,663.9	2,978.7	3,448.6	3,222.4	3,193.7	3,333.8	4.6
SRAM	906.4	876.5	1,277.0	1,044.7	932.6	925.0	1,033.2	1,239.3	1,268.9	4.0
EPROM	476.0	457.7	499.0	449.8	386.2	368.5	353.6	339.4	332.4	-5.9
Flash	74.1	123.7	232.5	376.9	513.5	668.8	791.6	926.2	964.5	20.7
ROM	444.8	456.2	425.5	306.6	285.5	295.4	324.6	350.9	338.1	2.0
EEPROM	459.7	580.4	789.6	1,291.1	1,671.2	2,134.9	2,585.8	2,854.8	3,093.8	19.1
Total	**3,971.2**	**4,300.2**	**5,738.0**	**6,133.0**	**6,767.7**	**7,841.2**	**8,311.2**	**8,904.3**	**9,331.5**	**8.8**
Growth (%)	**-**	**8.3**	**33.4**	**6.9**	**10.3**	**15.9**	**6.0**	**7.1**	**4.8**	**-**

Source: Dataquest (June 1997)

Table 2-3
Average Selling Price for Shipments of MOS Memory to the World, 1993-2001 (U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
DRAM	8.95	12.66	16.61	9.95	8.51	8.78	14.91	25.66	20.01	15.0
SRAM	3.84	4.71	4.80	4.52	5.77	8.17	9.45	10.41	11.25	20.0
EPROM	2.98	3.15	2.68	2.81	3.19	3.49	3.78	3.97	4.07	7.7
Flash	9.79	8.02	7.94	7.50	6.55	6.71	9.56	9.45	9.82	5.5
ROM	3.89	4.76	5.02	5.10	4.98	5.05	6.63	6.39	6.74	5.7
EEPROM	1.07	0.96	0.86	0.82	0.85	0.87	1.08	0.98	1.14	6.8
Average	**5.61**	**7.48**	**9.39**	**6.19**	**5.64**	**5.99**	**8.40**	**12.35**	**10.46**	**11.1**
Growth (%)	-	33.3	25.5	-34.1	-8.9	6.2	40.2	47.0	-15.3	-

Source: Dataquest (June 1997)

Table 2-4
Shipments of MOS Memory to the World, 1993-2001 (Millions of Megabytes)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
DRAM	555.9	853.2	1,560.8	2,766.0	4,797.6	7,409.0	11,600.0	22,166.0	38,198.6	69.1
SRAM	32.2	36.8	58.5	64.3	86.6	129.2	213.0	363.3	574.6	55.0
EPROM	46.0	48.0	54.7	61.0	63.5	74.8	88.0	101.9	119.9	14.5
Flash	12.1	27.8	85.9	160.2	277.0	492.3	825.8	1,371.5	1,936.1	64.6
ROM	890.1	726.1	691.5	530.8	621.5	986.8	1,564.5	2,457.1	3,176.0	43.0
EEPROM	0.4	0.7	0.9	1.4	2.4	4.2	7.8	15.4	28.4	82.6
Total	**1,536.7**	**1,692.6**	**2,452.3**	**3,583.7**	**5,848.6**	**9,096.3**	**14,299.1**	**26,475.2**	**44,033.6**	**65.2**
Growth (%)	-	**10.1**	**44.9**	**46.1**	**63.2**	**55.5**	**57.2**	**85.2**	**66.3**	-

Source: Dataquest (June 1997)

Table 2-5
Price per Megabyte for Shipments of MOS Memory to the World, 1993-2001 (U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
DRAM	25.92	26.80	26.75	9.58	5.28	4.09	4.14	3.70	1.75	-28.8
SRAM	108.23	112.29	104.82	73.38	62.17	58.48	45.83	35.51	24.83	-19.5
EPROM	30.81	30.08	24.43	20.72	19.40	17.18	15.19	13.24	11.29	-11.4
Flash	59.96	35.68	21.49	17.66	12.14	9.11	7.75	6.38	4.89	-22.6
ROM	1.94	2.99	3.09	2.95	2.29	1.51	1.25	0.91	0.72	-24.6
EEPROM	1,135.01	817.41	769.43	743.15	593.57	439.43	294.29	181.53	124.42	-30.1
Average	**14.49**	**19.00**	**21.97**	**10.59**	**6.53**	**5.16**	**4.88**	**4.15**	**2.22**	**-26.8**
Growth (%)	-	**31.1**	**15.6**	**-51.8**	**-38.3**	**-21.0**	**-5.4**	**-15.0**	**-46.5**	-

Source: Dataquest (June 1997)

Table 2-6
Factory Revenue from Shipments of DRAM to the World, 1993-2001 (Millions of U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
64K Standard	5.3	3.3	-	-	-	-	-	-	-	-
256K Standard	109.5	53.7	54.9	17.4	1.4	-	-	-	-	-100.0
256K Video RAM	102.9	63.1	49.3	20.3	15.9	5.8	5.3	2.6	2.6	-33.7
1Mb Standard	1,618.2	1,541.5	1,850.6	545.7	328.8	235.6	182.7	81.4	18.0	-49.5
1Mb Video RAM	774.8	566.1	10.1	237.1	154.2	95.0	58.5	34.7	29.3	-34.2
2Mb Video RAM	236.7	409.8	581.2	591.7	509.3	393.5	223.7	146.2	103.0	-29.5
4Mb Standard	9,948.7	14,402.4	21,041.4	6,519.6	1,556.6	720.8	518.6	208.1	82.9	-58.2
4Mb Video RAM	14.5	110.9	521.7	442.0	757.9	872.2	870.6	522.2	157.8	-18.6
8Mb SGRAM	-	-	-	510.2	400.0	600.0	1,000.0	400.0	150.0	-21.7
16Mb Standard	1,600.8	5,712.9	17,641.4	16,941.7	16,954.4	18,064.0	11,519.8	6,119.8	829.1	-45.3
64Mb Standard	-	-	4.3	681.2	4,670.0	8,914.8	24,593.8	49,491.3	34,272.7	118.9
256Mb Standard	-	-	-	-	-	369.8	9,066.6	24,937.0	31,054.7	-
Total	**14,411.4**	**22,863.7**	**41,754.9**	**26,506.9**	**25,348.5**	**30,271.5**	**48,039.6**	**81,943.3**	**66,700.1**	**20.3**
Growth (%)	**68.8**	**58.7**	**82.6**	**-36.5**	**-4.4**	**19.4**	**58.7**	**70.6**	**-18.6**	**-**

Source: Dataquest (June 1997)

Table 2-7
Shipments of DRAM to the World, 1993-2001 (Millions of Units)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
64K Standard	4.7	2.7	1.2	-	-	-	-	-	-	-
256K Standard	71.0	33.3	31.8	11.2	0.9	-	-	-	-	-100.0
256K Video RAM	33.8	21.6	16.7	7.8	6.2	2.3	2.1	1.0	1.0	-33.7
1Mb Standard	478.6	376.0	455.2	216.7	151.0	121.0	98.3	48.1	10.6	-45.3
1Mb Video RAM	122.9	92.8	1.7	42.4	29.4	20.0	14.1	10.0	9.0	-26.7
2Mb Video RAM	18.4	35.9	51.9	61.0	52.6	42.0	31.7	24.0	20.6	-19.5
4Mb Standard	858.8	1,131.4	1,592.8	1,268.6	654.5	339.9	241.5	101.5	44.9	-48.7
4Mb Video RAM	0.4	3.9	22.3	32.1	78.1	96.4	96.2	60.1	19.7	-9.3
8Mb SGRAM	-	-	-	21.1	50.0	100.0	200.0	100.0	50.0	18.8
16Mb Standard	21.6	108.1	340.8	996.3	1,883.8	2,461.3	1,613.3	833.1	148.3	-31.7
64Mb Standard	-	-	-	6.7	72.2	265.1	901.0	1,841.8	2,464.1	225.9
256Mb Standard	-	-	-	-	-	0.6	24.2	174.1	565.6	-
Total	**1,610.2**	**1,805.7**	**2,514.4**	**2,663.9**	**2,978.7**	**3,448.6**	**3,222.4**	**3,193.7**	**3,333.8**	**4.6**
Growth (%)	**9.2**	**12.1**	**39.2**	**5.9**	**11.8**	**15.8**	**-6.6**	**-0.9**	**4.4**	**-**

Source: Dataquest (June 1997)

Table 2-8
Average Selling Price for Shipments of DRAM to the World, 1993-2001 (U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
64K Standard	1.13	1.22	-	-	-	-	-	-	-	-
256K Standard	1.54	1.61	1.73	1.55	1.56	-	-	-	-	-
256K Video RAM	3.04	2.92	2.95	2.60	2.56	2.52	2.52	2.60	2.60	-
1Mb Standard	3.38	4.10	4.07	2.52	2.18	1.95	1.86	1.69	1.70	-7.6
1Mb Video RAM	6.30	6.10	5.94	5.59	5.24	4.75	4.15	3.47	3.26	-10.2
2Mb Video RAM	12.86	11.42	11.20	9.70	9.68	9.37	7.06	6.09	5.00	-12.4
4Mb Standard	11.58	12.73	13.21	5.14	2.38	2.12	2.15	2.05	1.85	-18.5
4Mb Video RAM	36.25	28.44	23.39	13.77	9.70	9.05	9.05	8.69	8.01	-10.3
8Mb SGRAM	-	-	-	24.18	8.00	6.00	5.00	4.00	3.00	-34.1
16Mb Standard	74.11	52.85	51.76	17.00	9.00	7.34	7.14	7.35	5.59	-19.9
64Mb Standard	-	-	-	101.67	64.68	33.63	27.30	26.87	13.91	-32.8
256Mb Standard	-	-	-	-	-	616.33	374.65	143.23	54.91	-
Average	**8.95**	**12.66**	**16.61**	**9.95**	**8.51**	**8.78**	**14.91**	**25.66**	**20.01**	**15.0**
Growth (%)	**54.6**	**41.5**	**31.2**	**-40.1**	**-14.5**	**3.2**	**69.8**	**72.1**	**-22.0**	**-**

Source: Dataquest (June 1997)

Table 2-9
Shipments of DRAM to the World, 1994-2001 (Millions of Megabytes)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
64K Standard	0	0	0	0	0	0	0	0	0	-
256K Standard	2.2	1.0	1.0	0.4	0	0	0	0	0	-100.0
256K Video RAM	1.1	0.7	0.5	0.2	0.2	0.1	0.1	0	0	-100.0
1Mb Standard	59.8	47.0	56.9	27.1	18.9	15.1	12.3	6.0	1.3	-45.5
1Mb Video RAM	15.4	11.6	0.2	5.3	3.7	2.5	1.8	1.3	1.1	-27.0
2Mb Video RAM	4.6	9.0	13.0	15.3	13.2	10.5	7.9	6.0	5.2	-19.4
4Mb Standard	429.4	565.7	796.4	634.3	327.3	170.0	120.8	50.8	22.5	-48.7
4Mb Video RAM	0.2	2.0	11.2	16.1	39.1	48.2	48.1	30.1	9.9	-9.3
8Mb SGRAM	0	0	0	21.1	50.0	100.0	200.0	100.0	50.0	18.8
16Mb Standard	43.2	216.2	681.6	1,992.6	3,767.6	4,922.6	3,226.6	1,666.2	296.6	-31.7
64Mb Standard	0	0	0	53.6	577.6	2,120.8	7,208.0	14,734.4	19,712.8	225.9
256Mb Standard	0	0	0	0	0	19.2	774.4	5,571.2	18,099.2	-
Total	**555.9**	**853.2**	**1,560.8**	**2,766.0**	**4,797.6**	**7,409.0**	**11,600.0**	**22,166.0**	**38,198.6**	**69.1**
Growth (%)	**64.7**	**53.5**	**82.9**	**77.2**	**73.4**	**54.4**	**56.6**	**91.1**	**72.3**	**-**

Source: Dataquest (June 1997)

Table 2-10
Price per Megabyte for Shipments of DRAM to the World, 1993-2001 (U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
64K Standard	-	-	-	-	-	-	-	-	-	-
256K Standard	49.77	53.70	54.90	43.50	-	-	-	-	-	-
256K Video RAM	93.55	90.14	98.60	101.50	79.50	58.00	53.00	-	-	-
1Mb Standard	27.06	32.80	32.52	20.14	17.40	15.60	14.85	13.57	13.85	-7.2
1Mb Video RAM	50.31	48.80	50.50	44.74	41.68	38.00	32.50	26.69	26.64	-9.8
2Mb Video RAM	51.46	45.53	44.71	38.67	38.58	37.48	28.32	24.37	19.81	-12.5
4Mb Standard	23.17	25.46	26.42	10.28	4.76	4.24	4.29	4.10	3.68	-18.6
4Mb Video RAM	72.50	55.45	46.58	27.45	19.38	18.10	18.10	17.35	15.94	-10.3
8Mb SGRAM	-	-	-	24.18	8.00	6.00	5.00	4.00	3.00	-34.1
16Mb Standard	37.06	26.42	25.88	8.50	4.50	3.67	3.57	3.67	2.80	-19.9
64Mb Standard	-	-	-	12.71	8.09	4.20	3.41	3.36	1.74	-32.8
256Mb Standard	-	-	-	-	-	19.26	11.71	4.48	1.72	-
Average	**25.92**	**26.80**	**26.75**	**9.58**	**5.28**	**4.09**	**4.14**	**3.70**	**1.75**	**-28.8**
Growth (%)	**2.5**	**3.4**	**-0.2**	**-64.2**	**-44.9**	**-22.5**	**1.2**	**-9.5**	**-52.7**	**-**

Source: Dataquest (June 1997)

Table 2-11
Factory Revenue from Shipments of SRAM to the World, 1993-2001 (Millions of U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
16K										
4-8ns	-	-	-	-	-	-	-	-	-	-
10, 12, 15ns	3.3	4.3	4.7	0.9	0.7	0.5	0.3	0.2	0.2	-26.0
20, 25, 35ns	12.5	16.5	7.8	11.1	7.0	3.7	2.5	1.8	1.3	-34.9
45, 55, 70ns	3.6	4.6	1.4	1.6	0.7	0.4	0.1	0.1	0.1	-42.6
Slow	100.9	80.8	54.0	12.7	5.7	3.8	2.0	1.7	1.1	-38.7
Pseudo	-	-	-	-	-	-	-	-	-	-
64K										
4-8ns	25.5	8.6	-	4.8	11.4	20.9	24.4	22.1	13.7	23.3
10, 12, 15ns	23.6	46.7	94.0	63.8	40.2	29.7	23.5	19.5	15.7	-24.5
20, 25, 35ns	119.1	98.4	79.2	44.0	28.5	19.7	13.5	9.5	7.2	-30.4
45, 55, 70ns	27.6	24.1	72.6	17.2	12.4	9.2	7.5	6.7	5.4	-20.7
Slow	437.9	273.3	226.4	159.2	93.0	66.5	51.2	43.2	33.8	-26.7
Pseudo	7.0	7.9	10.2	6.9	-	-	-	-	-	-100.0
256K										
4-8ns	8.9	11.1	134.8	43.6	21.7	15.7	13.0	11.6	10.2	-25.2
10, 12, 15ns	65.7	302.5	969.0	570.2	220.2	115.6	56.3	32.5	17.0	-50.5
20, 25, 35ns	394.4	429.3	349.0	84.1	52.3	31.1	21.9	15.6	12.3	-31.9
45, 55, 70ns	90.6	157.1	234.9	112.5	59.9	44.2	35.2	32.3	28.2	-24.2
Slow	813.1	675.5	511.2	552.6	312.3	171.5	136.7	125.6	104.3	-28.4
Pseudo	140.8	118.9	89.5	29.7	13.3	7.6	4.2	3.2	2.2	-40.6
1Mb										
4-8ns	33.5	105.6	185.7	377.9	642.0	856.0	941.6	905.8	627.0	10.7
10, 12, 15ns	197.3	327.9	1,291.2	594.5	1,170.0	1,942.6	2,076.0	2,265.8	1,720.0	23.7
20, 25, 35ns	124.1	226.3	264.7	411.9	544.2	519.0	408.8	345.8	171.8	-16.0
45, 55, 70ns	100.3	81.1	494.8	59.6	25.0	17.6	12.0	9.3	7.0	-34.8
Slow	496.6	550.2	627.3	695.2	887.0	1,026.5	1,085.6	1,113.6	855.4	4.2
Pseudo	72.9	72.0	85.5	101.2	63.3	41.6	31.5	26.7	24.0	-25.0

Table 2-11 (Continued)
Factory Revenue from Shipments of SRAM to the World, 1993-2001 (Millions of U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
4Mb										
4-8ns	-	-	-	12.5	88.2	256.8	428.0	623.4	745.3	126.5
10, 12, 15ns	12.0	5.1	23.8	62.4	163.3	429.5	833.4	1,182.7	1,305.9	83.7
20, 25, 35ns	3.8	124.6	48.3	106.7	147.6	487.0	1,052.3	1,538.3	1,928.8	78.4
45, 55, 70ns	15.5	65.5	62.8	9.2	20.4	29.4	52.5	77.7	89.5	57.6
Slow	50.5	190.4	77.1	562.9	750.1	1,093.1	1,626.1	2,483.8	2,716.7	37.0
Pseudo	104.1	123.9	132.0	9.5	3.3	1.4	1.1	1.1	1.0	-36.3
16Mb										
4-8ns	-	-	-	-	-	34.5	65.7	150.3	279.0	-
10, 12, 15ns	-	-	-	-	-	54.0	94.9	333.2	650.9	-
20, 25, 35ns	-	-	-	-	-	43.1	121.8	472.7	735.7	-
45, 55, 70ns	-	-	-	-	-	34.0	194.8	414.1	702.0	-
Slow	-	-	-	-	-	149.2	342.9	629.7	1,456.1	-
Pseudo	-	-	-	-	-	-	-	-	-	-
Total	3,485.1	4,132.2	6,131.9	4,718.4	5,383.7	7,555.4	9,761.3	12,899.6	14,268.8	24.8
Growth (%)	16.5	18.6	48.4	-23.1	14.1	40.3	29.2	32.2	10.6	-

Source: Dataquest (June 1997)

Table 2-12
Shipments of SRAM to the World, 1993-2001 (Millions of Units)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
16K										
4-8ns	-	-	-	-	-	-	-	-	-	-
10, 12, 15ns	1.3	1.7	1.7	0.3	0.3	0.2	0.1	0.1	0.1	-19.7
20, 25, 35ns	6.9	7.0	3.0	5.1	3.0	1.5	1.0	0.7	0.5	-37.2
45, 55, 70ns	2.9	2.4	1.3	1.6	0.7	0.4	0.1	0.1	0.1	-42.6
Slow	47.2	35.9	28.8	12.8	5.9	3.7	1.8	1.6	1.0	-39.9
Pseudo	-	-	-	-	-	-	-	-	-	-
64K										
4-8ns	1.7	0.7	-	0.5	1.1	2.0	2.3	2.1	1.3	21.1
10, 12, 15ns	9.2	16.7	44.3	30.1	19.0	14.0	11.1	9.2	7.4	-24.5
20, 25, 35ns	57.4	50.4	37.5	29.3	19.0	13.1	9.0	6.3	4.8	-30.4
45, 55, 70ns	16.2	15.1	53.8	11.5	8.3	6.1	5.0	4.5	3.6	-20.7
Slow	218.7	151.8	156.6	106.2	62.0	44.3	34.1	28.8	22.5	-26.7
Pseudo	4.7	4.8	4.0	2.5	1.2	0.5	0.2	-	-	-100.0
256K										
4-8ns	0.7	0.7	6.4	4.1	3.2	2.8	2.4	2.3	2.0	-13.4
10, 12, 15ns	9.8	41.5	295.4	186.0	77.8	45.0	22.5	13.0	6.8	-48.4
20, 25, 35ns	91.9	111.3	111.1	56.1	29.1	17.3	12.2	8.7	6.8	-34.4
45, 55, 70ns	28.7	48.7	84.2	44.4	33.3	24.6	19.6	18.0	15.7	-18.8
Slow	243.9	211.6	178.6	229.4	173.7	95.4	76.0	69.8	58.0	-24.0
Pseudo	62.6	52.0	36.4	12.8	6.5	3.8	2.1	1.6	1.1	-38.8
1Mb										
4-8ns	0.2	0.6	2.6	16.3	30.0	40.0	44.0	42.3	29.3	12.4
10, 12, 15ns	2.7	5.3	41.9	69.0	130.0	176.6	207.6	251.8	215.0	25.5
20, 25, 35ns	7.6	15.9	23.4	53.3	90.7	103.8	102.2	94.3	49.2	-1.6
45, 55, 70ns	11.5	9.1	49.0	9.0	5.0	3.9	3.0	2.5	2.0	-26.0
Slow	54.5	62.3	85.2	124.5	177.4	228.1	271.4	303.6	245.2	14.5
Pseudo	17.6	18.2	19.4	20.8	16.7	11.3	8.4	7.2	6.5	-20.8

Table 2-12 (Continued)
Shipments of SRAM to the World, 1993-2001 (Millions of Units)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
4Mb										
4-8ns	-	-	-	0.1	1.0	3.2	6.2	10.7	14.9	172.0
10, 12, 15ns	-	-	0.1	0.8	2.6	8.6	22.9	41.5	57.4	135.1
20, 25, 35ns	-	0.8	0.5	2.0	3.9	17.4	51.8	96.6	154.3	138.5
45, 55, 70ns	0.1	0.6	0.9	0.2	0.7	1.4	3.0	5.0	7.2	104.8
Slow	0.5	1.9	1.1	15.2	30.0	49.8	92.9	159.3	217.3	70.2
Pseudo	7.9	9.5	9.8	0.8	0.5	0.3	0.2	0.2	0.2	-24.2
16Mb										
4-8ns	-	-	-	-	-	0.1	0.2	0.9	2.5	-
10, 12, 15ns	-	-	-	-	-	0.4	1.3	5.3	14.5	-
20, 25, 35ns	-	-	-	-	-	0.5	1.6	8.0	21.0	-
45, 55, 70ns	-	-	-	-	-	0.9	5.3	14.9	35.1	-
Slow	-	-	-	-	-	4.0	11.7	28.4	65.6	-
Pseudo	-	-	-	-	-	-	-	-	-	-
Total	**906.4**	**876.5**	**1,277.0**	**1,044.7**	**932.6**	**925.0**	**1,033.2**	**1,239.3**	**1,268.9**	**4.0**
Growth (%)	**7.6**	**-3.3**	**45.7**	**-18.2**	**-10.7**	**-0.8**	**11.7**	**19.9**	**2.4**	**-**

Source: Dataquest (June 1997)

Table 2-13
Average Selling Price for Shipments of SRAM to the World, 1993-2001 (U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
16K										
4-8ns	-	-	-	-	-	-	-	-	-	-
10, 12, 15ns	2.54	2.53	2.76	3.00	2.33	2.50	3.00	2.00	2.00	-7.8
20, 25, 35ns	1.81	2.36	2.60	2.18	2.33	2.47	2.50	2.57	2.60	3.6
45, 55, 70ns	1.24	1.92	1.08	1.00	1.00	1.00	1.00	1.00	1.00	-
Slow	2.14	2.25	1.88	0.99	0.97	1.03	1.11	1.06	1.10	2.1
Pseudo	-	-	-	-	-	-	-	-	-	-
64K										
4-8ns	15.00	12.29	-	9.60	10.36	10.45	10.61	10.52	10.54	1.9
10, 12, 15ns	2.57	2.80	2.12	2.12	2.12	2.12	2.12	2.12	2.12	-
20, 25, 35ns	2.07	1.95	2.11	1.50	1.50	1.50	1.50	1.51	1.50	-
45, 55, 70ns	1.70	1.60	1.35	1.50	1.49	1.51	1.50	1.49	1.50	-
Slow	2.00	1.80	1.45	1.50	1.50	1.50	1.50	1.50	1.50	-
Pseudo	1.49	1.65	2.55	2.76	-	-	-	-	-	-
256K										
4-8ns	12.71	15.86	21.06	10.63	6.78	5.61	5.42	5.04	5.10	-13.7
10, 12, 15ns	6.70	7.29	3.28	3.07	2.83	2.57	2.50	2.50	2.50	-4.0
20, 25, 35ns	4.29	3.86	3.14	1.50	1.80	1.80	1.80	1.79	1.81	3.8
45, 55, 70ns	3.16	3.23	2.79	2.53	1.80	1.80	1.80	1.79	1.80	-6.6
Slow	3.33	3.19	2.86	2.41	1.80	1.80	1.80	1.80	1.80	-5.7
Pseudo	2.25	2.29	2.46	2.32	2.05	2.00	2.00	2.00	2.00	-2.9
1Mb										
4-8ns	167.50	176.00	71.42	23.18	21.40	21.40	21.40	21.41	21.40	-1.6
10, 12, 15ns	73.07	61.87	30.82	8.62	9.00	11.00	10.00	9.00	8.00	-1.5
20, 25, 35ns	16.33	14.23	11.31	7.73	6.00	5.00	4.00	3.67	3.49	-14.7
45, 55, 70ns	8.72	8.91	10.10	6.62	5.00	4.51	4.00	3.72	3.50	-12.0
Slow	9.11	8.83	7.36	5.58	5.00	4.50	4.00	3.67	3.49	-9.0
Pseudo	4.14	3.96	4.41	4.87	3.79	3.68	3.75	3.71	3.69	-5.4

Table 2-13 (Continued)
Average Selling Price for Shipments of SRAM to the World, 1993-2001 (U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
4Mb										
4-8ns	-	-	-	125.00	88.20	80.25	69.03	58.26	50.02	-16.7
10, 12, 15ns	-	-	238.00	78.00	62.81	49.94	36.39	28.50	22.75	-21.8
20, 25, 35ns	-	155.75	96.60	53.35	37.85	27.99	20.31	15.92	12.50	-25.2
45, 55, 70ns	155.00	109.17	69.78	46.00	29.14	21.00	17.50	15.54	12.43	-23.0
Slow	101.00	100.21	70.09	37.03	25.00	21.95	17.50	15.59	12.50	-19.5
Pseudo	13.18	13.04	13.47	11.88	6.60	4.67	5.50	5.50	5.00	-15.9
16Mb										
4-8ns	-	-	-	-	-	345.00	328.50	167.00	111.60	-
10, 12, 15ns	-	-	-	-	-	135.00	73.00	62.87	44.89	-
20, 25, 35ns	-	-	-	-	-	86.20	76.13	59.09	35.03	-
45, 55, 70ns	-	-	-	-	-	37.78	36.75	27.79	20.00	-
Slow	-	-	-	-	-	37.30	29.31	22.17	22.20	-
Pseudo	-	-	-	-	-	-	-	-	-	-
Average	**3.84**	**4.71**	**4.80**	**4.52**	**5.77**	**8.17**	**9.45**	**10.41**	**11.25**	**20.0**
Growth (%)	**8.2**	**22.7**	**1.9**	**-5.8**	**27.7**	**41.6**	**63.8**	**27.4**	**8.1**	**-**

Source: Dataquest (June 1997)

Table 2-14
Shipments of SRAM to the World, 1993-2001 (Thousands of Megabytes*)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
16K										
4-8ns	0	0	0	0	0	0	0	0	0	-
10, 12, 15ns	2.5	3.3	3.3	0.6	0.6	0.4	0.2	0.2	0.2	-42.9
20, 25, 35ns	13.5	13.7	5.9	10.0	5.9	2.9	2.0	1.4	1.0	-29.9
45, 55, 70ns	5.7	4.7	2.5	3.1	1.4	0.8	0.2	0.2	0.2	-39.7
Slow	92.2	70.1	56.3	25.0	11.5	7.2	3.5	3.1	2.0	-48.7
Pseudo	0	0	0	0	0	0	0	0	0	-
64K										
4-8ns	13.3	5.5	0	3.9	8.6	15.6	18.0	16.4	10.2	-
10, 12, 15ns	71.9	130.5	346.1	235.2	148.4	109.4	86.7	71.9	57.8	-30.1
20, 25, 35ns	448.4	393.8	293.0	228.9	148.4	102.3	70.3	49.2	37.5	-33.7
45, 55, 70ns	126.6	118.0	420.3	89.8	64.8	47.7	39.1	35.2	28.1	-41.8
Slow	1,708.6	1,185.9	1,223.4	829.7	484.4	346.1	266.4	225.0	175.8	-32.2
Pseudo	36.7	37.5	31.3	19.5	9.4	3.9	1.6	0	0	-100.0
256K										
4-8ns	21.9	21.9	200.0	128.1	100.0	87.5	75.0	71.9	62.5	-20.8
10, 12, 15ns	306.3	1,296.9	9,231.3	5,812.5	2,431.3	1,406.3	703.1	406.3	212.5	-53.0
20, 25, 35ns	2,871.9	3,478.1	3,471.9	1,753.1	909.4	540.6	381.3	271.9	212.5	-42.8
45, 55, 70ns	896.9	1,521.9	2,631.3	1,387.5	1,040.6	768.8	612.5	562.5	490.6	-28.5
Slow	7,621.9	6,612.5	5,581.3	7,168.8	5,428.1	2,981.3	2,375.0	2,181.3	1,812.5	-20.1
Pseudo	1,956.3	1,625.0	1,137.5	400.0	203.1	118.8	65.6	50.0	34.4	-50.3
1Mb										
4-8ns	25.0	75.0	325.0	2,037.5	3,750.0	5,000.0	5,500.0	5,287.5	3,662.5	62.3
10, 12, 15ns	337.5	662.5	5,237.5	8,625.0	16,250.0	22,075.0	25,950.0	31,475.0	26,875.0	38.7
20, 25, 35ns	950.0	1,987.5	2,925.0	6,662.5	11,337.5	12,975.0	12,775.0	11,787.5	6,150.0	16.0
45, 55, 70ns	1,437.5	1,137.5	6,125.0	1,125.0	625.0	487.5	375.0	312.5	250.0	-47.3
Slow	6,812.5	7,787.5	10,650.0	15,562.5	22,175.0	28,512.5	33,925.0	37,950.0	30,650.0	23.5
Pseudo	2,200.0	2,275.0	2,425.0	2,600.0	2,087.5	1,412.5	1,050.0	900.0	812.5	-19.6

Table 2-14 (Continued)
Shipments of SRAM to the World, 1993-2001 (Thousands of Megabytes*)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
4Mb										
4-8ns	0	0	0	50.0	500.0	1,600.0	3,100.0	5,350.0	7,450.0	-
10, 12, 15ns	0	0	50.0	400.0	1,300.0	4,300.0	11,450.0	20,750.0	28,700.0	256.3
20, 25, 35ns	0	400.0	250.0	1,000.0	1,950.0	8,700.0	25,900.0	48,300.0	77,150.0	214.7
45, 55, 70ns	50.0	300.0	450.0	100.0	350.0	700.0	1,500.0	2,500.0	3,600.0	51.6
Slow	250.0	950.0	550.0	7,600.0	15,000.0	24,900.0	46,450.0	79,650.0	108,650.0	187.8
Pseudo	3,950.0	4,750.0	4,900.0	400.0	250.0	150.0	100.0	100.0	100.0	-54.1
16Mb										
4-8ns	0	0	0	0	0	200.0	400.0	1,800.0	5,000.0	-
10, 12, 15ns	0	0	0	0	0	800.0	2,600.0	10,600.0	29,000.0	-
20, 25, 35ns	0	0	0	0	0	1,000.0	3,200.0	16,000.0	42,000.0	-
45, 55, 70ns	0	0	0	0	0	1,800.0	10,600.0	29,800.0	70,200.0	-
Slow	0	0	0	0	0	8,000.0	23,400.0	56,800.0	131,200.0	-
Pseudo	0	0	0	0	0	0	0	0	0	-
Total (in Millions)	**32.2**	**36.8**	**58.5**	**64.3**	**86.6**	**129.2**	**213.0**	**363.3**	**574.6**	**57.9**
Growth (%)	**44.9**	**14.3**	**59.0**	**9.9**	**34.7**	**49.2**	**64.9**	**70.6**	**58.2**	-

*Shown in thousands for added resolution.
Source: Dataquest (June 1997)

Table 2-15
Price per Megabyte for Shipments of SRAM to the World, 1993-2001 (U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
16K										
4-8ns	-	-	-	-	-	-	-	-	-	-
10, 12, 15ns	1,320.00	1,303.03	1,424.24	1,500.00	1,166.67	1,250.00	1,500.00	1,000.00	1,000.00	-6.8
20, 25, 35ns	925.93	1,204.38	1,322.03	1,110.00	1,186.44	1,275.86	1,250.00	1,285.71	1,300.00	-0.3
45, 55, 70ns	631.58	978.72	560.00	516.13	500.00	500.00	500.00	500.00	500.00	-2.2
Slow	1,094.36	1,152.64	959.15	508.00	495.65	527.78	571.43	548.39	550.00	-10.5
Pseudo	-	-	-	-	-	-	-	-	-	-
64K										
4-8ns	1,917.29	1,563.64	-	1,230.77	1,325.58	1,339.74	1,355.56	1,347.56	1,343.14	-
10, 12, 15ns	328.23	357.85	271.60	271.26	270.89	271.48	271.05	271.21	271.63	-
20, 25, 35ns	265.61	249.87	270.31	192.22	192.05	192.57	192.03	193.09	192.00	-6.6
45, 55, 70ns	218.01	204.24	172.73	191.54	191.36	192.87	191.82	190.34	192.17	2.2
Slow	256.29	230.46	185.06	191.88	191.99	192.14	192.19	192.00	192.26	0.8
Pseudo	190.74	210.67	325.88	353.85	0	0	0	-	-	-
256K										
4-8ns	406.39	506.85	674.00	340.36	217.00	179.43	173.33	161.34	163.20	-24.7
10, 12, 15ns	214.50	233.25	104.97	98.10	90.57	82.20	80.07	79.99	80.00	-5.3
20, 25, 35ns	137.33	123.43	100.52	47.97	57.51	57.53	57.44	57.37	57.88	-10.5
45, 55, 70ns	101.01	103.23	89.27	81.08	57.56	57.49	57.47	57.42	57.48	-8.4
Slow	106.68	102.16	91.59	77.08	57.53	57.53	57.56	57.58	57.54	-8.9
Pseudo	71.97	73.17	78.68	74.25	65.48	63.97	64.02	64.00	63.95	-4.1
1Mb										
4-8ns	1,340.00	1,408.00	571.38	185.47	171.20	171.20	171.20	171.31	171.19	-21.4
10, 12, 15ns	584.59	494.94	246.53	68.93	72.00	88.00	80.00	71.99	64.00	-23.6
20, 25, 35ns	130.63	113.86	90.50	61.82	48.00	40.00	32.00	29.34	27.93	-21.0
45, 55, 70ns	69.77	71.30	80.78	52.98	40.00	36.10	32.00	29.76	28.00	-19.1
Slow	72.90	70.65	58.90	44.67	40.00	36.00	32.00	29.34	27.91	-13.9
Pseudo	33.14	31.65	35.26	38.92	30.32	29.45	30.00	29.67	29.54	-3.5

Table 2-15 (Continued)
Price per Megabyte for Shipments of SRAM to the World, 1993-2001 (U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
4Mb										
4-8ns	-	-	-	250.00	176.40	160.50	138.06	116.52	100.04	-
10, 12, 15ns	-	-	476.00	156.00	125.62	99.88	72.79	57.00	45.50	-37.5
20, 25, 35ns	-	311.50	193.20	106.70	75.69	55.98	40.63	31.85	25.00	-33.6
45, 55, 70ns	310.00	218.33	139.56	92.00	58.29	42.00	35.00	31.08	24.86	-29.2
Slow	202.00	200.42	140.18	74.07	50.01	43.90	35.01	31.18	25.00	-29.2
Pseudo	26.35	26.08	26.94	23.75	13.20	9.33	11.00	11.00	10.00	-18.0
16Mb										
4-8ns	-	-	-	-	-	172.50	164.25	83.50	55.80	-
10, 12, 15ns	-	-	-	-	-	67.50	36.50	31.43	22.44	-
20, 25, 35ns	-	-	-	-	-	43.10	38.06	29.54	17.52	-
45, 55, 70ns	-	-	-	-	-	18.89	18.38	13.90	10.00	-
Slow	-	-	-	-	-	18.65	14.65	11.09	11.10	-
Pseudo	-	-	-	-	-	-	-	-	-	-
Average	108.23	112.29	104.82	73.38	62.17	58.48	45.83	35.51	24.83	-25.0
Growth (%)	-19.6	3.8	-6.7	-30.0	-15.3	-5.9	-21.6	-22.5	-30.1	-

Source: Dataquest (June 1997)

Table 2-16
Factory Revenue from Shipments of EPROM to the World, 1993-2001 (Millions of U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
16K	11.8	10.2	9.0	5.1	3.6	3.3	2.8	2.7	2.4	-14.0
32K	17.1	8.4	8.2	4.0	2.3	1.7	1.6	1.5	1.4	-18.9
64K	49.8	41.1	43.7	32.1	23.4	15.6	11.9	11.1	8.9	-22.6
128K	37.0	26.0	24.2	11.6	7.0	6.0	5.6	5.6	5.2	-14.8
256K	258.4	276.2	230.0	209.9	176.0	167.5	141.2	116.8	100.0	-13.8
512K	293.4	284.5	258.3	226.0	211.6	194.1	182.3	166.0	153.5	-7.4
1Mb	303.6	276.2	211.6	252.2	234.0	217.5	210.3	191.8	177.0	-6.8
2Mb	117.9	131.6	179.0	153.1	123.0	93.2	75.0	63.0	52.9	-19.1
4Mb	328.3	389.0	345.7	343.3	393.7	476.8	540.0	551.6	530.8	9.1
8Mb	-	0.8	26.8	23.5	35.7	68.7	104.7	153.0	204.4	54.1
16Mb	-	-	-	3.0	21.7	40.6	60.9	85.6	117.0	108.1
Total	**1,417.3**	**1,444.0**	**1,336.5**	**1,263.8**	**1,232.0**	**1,285.0**	**1,336.3**	**1,348.7**	**1,353.5**	**1.4**
Growth (%)	**15.7**	**1.9**	**-7.4**	**-5.4**	**-2.5**	**4.3**	**4.0**	**0.9**	**0.4**	-

Source: Dataquest (June 1997)

Table 2-17
Shipments of EPROM to the World, 1993-2001 (Millions of Units)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
16K	5.5	4.3	4.4	2.5	1.8	1.4	1.1	1.0	0.9	-18.5
32K	7.6	3.3	3.6	1.7	1.0	0.7	0.6	0.5	0.5	-21.7
64K	31.1	27.2	28.1	19.4	13.6	8.2	5.9	5.0	4.0	-27.1
128K	21.3	16.3	15.7	8.2	4.9	3.8	3.3	3.0	2.8	-19.3
256K	142.8	141.6	145.0	114.6	88.0	83.8	70.6	58.4	50.0	-15.3
512K	115.5	117.1	139.9	114.7	92.0	80.9	72.9	66.4	61.4	-11.7
1Mb	98.3	85.0	84.0	97.0	90.0	79.1	71.3	65.0	60.0	-9.2
2Mb	22.2	25.1	38.0	37.3	30.0	23.3	20.0	16.8	14.1	-17.7
4Mb	31.7	37.8	38.4	52.0	60.1	76.9	90.0	95.1	96.5	13.2
8Mb	-	-	1.9	2.3	3.8	8.1	13.6	20.4	29.2	66.2
16Mb	-	-	-	0.1	1.0	2.3	4.3	7.8	13.0	164.7
Total	**476.0**	**457.7**	**499.0**	**449.8**	**386.2**	**368.5**	**353.6**	**339.4**	**332.4**	**-5.9**
Growth (%)	**12.4**	**-3.8**	**9.0**	**-9.9**	**-14.1**	**-4.6**	**-4.0**	**-4.0**	**-2.1**	**-**

Source: Dataquest (June 1997)

Table 2-18
Average Selling Price for Shipments of EPROM to the World, 1993-2001 (U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
16K	2.15	2.37	2.05	2.04	2.00	2.36	2.55	2.70	2.67	5.5
32K	2.25	2.55	2.28	2.35	2.30	2.43	2.67	3.00	2.80	3.6
64K	1.60	1.51	1.56	1.65	1.72	1.90	2.02	2.22	2.23	6.2
128K	1.74	1.60	1.54	1.41	1.43	1.58	1.70	1.87	1.86	5.7
256K	1.81	1.95	1.59	1.83	2.00	2.00	2.00	2.00	2.00	1.8
512K	2.54	2.43	1.85	1.97	2.30	2.40	2.50	2.50	2.50	4.9
1Mb	3.09	3.25	2.52	2.60	2.60	2.75	2.95	2.95	2.95	2.6
2Mb	5.31	5.24	4.71	4.10	4.10	4.00	3.75	3.75	3.75	-1.8
4Mb	10.36	10.29	9.00	6.60	6.55	6.20	6.00	5.80	5.50	-3.6
8Mb	-	-	14.11	10.22	9.39	8.48	7.70	7.50	7.00	-7.3
16Mb	-	-	-	30.00	21.70	17.65	14.16	10.97	9.00	-21.4
Average	**2.98**	**3.15**	**2.68**	**2.81**	**3.19**	**3.49**	**3.78**	**3.97**	**4.07**	**7.7**
Growth (%)	**2.9**	**5.7**	**-14.9**	**4.9**	**13.5**	**9.4**	**8.3**	**5.0**	**2.5**	**-**

Source: Dataquest (June 1997)

Table 2-19
Shipments of EPROM to the World, 1993-2001 (Millions of Megabytes)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
16K	0	0	0	0	0	0	0	0	0	-
32K	0	0	0	0	0	0	0	0	0	-
64K	0.2	0.2	0.2	0.2	0.1	0.1	0	0	0	-100.0
128K	0.3	0.3	0.2	0.1	0.1	0.1	0.1	0	0	-100.0
256K	4.5	4.4	4.5	3.6	2.8	2.6	2.2	1.8	1.6	-15.0
512K	7.2	7.3	8.7	7.2	5.8	5.1	4.6	4.2	3.8	-12.0
1Mb	12.3	10.6	10.5	12.1	11.3	9.9	8.9	8.1	7.5	-9.1
2Mb	5.6	6.3	9.5	9.3	7.5	5.8	5.0	4.2	3.5	-17.8
4Mb	15.9	18.9	19.2	26.0	30.1	38.5	45.0	47.6	48.3	13.2
8Mb	0	0	1.9	2.3	3.8	8.1	13.6	20.4	29.2	66.2
16Mb	0	0	0	0.2	2.0	4.6	8.6	15.6	26.0	164.7
Total	**46.0**	**48.0**	**54.7**	**61.0**	**63.5**	**74.8**	**88.0**	**101.9**	**119.9**	**14.5**
Growth (%)	**52.9**	**4.3**	**14.0**	**11.5**	**4.1**	**17.8**	**17.6**	**15.8**	**17.7**	**-**

Source: Dataquest (June 1997)

Table 2-20
Price per Megabyte for Shipments of EPROM to the World, 1993-2001 (U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
16K	-	-	-	-	-	-	-	-	-	-
32K	-	-	-	-	-	-	-	-	-	-
64K	249.00	205.50	218.50	160.50	234.00	156.00	-	-	-	-100.0
128K	123.33	86.67	121.00	116.00	70.00	60.00	56.00	-	-	-100.0
256K	57.42	62.77	51.11	58.31	62.86	64.42	64.18	64.89	62.50	1.4
512K	40.75	38.97	29.69	31.39	36.48	38.06	39.63	39.52	40.39	5.2
1Mb	24.68	26.06	20.15	20.84	20.71	21.97	23.63	23.68	23.60	2.5
2Mb	21.05	20.89	18.84	16.46	16.40	16.07	15.00	15.00	15.11	-1.7
4Mb	20.65	20.58	18.01	13.20	13.08	12.38	12.00	11.59	10.99	-3.6
8Mb	-	-	14.11	10.22	9.39	8.48	7.70	7.50	7.00	-7.3
16Mb	-	-	-	15.00	10.85	8.83	7.08	5.49	4.50	-21.4
Average	**30.81**	**30.08**	**24.43**	**20.72**	**19.40**	**17.18**	**15.19**	**13.24**	**11.29**	**-11.4**
Growth (%)	**-24.3**	**-2.4**	**-18.8**	**-15.2**	**-6.4**	**-11.4**	**-11.6**	**-12.8**	**-14.7**	**-**

Source: Dataquest (June 1997)

Table 2-21
Factory Revenue from Shipments of Flash Memory to the World, 1993-2001 (Millions of U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
256K	50.3	49.7	22.5	14.8	12.2	10.2	7.8	6.0	3.8	-23.8
512K	39.3	42.0	24.1	71.1	104.8	120.6	139.4	150.4	117.1	10.5
1Mb	279.1	337.2	344.6	520.1	427.2	421.2	409.1	415.3	331.8	-8.6
2Mb	208.5	182.8	223.1	247.2	266.4	239.3	200.9	149.5	113.2	-14.5
4Mb	109.7	131.6	565.2	924.8	820.3	810.2	772.2	687.2	564.2	-9.4
8Mb	37.7	158.5	181.1	610.7	724.1	912.0	1,184.0	1,492.1	1,605.2	21.3
16Mb	0.9	90.1	485.1	428.1	913.0	1,334.0	2,023.2	2,997.0	2,654.3	44.0
32Mb	-	-	-	11.7	84.5	513.3	812.1	1,132.4	1,638.2	168.7
64Mb	-	-	-	-	10.1	124.8	745.3	1,351.8	1,648.7	-
128Mb	-	-	-	-	-	-	102.5	372.6	793.7	-
Total	725.5	991.9	1,845.7	2,828.5	3,362.6	4,485.6	6,396.5	8,754.3	9,470.2	27.3
Growth (%)	182.6	36.7	86.1	53.2	18.9	33.4	42.6	36.9	8.2	-

Source: Dataquest (June 1997)

Table 2-22
Shipments of Flash Memory to the World, 1993-2001 (Millions of Units)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
256K	10.8	11.4	7.6	8.0	5.1	3.4	2.3	1.5	1.0	-34.0
512K	6.8	9.3	7.7	23.9	38.1	45.0	47.1	42.0	32.7	6.5
1Mb	37.6	68.4	103.9	146.3	160.0	180.0	164.3	145.2	116.0	-4.5
2Mb	13.6	18.4	33.3	37.2	48.0	52.6	49.0	40.4	30.6	-3.8
4Mb	4.1	8.3	56.0	95.2	140.7	165.0	176.7	164.8	135.3	7.3
8Mb	1.2	6.4	12.1	50.4	75.6	114.0	160.0	203.0	218.4	34.1
16Mb	-	1.5	11.9	15.6	44.0	92.0	144.0	222.0	241.3	72.9
32Mb	-	-	-	0.2	1.9	15.3	34.6	69.6	117.0	257.6
64Mb	-	-	-	0.1	0.1	1.5	12.8	33.8	60.0	259.4
128Mb	-	-	-	-	-	-	0.8	3.9	12.2	-
Total	**74.1**	**123.7**	**232.5**	**376.9**	**513.5**	**668.8**	**791.6**	**926.2**	**964.5**	**20.7**
Growth (%)	**163.8**	**66.9**	**88.0**	**62.1**	**36.2**	**30.2**	**18.4**	**17.0**	**4.1**	**-**

Source: Dataquest (June 1997)

Table 2-23
Average Selling Price for Shipments of Flash Memory to the World, 1993-2001 (U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
256K	4.66	4.36	2.96	1.85	2.39	3.00	2.29	4.00	3.80	5.1
512K	5.78	4.52	3.13	2.97	2.75	2.68	3.10	3.58	3.58	2.7
1Mb	7.42	4.93	3.32	3.56	2.67	2.34	2.27	2.86	2.86	-2.9
2Mb	15.33	9.93	6.70	6.65	5.55	4.55	3.82	3.70	3.70	-11.2
4Mb	26.76	15.86	10.09	9.71	5.83	4.91	4.68	4.17	4.17	-16.2
8Mb	31.42	24.77	14.97	12.12	9.58	8.00	10.39	7.35	7.35	-13.3
16Mb	-	60.07	40.76	27.44	20.75	14.50	21.99	13.50	11.00	-23.0
32Mb	-	-	-	58.50	44.47	33.55	53.08	16.27	14.00	-
64Mb	-	-	-	-	101.00	83.20	496.87	39.99	27.48	-
128Mb	-	-	-	-	-	-	-	95.54	65.06	-
Average	**9.79**	**8.02**	**7.94**	**7.50**	**6.55**	**6.71**	**9.56**	**9.45**	**9.82**	**4.3**
Growth (%)	**7.1**	**-18.1**	**-1.0**	**-5.5**	**-12.7**	**2.4**	**42.5**	**-1.2**	**3.9**	**-**

Source: Dataquest (June 1997)

Table 2-24
Shipments of Flash Memory to the World, 1993-2001 (Millions of Megabytes)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
256K	0.3	0.4	0.2	0.3	0.2	0.1	0.1	0	0	-100.0
512K	0.4	0.6	0.5	1.5	2.4	2.8	2.9	2.6	2.0	5.9
1Mb	4.7	8.6	13.0	18.3	20.0	22.5	20.5	18.2	14.5	-4.5
2Mb	3.4	4.6	8.3	9.3	12.0	13.2	12.3	10.1	7.7	-3.7
4Mb	2.1	4.2	28.0	47.6	70.4	82.5	88.4	82.4	67.7	7.3
8Mb	1.2	6.4	12.1	50.4	75.6	114.0	160.0	203.0	218.4	34.1
16Mb	0	3.0	23.8	31.2	88.0	184.0	288.0	444.0	482.6	72.9
32Mb	0	0	0	0.8	7.6	61.2	138.4	278.4	468.0	257.6
64Mb	0	0	0	0.8	0.8	12.0	102.4	270.4	480.0	259.4
128Mb	0	0	0	0	0	0	12.8	62.4	195.2	-
Total	**12.1**	**27.8**	**85.9**	**160.2**	**277.0**	**492.3**	**825.8**	**1,371.5**	**1,936.1**	**64.6**
Growth (%)	**167.6**	**129.8**	**209.0**	**86.5**	**72.9**	**77.7**	**67.7**	**66.1**	**41.2**	**-**

Source: Dataquest (June 1997)

Table 2-25
Price per Megabyte for Shipments of Flash Memory to the World, 1993-2001 (U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
256K	167.67	124.25	112.50	49.33	61.00	102.00	78.00	-	-	-100.0
512K	98.25	70.00	48.20	47.40	43.67	43.07	48.07	57.85	58.55	4.3
1Mb	59.38	39.21	26.51	28.42	21.36	18.72	19.96	22.82	22.88	-4.2
2Mb	61.32	39.74	26.88	26.58	22.20	18.13	16.33	14.80	14.70	-11.2
4Mb	52.24	31.33	20.19	19.43	11.65	9.82	8.74	8.34	8.33	-15.6
8Mb	31.42	24.77	14.97	12.12	9.58	8.00	7.40	7.35	7.35	-9.5
16Mb	-	30.03	20.38	13.72	10.38	7.25	7.03	6.75	5.50	-16.7
32Mb	-	-	-	14.63	11.12	8.39	5.87	4.07	3.50	-24.9
64Mb	-	-	-	00	12.63	10.40	7.28	5.00	3.43	-
128Mb	-	-	-	-	-	-	8.01	5.97	4.07	-
Average	**59.96**	**35.68**	**21.49**	**17.66**	**12.14**	**9.11**	**7.75**	**6.38**	**4.89**	**-22.6**
Growth (%)	**5.6**	**-40.5**	**-39.8**	**-17.8**	**-31.3**	**-25.0**	**-14.9**	**-17.7**	**-23.4**	**-**

Source: Dataquest (June 1997)

Table 2-26
Factory Revenue from Shipments of ROM to the World, 1993-2001 (Millions of U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
64K	0.9	0.3	0.2	5.2	-	-	-	-	-	-100.0
128K	1.5	0.4	0.3	4.9	0.1	0.1	-	-	-	-100.0
256K	17.6	12.2	8.0	10.4	2.6	1.9	1.3	0.9	0.4	-47.9
512K	14.4	8.1	6.5	8.8	1.1	0.7	0.5	0.3	0.2	-53.1
1Mb	82.5	79.7	49.5	32.5	9.4	5.1	2.8	1.6	0.8	-52.3
2Mb	99.2	130.3	123.4	39.9	39.0	23.1	12.6	5.8	3.1	-40.0
4Mb	357.4	439.7	412.1	267.4	175.8	119.9	71.2	43.9	23.5	-38.5
8Mb	592.5	587.0	423.5	308.6	184.6	123.2	73.7	38.7	24.0	-40.0
16Mb	564.7	792.2	840.4	502.4	261.0	160.0	112.0	78.8	54.0	-36.0
32Mb	-	122.5	270.7	218.5	327.0	305.4	307.2	275.5	177.8	-4.0
64Mb	-	-	-	165.5	339.4	624.4	952.4	818.9	644.0	31.2
128Mb	-	-	-	-	80.9	129.3	259.1	674.3	789.3	-
256Mb	-	-	-	-	-	-	164.7	303.0	560.5	-
Total	**1,730.7**	**2,172.4**	**2,134.6**	**1,564.1**	**1,420.9**	**1,493.1**	**1,957.5**	**2,241.7**	**2,277.6**	**7.8**
Growth (%)	**19.6**	**25.5**	**-1.7**	**-26.7**	**-9.2**	**5.1**	**31.1**	**14.5**	**1.6**	**-**

Source: Dataquest (June 1997)

Table 2-27
Shipments of ROM to the World, 1993-2001 (Millions of Units)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
64K	1.1	0.3	0.2	0.2	0.1	-	-	-	-	-100.0
128K	1.6	0.5	0.4	0.3	0.1	0.1	-	-	-	-100.0
256K	15.7	11.0	7.3	4.0	2.5	1.6	1.1	0.6	0.3	-40.4
512K	11.7	5.8	5.2	3.1	0.9	0.5	0.3	0.2	0.1	-49.7
1Mb	55.3	39.3	30.1	17.5	7.5	4.1	2.0	1.0	0.5	-50.9
2Mb	42.6	51.1	48.7	28.7	22.6	14.7	8.0	3.7	2.0	-41.3
4Mb	125.4	129.7	122.9	83.6	73.1	54.7	40.0	28.0	15.0	-29.1
8Mb	122.7	123.8	85.6	71.0	57.7	44.0	32.7	21.5	15.0	-26.7
16Mb	68.7	90.3	106.1	70.7	60.0	50.0	40.0	35.0	30.0	-15.8
32Mb	-	4.4	19.0	23.6	41.6	70.2	96.0	98.4	79.0	27.3
64Mb	-	-	-	3.6	17.9	50.3	84.7	94.2	86.2	88.7
128Mb	-	-	-	0.3	1.4	4.9	18.2	62.3	90.0	212.9
256Mb	-	-	-	-	0.1	0.3	1.6	6.0	20.0	-
Total	**444.8**	**456.2**	**425.5**	**306.6**	**285.5**	**295.4**	**324.6**	**350.9**	**338.1**	**2.0**
Growth (%)	**6.4**	**2.6**	**-6.7**	**-27.9**	**-6.9**	**3.5**	**9.9**	**8.1**	**-3.6**	**-**

Source: Dataquest (June 1997)

Table 2-28
Average Selling Price for Shipments of ROM to the World, 1993-2001 (U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
64K	0.82	1.00	1.00	26.00	-	-	-	-	-	-
128K	0.94	0.80	0.75	16.33	1.00	1.00	-	-	-	-
256K	1.12	1.11	1.10	2.60	1.04	1.19	0.81	1.50	1.33	3.9
512K	1.23	1.40	1.25	2.84	1.22	1.40	1.00	1.50	2.00	9.9
1Mb	1.49	2.03	1.64	1.86	1.25	1.24	0.68	1.60	1.60	-0.5
2Mb	2.33	2.55	2.53	1.39	1.73	1.57	0.86	1.57	1.55	-9.3
4Mb	2.85	3.39	3.35	3.20	2.40	2.19	1.30	1.57	1.57	-14.1
8Mb	4.83	4.74	4.95	4.35	3.20	2.80	1.68	1.80	1.60	-20.2
16Mb	8.22	8.77	7.92	7.11	4.35	3.20	2.24	2.25	1.80	-25.6
32Mb	-	27.84	14.25	9.26	7.86	4.35	4.38	2.80	2.25	-30.9
64Mb	-	-	-	45.97	18.96	12.41	18.93	8.69	7.47	-
128Mb	-	-	-	-	57.79	26.39	52.88	10.82	8.77	-
256Mb	-	-	-	-	-	-	549.00	50.50	28.03	-
Average	**3.89**	**4.76**	**5.02**	**5.10**	**4.98**	**5.05**	**6.63**	**6.39**	**6.74**	**6.1**
Growth (%)	**12.5**	**22.4**	**5.5**	**1.6**	**-2.4**	**1.4**	**33.1**	**26.5**	**5.5**	**-**

Source: Dataquest (June 1997)

Table 2-29
Shipments of ROM to the World, 1993-2001 (Millions of Megabytes)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
64K	17.6	4.8	3.2	3.2	1.6	0	0	0	0	-100.0
128K	27.2	8.5	6.8	5.1	1.7	1.7	0	0	0	-100.0
256K	282.6	198.0	131.4	72.0	45.0	28.8	19.8	10.8	5.4	-47.2
512K	222.3	110.2	98.8	58.9	17.1	9.5	5.7	3.8	1.9	-54.6
1Mb	6.9	4.9	3.8	2.2	0.9	0.5	0.3	0.1	0.1	-51.7
2Mb	10.7	12.8	12.2	7.2	5.7	3.7	2.0	0.9	0.5	-47.2
4Mb	62.7	64.9	61.5	41.8	36.6	27.4	20.0	14.0	7.5	-34.3
8Mb	122.7	123.8	85.6	71.0	57.7	44.0	32.7	21.5	15.0	-29.4
16Mb	137.4	180.6	212.2	141.4	120.0	100.0	80.0	70.0	60.0	-22.3
32Mb	0	17.6	76.0	94.4	166.4	280.8	384.0	393.6	316.0	33.0
64Mb	0	0	0	28.8	143.2	402.4	677.6	753.6	689.6	-
128Mb	0	0	0	4.8	22.4	78.4	291.2	996.8	1,440.0	-
256Mb	0	0	0	0	3.2	9.6	51.2	192.0	640.0	-
Total	**890.1**	**726.1**	**691.5**	**530.8**	**621.5**	**986.8**	**1,564.5**	**2,457.1**	**3,176.0**	**35.6**
Growth (%)	**80.0**	**-18.4**	**-4.8**	**-23.2**	**17.1**	**58.8**	**151.7**	**149.0**	**29.3**	**-**

Source: Dataquest (June 1997)

Table 2-30
Price per Megabyte for Shipments of ROM to the World, 1993-2001 (U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
64K	05	06	06	1.63	00	-	-	-	-	-
128K	06	05	04	0.96	06	06	-	-	-	-
256K	06	06	06	0.14	06	07	07	08	07	-12.9
512K	06	07	07	0.15	06	07	09	08	0.11	-6.0
1Mb	11.96	16.27	13.03	14.77	10.44	10.20	9.33	16.00	8.00	-11.5
2Mb	9.27	10.18	10.11	5.54	6.84	6.24	6.30	6.44	6.20	2.3
4Mb	5.70	6.78	6.70	6.40	4.80	4.38	3.56	3.14	3.13	-13.3
8Mb	4.83	4.74	4.95	4.35	3.20	2.80	2.25	1.80	1.60	-18.1
16Mb	4.11	4.39	3.96	3.55	2.18	1.60	1.40	1.13	0.90	-24.0
32Mb	-	6.96	3.56	2.31	1.97	1.09	0.80	0.70	0.56	-24.7
64Mb	-	-	-	5.75	2.37	1.55	1.41	1.09	0.93	-30.5
128Mb	-	-	-	00	3.61	1.65	0.89	0.68	0.55	NM
256Mb	-	-	-	-	00	00	3.22	1.58	0.88	-
Average	**1.94**	**2.99**	**3.09**	**2.95**	**2.29**	**1.51**	**1.25**	**0.91**	**0.72**	**-24.6**
Growth (%)	**-33.5**	**54.1**	**3.3**	**-4.5**	**-22.4**	**-34.1**	**-45.4**	**-39.7**	**-20.9**	**-**

NM = Not meaningful
Source: Dataquest (June 1997)

Table 2-31
Factory Revenue from Shipments of EEPROM to the World, 1993-2001 (Millions of U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
256b	36.3	14.7	12.1	112.5	132.5	132.0	124.2	102.7	85.9	-5.3
512b	4.1	5.1	8.5	10.9	12.0	18.0	19.6	16.9	10.9	-
1K	87.7	116.3	129.5	121.9	142.4	134.5	115.2	93.8	78.1	-8.5
2K	83.2	81.1	96.1	82.8	97.8	125.1	147.3	154.4	143.7	11.7
4K	67.1	66.8	77.5	158.1	207.2	259.3	320.0	322.3	258.1	10.3
8K	7.4	10.0	25.7	41.4	77.0	125.6	185.5	210.7	198.6	36.8
16K	44.1	55.0	90.9	165.0	192.6	296.5	367.5	384.7	359.3	16.8
64K	101.7	121.5	133.0	210.6	238.4	259.5	274.9	338.3	401.2	13.8
256K	48.0	54.0	42.4	70.9	152.4	198.2	272.4	319.2	403.9	41.6
512K	1.5	7.7	3.0	2.7	5.0	90.3	187.0	353.5	478.9	181.7
1Mb	10.7	25.6	13.9	82.2	85.7	80.2	123.6	291.9	612.0	49.4
4Mb	-	-	47.5	3.7	82.1	128.4	163.8	208.1	502.6	167.1
Total	**491.8**	**557.8**	**680.1**	**1,062.7**	**1,425.1**	**1,847.6**	**2,301.0**	**2,796.5**	**3,533.2**	**27.2**
Growth (%)	**33.3**	**13.4**	**21.9**	**56.3**	**34.1**	**29.6**	**24.5**	**21.5**	**26.3**	-

Source: Dataquest (June 1997)

Table 2-32
Shipments of EEPROM to the World, 1993-2001 (Millions of Units)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
256b	66.1	29.5	28.3	326.4	432.7	473.0	445.0	368.0	308.0	61.2
512b	6.2	8.7	18.9	25.8	43.2	64.5	70.4	60.4	39.2	15.7
1K	195.0	258.4	302.5	375.2	450.4	482.0	442.4	360.0	300.0	-0.2
2K	101.4	132.9	182.2	197.1	233.0	332.0	455.0	477.0	444.0	19.5
4K	39.2	66.8	104.5	159.7	209.7	277.8	391.0	450.0	460.0	34.5
8K	3.5	8.7	33.7	38.2	74.3	129.3	211.7	289.0	331.0	57.9
16K	22.2	33.7	62.0	85.1	105.4	200.0	298.0	391.0	439.0	47.9
64K	21.7	35.7	52.2	73.5	95.0	120.0	156.0	233.0	347.0	46.1
256K	4.3	5.4	5.0	8.4	25.0	45.0	84.0	134.0	223.0	113.7
512K	-	0.2	0.1	0.1	0.3	8.2	25.0	68.3	130.7	320.0
1Mb	0.1	0.4	0.2	1.6	2.0	2.7	6.4	22.3	71.9	224.4
4Mb	-	0.1	0.1	-	0.2	0.4	0.9	1.8	6.4	129.7
Total	**459.7**	**580.4**	**789.6**	**1,291.1**	**1,671.2**	**2,134.9**	**2,585.8**	**2,854.8**	**3,093.8**	**31.4**
Growth (%)	**53.3**	**26.3**	**36.0**	**63.5**	**29.4**	**27.7**	**21.1**	**10.4**	**8.4**	-

Source: Dataquest (June 1997)

Table 2-33
Average Selling Price for Shipments of EEPROM to the World, 1993-2001 (U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
256b	0.55	0.50	0.43	0.34	0.31	0.28	0.26	0.28	0.28	-8.2
512b	0.66	0.59	0.45	0.42	0.28	0.28	0.30	0.28	0.28	-9.1
1K	0.45	0.45	0.43	0.32	0.32	0.28	0.24	0.26	0.26	-9.6
2K	0.82	0.61	0.53	0.42	0.42	0.38	0.44	0.32	0.32	-9.6
4K	1.71	1.00	0.74	0.99	0.99	0.93	1.15	0.72	0.56	-5.4
8K	2.11	1.15	0.76	1.08	1.04	0.97	1.43	0.73	0.60	-4.6
16K	1.99	1.63	1.47	1.94	1.83	1.48	1.84	0.98	0.82	-11.0
64K	4.69	3.40	2.55	2.87	2.51	2.16	2.29	1.45	1.16	-14.6
256K	11.16	10.00	8.48	8.44	6.10	4.40	6.05	2.38	1.81	-26.6
512K	-	38.50	30.00	27.00	16.67	11.01	22.80	5.18	3.66	-34.3
1Mb	107.00	64.00	69.50	51.38	42.85	29.70	45.78	13.09	8.51	-34.3
4Mb	-	-	475.00	-	410.50	321.00	409.50	115.61	78.53	-30.2
Average	**1.07**	**0.96**	**0.86**	**0.82**	**0.85**	**0.87**	**1.08**	**0.98**	**1.14**	**5.8**
Growth (%)	**-13.0**	**-10.3**	**-10.4**	**-4.7**	**3.7**	**2.4**	**24.1**	**-9.3**	**16.3**	**-**

Source: Dataquest (June 1997)

Table 2-34
Shipments of EEPROM to the World, 1993-2001 (Thousands of Megabytes*)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
256b	2.0	0.9	0.9	10.0	13.2	14.4	13.6	11.2	9.4	-1.2
512b	0.4	0.5	1.2	1.6	2.6	3.9	4.3	3.7	2.4	8.4
1K	23.8	31.5	36.9	45.8	55.0	58.8	54.0	43.9	36.6	-4.4
2K	24.8	32.4	44.5	48.1	56.9	81.1	111.1	116.5	108.4	17.6
4K	19.1	32.6	51.0	78.0	102.4	135.6	190.9	219.7	224.6	23.6
8K	3.4	8.5	32.9	37.3	72.6	126.3	206.7	282.2	323.2	54.0
16K	43.4	65.8	121.1	166.2	205.9	390.6	582.0	763.7	857.4	38.8
64K	169.5	278.9	407.8	574.2	742.2	937.5	1,218.8	1,820.3	2,710.9	36.4
256K	134.4	168.8	156.3	262.5	781.3	1,406.3	2,625.0	4,187.5	6,968.8	92.7
512K	0	12.5	6.3	6.3	18.8	512.5	1,562.5	4,268.8	8,168.8	319.3
1Mb	12.5	50.0	25.0	200.0	250.0	337.5	800.0	2,787.5	8,987.5	114.1
4Mb	0	50.0	50.0	0	100.0	200.0	450.0	900.0	3,200.0	NM
Total	**433.3**	**682.4**	**883.9**	**1,430.0**	**2,400.9**	**4,204.5**	**7,818.9**	**15,405.0**	**28,398.0**	**81.8**
Growth (%)	**26.3**	**57.5**	**29.5**	**61.8**	**67.9**	**75.1**	**86.0**	**97.0**	**84.3**	-

NM = Not meaningful
*Shown in thousands for added resolution.
Source: Dataquest (June 1997)

Table 2-35
Price per Megabyte for Shipments of EEPROM to the World, 1993-2001 (U.S. Dollars)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	CAGR (%) 1996-2001
256b	18,150.00	16,333.33	13,444.44	11,250.00	10,037.88	9,166.67	9,132.35	9,169.64	9,138.30	-7.4
512b	10,250.00	10,200.00	7,083.33	6,812.50	4,615.38	4,615.38	4,558.14	4,567.57	4,541.67	-8.5
1K	3,684.87	3,692.06	3,509.49	2,661.57	2,589.09	2,287.41	2,133.33	2,136.67	2,133.88	-9.5
2K	3,354.84	2,503.09	2,159.55	1,721.41	1,718.80	1,542.54	1,325.83	1,325.32	1,325.65	-9.3
4K	3,513.09	2,049.08	1,519.61	2,026.92	2,023.44	1,912.24	1,676.27	1,467.00	1,149.15	-5.4
8K	2,176.47	1,176.47	781.16	1,109.92	1,060.61	994.46	897.44	746.63	614.48	-4.7
16K	1,016.13	835.87	750.62	992.78	935.41	759.09	631.44	503.73	419.06	-11.0
64K	600.00	435.64	326.14	366.77	321.21	276.80	225.55	185.85	148.00	-14.6
256K	357.14	319.91	271.27	270.10	195.06	140.94	103.77	76.23	57.96	-26.6
512K	-	616.00	476.19	428.57	265.96	176.20	119.68	82.81	58.63	-34.2
1Mb	856.00	512.00	556.00	411.00	342.80	237.63	154.50	104.72	68.09	-34.3
4Mb	-	00	950.00	-	821.00	642.00	364.00	231.22	157.06	-30.2
Average	**1,135.01**	**817.41**	**769.43**	**743.15**	**593.57**	**439.43**	**294.29**	**181.53**	**124.42**	**-30.5**
Growth (%)	**5.6**	**-28.0**	**-5.9**	**-3.4**	**-20.1**	**-26.0**	**-33.0**	**-38.3**	**-31.5**	**-**

Source: Dataquest (June 1997)

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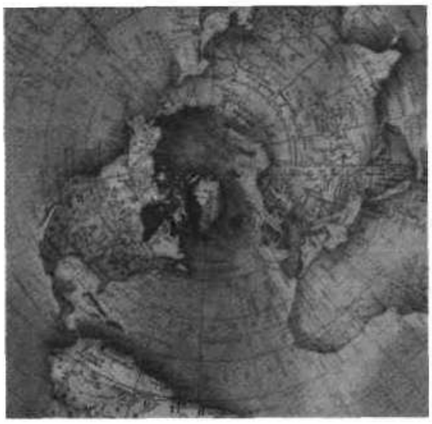

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Dataquest

1996 SRAM Unit Shipments

Market Statistics

Program: Memories Worldwide
Product Code: MMRY-WW-MS-9704
Publication Date: June 30, 1997
Filing: Market Statistics

1996 SRAM Unit Shipments

Market Statistics

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Chapter 1
Introduction

This document contains detailed statistics on the 1996 SRAM market. Analyses of companies' MOS memory shipments provide insight into high-technology markets and reinforce estimates of consumption, production, and company revenue.

Dataquest's Memories Worldwide program provides qualitative analysis of this data as part of a yearly subscription to its service. Clients of this program can find qualitative information in the Dataquest Memories Worldwide binder. Dataquest's client inquiry service can provide historical or more detailed information regarding the MOS memory market on request.

This introduction to the subsequent tables defines the market segments specific to this document. For a complete description of all market segments tracked by Dataquest, please refer to *Final Semiconductor Market Definitions* (SEMI-WW-GU-9701, February 5, 1997). A subscription to any Dataquest semiconductor service includes this guide.

Metric Definitions

Unit Shipments

Dataquest defines unit shipments as "for-revenue transfers of own-branded semiconductor products" from a device manufacturer (for example, Samsung) to an electronic equipment manufacturer (for example, Compaq Computer), subsystem assembler (for example, Kingston or SanDisk), or device reseller (for example, Arrow Electronics). This study counts the volume of devices sold (that is, units) rather than the dollar value of that volume (that is, not sales).

Inclusions for Unit Shipments

For shipments of devices on assembled subsystems (for example, modules), Dataquest counts the devices on the module rather than the module itself. Dataquest considers those devices shipped when the device manufacturer sells the module.

If a company sells any portion of a product category (for example, DRAM or EPROM) outside the company, then Dataquest includes all shipments of that category. For example, company ABC manufactures DRAM and EPROM. ABC's production of PCs consumes 99 percent of its DRAM and 100 percent of its EPROM. Dataquest will include 100 percent of ABC's DRAM shipments and 0 percent of ABC's EPROM shipments. Dataquest considers captive product shipped when the company transfers the product to the electronic equipment business unit or production facility.

Exclusions for Unit Shipments

Dataquest excludes logic devices with embedded memory even if the device manufacturer produces the device with a memory process. Dataquest counts these as microcomponents or ASIC or digital logic.

Dataquest excludes product categories that the company consumes 100 percent internally (totally captive production).

Dataquest excludes devices produced under contract for another device manufacturer to sell under that second manufacturer's brand name (contract manufacturing or foundry).

Dataquest excludes internal transfers from headquarters to sales subsidiaries but counts these parts when the subsidiary invoices them to an end user, to a third party, or to a value-added reseller.

Average Selling Price

At the bottom of each table, Dataquest includes an average selling price (ASP) for each density. Average selling price is the average billing price per unit paid for a product when it leaves the factory, taking into account discounts given to the distribution channel and multiple-purchase discounts. Dataquest averages prices over all companies, package types, lot sizes, speed mixes, and accounts (including military and commercial).

Revenue

Multiplying a product's shipment total by its ASP yields "dollarized units," which Dataquest defines as revenue for this report. These prices are industrywide approximations for each market segment. Dataquest intends use of these prices only as guidelines. Actual negotiated market prices may vary because of manufacturer-specific factors such as product quality, special features, service, delivery performance, volume discount, or other factors that may enhance or detract from the product's value. Therefore, multiplying a company's unit shipments by the industrywide ASP may not yield an accurate revenue figure. For company revenue by product type, please consult *Worldwide Memory Market Share* (MMRY-WW-MS-9701, May 19, 1997). A subscription to Dataquest's Memories Worldwide program includes this report.

Memory Definitions and Categories

Memory IC

A memory IC is an integrated circuit capable of and dedicated to storing retrievable electronic information in binary form. Dataquest limits the scope of this research to MOS (metal oxide semiconductor) DRAM, SRAM, EEPROM, EPROM, flash, and ROM only.

Volatile Memory

A memory IC that loses its contents with power interruption. Volatile memories include DRAM and SRAM. Dataquest includes SRAM unit shipments in this report and publishes DRAM unit shipments in a separate report titled *1996 DRAM Unit Shipments* (MMRY-WW-MS-9702, June 1997).

Nonvolatile Memory

A memory IC that retains its contents with power interruption. Nonvolatile memories include EEPROM, EPROM, and ROM. Dataquest publishes nonvolatile unit shipments in a separate report titled *1996 Nonvolatile Memory Unit Shipments* (MMRY-WW-MS-9703).

Density

Dataquest classifies memory ICs by the number of bits the chip is able to store concurrently. Memory devices store bits in memory "cells" laid in rows and columns on the chip. The total number of cells is the density of the chip. Densities usually follow powers of two. For example, a 256-bit memory IC would contain 2^8 bits. Naming conventions have developed to append more dense chips with kilo- (K), mega- (or M), and giga- (G) to simplify references to that density. "Kilobits" (Kb) refers to 2^{10} bits. An 8Kb memory IC will contain 8 x 2^{10} bits (8,192 bits)—an "eight kilobit" chip. "Megabits" (Mb) refers to 2^{20} bits. A 4Mb memory IC will contain 4 x 2^{20} bits (4,194,304 bits)—a "four megabit" chip. "Gigabits" (Gb) refers to 2^{30} bits. A 1Gb memory IC will contain 1 x 2^{30} bits (1,073,741,824 bits)—a "one gigabit" chip. Dataquest limits the densities tracked according to device category. The tracked densities generally include all mainstream and high-volume densities.

This report includes SRAM densities from 16Kb through 4Mb.

Configuration

Along with density, Dataquest classifies memory ICs by their configuration (or organization) of the array of memory cells. The configuration is akin to the length and width of the array, with the product of these equaling the density. Memory IC manufacturers produce many different widths of the same density to accommodate each customer's system, data bus, and logic word width needs. Common configurations include x1 (1 bit wide), x4 (4 bits wide), x8 (8 bits wide), and x16 (16 bits wide).

Device Definitions

SRAM

SRAM stands for static random access memory. SRAMs have four-transistor memory cells, except for pseudo-SRAM (PSRAM), which has a single-transistor memory cell similar to a DRAM. SRAMs do not require cell refreshes. These are volatile memories with nonmultiplexed addressing (again, except for PSRAM). SRAM includes static RAM, multiport-SRAM (M-SRAM), battery-backed-up SRAM (BB-SRAM), and PSRAM. Dataquest subdivides the SRAM category into speed ranges based on maximum access times. The speed categories are 0 to 9ns, 10 to 19ns, 20 to 29ns, 30 to 44ns, 45 to 70ns, over 71ns, and PSRAM over 71ns.

Market Share Methodology

Dataquest uses primary and secondary sources to produce market statistics. The Memories Worldwide program surveys companies once a year to collect shipment data for each quarter of the previous year. Dataquest supplements this survey effort with additional primary and secondary research to verify market size, shipment totals, and pricing information. Dataquest's sources include the following:

- Device manufacturer surveys
- Information published by major industry participants

- Estimates made by knowledgeable and reliable industry spokespersons
- Industry or trade association data (including SIA-WSTS)
- Government data
- Published product literature and price lists
- Interviews with knowledgeable manufacturers, distributors, and users
- Relevant economic data
- Information and data from online or CD-ROM data banks
- Articles in both the general and trade press
- Reports from financial analysts
- End-user surveys

Despite the care taken in gathering, analyzing, and categorizing the data in a meaningful way, differences between Dataquest's data and other available data may exist. Various companies, government agencies, and trade associations may use different product or regional definitions or may include different companies in their summaries. Please keep these differences in mind when comparing data and numbers provided by Dataquest with those provided by other research companies.

Notes to Market Share Tables

To report market data in a more meaningful way, Dataquest sometimes consolidates or revises the numbers for a particular company, model, series, or industry. These notes explain any such changes contained in this document.

1. In 1992, MOSel and Vitelic merged to form Mosel Vitelic, which Dataquest listed as an Asia/Pacific device manufacturer.

2. In 1993, NMB Semiconductor changed its business name to Nittetsu Semiconductor.

3. In 1993, Dataquest included MOS memory shipments from International Business Machines.

4. In 1994, Dataquest changed Nittetsu Semiconductor to Nippon Steel Semiconductor.

5. In 1994, Dataquest included MOS memory shipments from Alliance Semiconductor.

6. In 1995, Dataquest included MOS memory shipments from G-Link.

7. In 1995, Dataquest included MOS memory shipments from Integrated Silicon Solution Inc.

8. In 1995, Dataquest changed Goldstar to LG Semicon.

9. In 1995, Dataquest included MOS memory shipments from Vanguard International.

10. In 1996, Dataquest included MOS memory shipments from Ramtron International.

11. In 1996, Dataquest included MOS memory shipments from Silicon Storage Technology.

12. In 1996, Dataquest included MOS memory shipments from Nan Ya Technology.

Chapter 2
Market Statistics Tables

Table 2-1
Each Company's Quarterly Shipments of SRAM by Density to the World, 1996
(Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Alliance					
All 64K	574	807	1,080	732	3,193
All 256K	2,650	2,690	5,810	5,200	16,350
All 512K	18	11	15	22	66
All 1Mb	600	400	290	170	1,460
Vendor Total	3,842	3,908	7,195	6,124	21,069
Cypress					
All 16K	413	340	303	234	1,290
All 64K	9,360	6,710	6,300	4,420	26,790
All 256K	12,750	8,760	8,580	7,440	37,530
All 1Mb	528	473	473	504	1,978
Vendor Total	23,051	16,283	15,655	12,599	67,588
Electronic Designs Inc.					
All 256K	75	55	55	50	235
All 1Mb	475	225	265	335	1,300
All 2Mb	75	90	110	160	435
All 4Mb	225	210	215	220	870
Vendor Total	850	580	645	765	2,840
Fujitsu					
All 16K	197	181	170	161	709
All 64K	1,608	1,003	1,054	821	4,486
All 256K	3,500	3,800	3,000	2,500	12,800
All 1Mb	1,700	850	425	210	3,185
All 4Mb	51	18	9	3	81
Vendor Total	7,056	5,852	4,658	3,695	21,261
G-Link					
All 64K	-	200	300	300	800
All 256K	315	500	350	200	1,365
All 512K	355	250	215	55	875
All 1Mb	80	55	40	40	215
Vendor Total	750	1,005	905	595	3,255

Table 2-1 (Continued)
Each Company's Quarterly Shipments of SRAM by Density to the World, 1996
(Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Hitachi					
All 16K	260	200	200	200	860
All 64K	2,000	2,000	2,000	2,000	8,000
All 256K	5,000	4,500	4,500	4,500	18,500
All 512K	800	500	500	500	2,300
All 1Mb	5,800	8,000	8,000	8,000	29,800
All 4Mb	1,400	1,600	1,600	1,600	6,200
Vendor Total	15,260	16,800	16,800	16,800	65,660
Hyundai					
All 64K	6,864	6,334	5,551	4,602	23,351
All 256K	10,246	10,322	10,044	9,804	40,417
Vendor Total	17,111	16,656	15,595	14,406	63,767
IBM Microelectronics					
All 1Mb	1,000	1,500	2,000	2,000	6,500
All 4Mb	-	-	-	2	2
Vendor Total	1,000	1,500	2,000	2,002	6,502
Integrated Device Technology					
All 16K	529	686	541	592	2,348
All 64K	1,596	1,740	1,777	2,078	7,191
All 256K	6,871	6,927	6,090	8,331	28,219
All 1Mb	955	1,315	1,815	1,730	5,815
Vendor Total	9,951	10,668	10,223	12,731	43,573
ISSI					
All 64K	1,850	1,840	1,415	1,470	6,575
All 256K	13,405	13,202	15,432	11,183	53,222
All 512K	862	344	515	325	2,046
All 1Mb	1,230	1,098	1,023	1,334	4,685
Vendor Total	17,347	16,484	18,385	17,233	69,449
LG Semicon					
All 16K	2,100	1,950	1,600	1,320	6,970
All 64K	5,450	5,120	4,760	4,250	19,580
All 256K	2,270	2,500	2,640	2,780	10,190
All 1Mb	1,560	1,970	2,230	2,420	8,180
Vendor Total	11,380	11,540	11,230	10,770	44,920
Matra					
All 16K	70	60	50	40	220
All 64K	115	99	82	66	362
All 256K	75	94	113	132	414
All 1Mb	14	18	21	25	78
Vendor Total	274	271	266	263	1,074

Table 2-1 (Continued)
Each Company's Quarterly Shipments of SRAM by Density to the World, 1996
(Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Matsushita					
All 64K	200	200	200	200	800
All 256K	800	800	800	800	3,200
Vendor Total	1,000	1,000	1,000	1,000	4,000
Micron					
All 256K	96	60	58	36	250
All 1Mb	830	780	845	845	3,300
All 2Mb	25	55	85	110	275
Vendor Total	951	895	988	991	3,825
Mitsubishi					
All 64K	1,400	1,340	1,280	1,250	5,270
All 256K	8,000	8,200	8,600	9,300	34,100
All 1Mb	4,560	4,990	5,290	5,635	20,475
All 4Mb	80	70	50	50	250
Vendor Total	14,040	14,600	15,220	16,235	60,095
Mosel Vitelic					
All 64K	633	618	719	595	2,565
All 256K	471	358	289	226	1,344
Vendor Total	1,104	976	1,008	821	3,909
Motorola					
All 64K	513	198	403	437	1,551
All 256K	8,817	4,966	4,407	4,775	22,965
All 512K	579	259	242	261	1,341
All 1Mb	3,205	3,605	3,255	3,640	13,705
All 4Mb	99	143	206	329	777
Vendor Total	13,213	9,171	8,513	9,442	40,339
NEC					
All 64K	1,340	1,250	1,100	1,000	4,690
All 256K	5,500	5,500	5,500	5,500	22,000
All 1Mb	6,700	6,200	5,900	8,200	27,000
All 4Mb	150	300	250	180	880
Vendor Total	13,690	13,250	12,750	14,880	54,570
Oki					
All 64K	35	32	29	23	119
All 256K	152	153	149	146	600
All 1Mb	544	488	522	565	2,119
All 4Mb	37	47	53	63	200
Vendor Total	768	720	753	797	3,038

Table 2-1 (Continued)
Each Company's Quarterly Shipments of SRAM by Density to the World, 1996
(Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Paradigm					
All 256K	959	676	661	579	2,875
All 1Mb	202	180	175	186	742
Vendor Total	1,161	856	836	765	3,617
Rohm					
All 16K	110	102	89	74	375
All 64K	2,051	1,893	1,659	1,375	6,978
All 256K	178	180	175	171	704
All 1Mb	260	236	250	269	1,015
Vendor Total	2,599	2,411	2,173	1,889	9,072
Samsung					
All 64K	1,730	1,370	1,640	1,130	5,870
All 256K	1,373	11,750	16,588	21,390	51,100
All 1Mb	13,670	13,000	14,715	17,270	58,655
All 2Mb	27	14	25	34	100
All 4Mb	540	550	555	570	2,215
Vendor Total	17,340	26,684	33,523	40,394	117,940
Sanyo					
All 16K	1,000	1,300	1,000	900	4,200
All 64K	500	600	500	400	2,000
All 256K	1,200	1,500	1,200	1,100	5,000
All 512K	350	500	350	300	1,500
All 1Mb	600	800	600	500	2,500
Vendor Total	3,650	4,700	3,650	3,200	15,200
Seiko Epson					
All 16K	18	18	17	17	70
All 64K	180	180	170	170	700
All 256K	600	350	250	250	1,450
All 1Mb	800	600	500	400	2,300
Vendor Total	1,598	1,148	937	837	4,520
SGS-Thomson					
All 256K	600	300	120	35	1,055
All 1Mb	249	223	221	236	929
Vendor Total	849	523	341	271	1,984
Sharp					
All 16K	801	739	648	537	2,725
All 64K	9,744	8,991	7,879	6,533	33,147
All 256K	4,838	4,861	4,730	4,614	19,043
All 1Mb	1,441	1,293	1,307	1,396	5,437
All 4Mb	135	135	136	137	543
Vendor Total	16,959	16,019	14,700	13,217	60,895

Table 2-1 (Continued)
Each Company's Quarterly Shipments of SRAM by Density to the World, 1996
(Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Sony					
All 64K	150	150	150	150	600
All 256K	7,500	7,500	7,500	7,500	30,000
All 512K	450	450	450	450	1,800
All 1Mb	9,675	9,675	9,675	9,675	38,700
All 4Mb	400	400	400	400	1,600
Vendor Total	18,175	18,175	18,175	18,175	72,700
Texas Instruments					
All 64K	1,675	965	555	320	3,515
Vendor Total	1,675	965	555	320	3,515
Toshiba					
All 64K	1,307	1,180	1,039	851	4,377
All 256K	10,503	9,804	9,553	9,145	39,005
All 1Mb	12,367	11,173	11,556	12,372	47,468
All 4Mb	1,154	1,313	1,430	1,607	5,504
Vendor Total	25,331	23,470	23,578	23,975	96,354
UMC					
All 16K	18	16	14	12	59
All 64K	1,296	1,156	1,022	831	4,304
All 256K	5,704	4,133	4,042	3,576	17,455
All 1Mb	1,149	1,008	923	977	4,057
Vendor Total	8,168	6,312	6,001	5,395	25,875
Winbond					
All 16K	1	1	1	1	3
All 64K	947	874	766	635	3,220
All 256K	17,843	15,081	14,712	13,697	61,334
All 1Mb	345	302	277	293	1,217
Vendor Total	19,136	16,258	15,756	14,626	65,775
Market Total					
All 16K	5,517	5,592	4,633	4,087	19,829
All 64K	53,118	46,849	43,429	36,639	180,034
All 256K	132,291	129,522	135,948	134,960	532,722
All 512K	3,414	2,314	2,287	1,913	9,928
All 1Mb	70,540	70,457	72,592	79,227	292,816
All 2Mb	127	159	220	304	810
All 4Mb	4,271	4,786	4,904	5,161	19,122
Total	269,278	259,679	264,013	262,291	1,055,261

Table 2-1 (Continued)
Each Company's Quarterly Shipments of SRAM by Density to the World, 1996
(Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Percentage Change from Previous Quarter	-20.4	-3.6	1.7	-.06	-
Average Selling Price ($)	6.79	5.45	4.66	3.67	5.15
Revenue ($M)	1,828,183	1,416,431	1,231,349	973,551	5,449,514
Market Share (% of Units)					
Americas Companies	27.4	24.0	25.0	24.0	25.1
European Companies	0.4	0.3	0.2	0.2	0.3
Japanese Companies	44.6	45.5	43.3	43.2	44.2
Asia/Pacific Companies	27.6	30.2	31.5	32.6	30.4
Total	100.0	100.0	100.0	100.0	100.00

Note: Numbers may not add to totals shown because of rounding.
Source: Dataquest (June 1997)

Table 2-2
Each Company's Quarterly Shipments of 16K SRAM by Configuration to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Cypress					
16Kx1	62	51	45	35	194
4Kx4	145	119	106	82	452
2Kx8	206	170	151	117	645
Vendor Total	413	340	303	234	1,290
Fujitsu					
16Kx1	158	144	136	129	567
4Kx4	39	36	34	32	142
Vendor Total	197	181	170	161	709
Hitachi					
16Kx1	47	36	36	36	155
4Kx4	88	68	68	68	292
2Kx8	125	96	96	96	413
Vendor Total	260	200	200	200	860
Integrated Device Technology					
4Kx4	122	226	146	189	684
2Kx8	407	460	395	403	1,664
Vendor Total	529	686	541	592	2,348
LG Semicon					
2Kx8	2,100	1,950	1,600	1,320	6,970
Vendor Total	2,100	1,950	1,600	1,320	6,970
Matra					
16Kx1	18	15	13	10	55
4Kx4	11	9	8	6	33
2Kx8	42	36	30	24	132
Vendor Total	70	60	50	40	220
Rohm					
2Kx8	110	102	89	74	375
Vendor Total	110	102	89	74	375
Sanyo					
2Kx8	1,000	1,300	1,000	900	4,200
Vendor Total	1,000	1,300	1,000	900	4,200
Seiko Epson					
2Kx8	18	18	17	17	70
Vendor Total	18	18	17	17	70
Sharp					
16Kx1	8	7	6	5	27
2Kx8	793	732	642	532	2,698
Vendor Total	801	739	648	537	2,725

Table 2-2 (Continued)
Each Company's Quarterly Shipments of 16K SRAM by Configuration to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
UMC					
2Kx8	18	16	14	12	59
Vendor Total	18	16	14	12	59
Winbond					
2Kx8	1	1	1	1	3
Vendor Total	1	1	1	1	3
Market Total					
16Kx1	292	254	237	215	997
4Kx4	404	459	362	378	1,602
2Kx8	4,820	4,880	4,035	3,494	17,229
Total	5,517	5,592	4,633	4,087	19,829
Percentage Change from Previous Quarter	-47.5	1.4	-17.2	-11.8	-
Average Selling Price ($)	5.16	5.05	4.32	4.36	4.77
Revenue ($M)	28	28	20	18	95
Market Share (% of Units)					
Americas Companies	17.1	18.3	18.2	20.2	18.3
European Companies	1.3	1.1	1.1	1.0	1.1
Japanese Companies	43.3	45.4	45.9	46.2	45.1
Asia/Pacific Companies	38.4	35.2	34.9	32.6	35.5
Total	100.0	100.0	100.0	100.0	100.0

Note: Numbers may not add to totals shown because of rounding.
Source: Dataquest (June 1997)

Table 2-3
Each Company's Quarterly Shipments of 16K SRAM by Speed to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Cypress					
10-19ns	83	68	61	47	258
20-29ns	248	204	182	141	774
45-70ns	83	68	61	47	258
Vendor Total	413	340	303	234	1,290
Fujitsu					
45-70ns	197	181	170	161	709
Vendor Total	197	181	170	161	709
Hitachi					
20-29ns	34	26	26	26	112
30-44ns	70	54	54	54	232
45-70ns	31	24	24	24	103
71ns+	125	96	96	96	413
Vendor Total	260	200	200	200	860
Integrated Device Technology					
10-19ns	16	21	27	24	87
20-29ns	280	405	276	266	1,227
30-44ns	122	117	97	118	454
45-70ns	95	103	103	148	449
71ns+	16	41	38	36	130
Vendor Total	529	686	541	592	2,348
LG Semicon					
71ns+	2,100	1,950	1,600	1,320	6,970
Vendor Total	2,100	1,950	1,600	1,320	6,970
Matra					
20-29ns	14	12	10	8	44
30-44ns	18	15	13	10	55
45-70ns	18	15	13	10	55
71ns+	21	18	15	12	66
Vendor Total	70	60	50	40	220
Rohm					
71ns+	110	102	89	74	375
Vendor Total	110	102	89	74	375
Sanyo					
20-29ns	170	221	170	144	705
30-44ns	340	442	330	297	1,409
71ns+	490	637	500	459	2,086
Vendor Total	1,000	1,300	1,000	900	4,200

Table 2-3 (Continued)
Each Company's Quarterly Shipments of 16K SRAM by Speed to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Seiko Epson					
71ns+	18	18	17	17	70
Vendor Total	18	18	17	17	70
Sharp					
71ns+	801	739	648	537	2,725
Vendor Total	801	739	648	537	2,725
UMC					
20-29ns	5	5	4	3	17
30-44ns	10	9	8	7	35
71ns+	2	2	2	2	8
Vendor Total	18	16	14	12	59
Winbond					
71ns+	1	1	1	1	3
Vendor Total	1	1	1	1	3
Market Total					
10-19ns	98	89	88	71	345
20-29ns	751	872	668	588	2,879
30-44ns	560	637	502	486	2,185
45-70ns	424	390	370	390	1,574
71ns+	3,684	3,604	3,005	2,553	12,846
Total	5,517	5,592	4,633	4,087	19,829
Percentage Change from Previous Quarter	-47.5	1.4	-17.2	-11.8	-
Average Selling Price ($)	5.16	5.05	4.32	4.36	4.77
Revenue ($M)	28	28	20	18	95
Market Share (% of Units)					
Americas Companies	17.1	18.3	18.2	20.2	18.3
European Companies	1.3	1.1	1.1	1.0	1.1
Japanese Companies	43.3	45.4	45.9	46.2	45.1
Asia/Pacific Companies	38.4	35.2	34.9	32.6	35.5
Total	100.0	100.0	100.0	100.0	100.0

Note: Numbers may not add to totals shown because of rounding.
Source: Dataquest (June 1997)

Table 2-4
Each Company's Quarterly Shipments of 64K SRAM by Configuration to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Alliance					
8Kx8	574	807	1,080	732	3,193
Vendor Total	574	807	1,080	732	3,193
Cypress					
64Kx1	1,123	671	630	398	2,822
16Kx4	1,310	939	882	575	3,706
8Kx8	6,552	4,898	4,599	3,315	19,364
8Kx9	374	201	189	133	897
Vendor Total	9,360	6,710	6,300	4,420	26,790
Fujitsu					
8Kx8	1,447	903	949	739	4,037
8Kx9	161	100	105	82	449
Vendor Total	1,608	1,003	1,054	821	4,486
G-Link					
8Kx8	-	200	300	300	800
Vendor Total	-	200	300	300	800
Hitachi					
64Kx1	540	540	540	540	2,160
16Kx4	340	340	340	340	1,360
8Kx8	1,120	1,120	1,120	1,120	4,480
Vendor Total	2,000	2,000	2,000	2,000	8,000
Hyundai					
8Kx8	6,864	6,334	5,551	4,602	23,351
Vendor Total	6,864	6,334	5,551	4,602	23,351
Integrated Device Technology					
64Kx1	16	17	18	21	72
16Kx4	1,564	1,688	1,741	2,036	7,030
8Kx8	16	35	18	21	89
Vendor Total	1,596	1,740	1,777	2,078	7,191
ISSI					
8Kx8	1,850	1,840	1,415	1,470	6,575
Vendor Total	1,850	1,840	1,415	1,470	6,575
LG Semicon					
8Kx8	5,450	5,120	4,760	4,250	19,580
Vendor Total	5,450	5,120	4,760	4,250	19,580
Matra					
64Kx1	23	20	16	13	72
16Kx4	46	40	33	26	145
8Kx8	46	40	33	26	145
Vendor Total	115	99	82	66	362

Table 2-4 (Continued)
Each Company's Quarterly Shipments of 64K SRAM by Configuration to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Matsushita					
8Kx8	200	200	200	200	800
Vendor Total	200	200	200	200	800
Mitsubishi					
64Kx1	224	214	218	213	869
16Kx4	252	241	230	213	936
8Kx8	924	884	832	825	3,465
Vendor Total	1,400	1,340	1,280	1,250	5,270
Mosel Vitelic					
8Kx8	633	618	719	595	2,565
Vendor Total	633	618	719	595	2,565
Motorola					
16Kx4	-	6	1	13	20
8Kx8	262	150	73	70	555
4Kx10/12	251	42	329	354	976
Vendor Total	513	198	403	437	1,551
NEC					
64Kx1	174	163	143	130	610
16Kx4	67	63	55	50	235
8Kx8	1,099	1,025	902	820	3,846
Vendor Total	1,340	1,250	1,100	1,000	4,690
Oki					
8Kx8	35	32	29	23	119
Vendor Total	35	32	29	23	119
Rohm					
8Kx8	2,051	1,893	1,659	1,375	6,978
Vendor Total	2,051	1,893	1,659	1,375	6,978
Samsung					
16Kx4	1,730	1,370	1,640	1,130	5,870
Vendor Total	1,730	1,370	1,640	1,130	5,870
Sanyo					
8Kx8	500	600	500	400	2,000
Vendor Total	500	600	500	400	2,000
Seiko Epson					
8Kx8	180	180	170	170	700
Vendor Total	180	180	170	170	700
Sharp					
8Kx8	9,744	8,991	7,879	6,533	33,147
Vendor Total	9,744	8,991	7,879	6,533	33,147

Table 2-4 (Continued)
Each Company's Quarterly Shipments of 64K SRAM by Configuration to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Sony					
16Kx4	23	23	23	23	90
8Kx8	128	128	128	128	510
Vendor Total	150	150	150	150	600
Texas Instruments					
64Kx1	484	276	159	91	1,011
16Kx4	1,191	689	396	229	2,504
Vendor Total	1,675	965	555	320	3,515
Toshiba					
8Kx8	823	743	655	545	2,766
8Kx9	484	437	384	306	1,611
Vendor Total	1,307	1,180	1,039	851	4,377
UMC					
8Kx8	1,296	1,156	1,022	831	4,304
Vendor Total	1,296	1,156	1,022	831	4,304
Winbond					
16Kx4	567	523	459	380	1,929
8Kx8	380	350	307	254	1,291
Vendor Total	947	874	766	635	3,220
Market Total					
64Kx1	2,584	1,902	1,724	1,406	7,615
16Kx4	7,090	5,921	5,799	5,014	23,825
8Kx8	42,174	38,247	34,897	29,343	144,660
8Kx9	1,019	738	679	521	2,957
4Kx10/12	251	42	329	354	976
Total	53,118	46,849	43,429	36,639	180,034
Percentage Change from Previous Quarter	-18.6	-11.8	-7.3	-15.6	-
Average Selling Price ($)	2.33	2.21	1.97	1.78	2.10
Revenue ($M)	123,766	103,536	85,554	65,217	378,072
Market Share (% of Units)					
Americas Companies	29.3	26.6	27.2	26.6	27.6
European Companies	0.2	0.2	0.2	0.2	0.2
Japanese Companies	38.6	40.2	39.3	40.3	39.5
Asia/Pacific Companies	31.9	33.0	33.3	32.9	32.7
Total	100.0	100.0	100.0	100.0	100.0

Note: Numbers may not add to totals shown because of rounding.
Source: Dataquest (June 1997)

Table 2-5
Each Company's Quarterly Shipments of 64K SRAM by Speed to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Alliance					
10-19ns	574	807	1,080	732	3,193
Vendor Total	574	807	1,080	732	3,193
Cypress					
10-19ns	5,335	3,154	3,150	1,856	13,495
20-29ns	1,872	1,678	1,449	1,193	6,192
30-44ns	1,872	1,678	1,449	1,193	6,192
45-70ns	281	201	252	177	911
Vendor Total	9,360	6,710	6,300	4,420	26,790
Fujitsu					
10-19ns	16	10	11	8	45
20-29ns	64	40	42	25	171
30-44ns	113	70	74	57	314
45-70ns	193	120	126	107	547
71ns+	1,222	762	801	624	3,409
Vendor Total	1,608	1,003	1,054	821	4,486
G-Link					
10-19ns	-	200	300	300	800
Vendor Total	-	200	300	300	800
Hitachi					
10-19ns	100	100	100	100	400
20-29ns	120	120	120	120	480
30-44ns	260	260	260	260	1,040
45-70ns	420	420	420	420	1,680
71ns+	1,100	1,100	1,100	1,100	4,400
Vendor Total	2,000	2,000	2,000	2,000	8,000
Hyundai					
71ns+	6,864	6,334	5,551	4,602	23,351
Vendor Total	6,864	6,334	5,551	4,602	23,351
Integrated Device Technology					
0-9ns	96	70	124	166	456
10-19ns	686	1,096	1,084	1,247	4,113
20-29ns	750	487	480	561	2,278
30-44ns	16	35	36	42	128
45-70ns	32	52	53	42	179
71ns+	16	-	-	21	37
Vendor Total	1,596	1,740	1,777	2,078	7,191

Table 2-5 (Continued)
Each Company's Quarterly Shipments of 64K SRAM by Speed to the World, 1996
(Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
ISSI					
10-19ns	1,850	1,840	1,415	1,470	6,575
Vendor Total	1,850	1,840	1,415	1,470	6,575
LG Semicon					
71ns+	5,450	5,120	4,760	4,250	19,580
Vendor Total	5,450	5,120	4,760	4,250	19,580
Matra					
10-19ns	6	5	4	3	18
20-29ns	26	22	18	15	81
30-44ns	35	30	25	20	109
45-70ns	40	35	29	23	127
71ns+	9	7	6	5	27
Vendor Total	115	99	82	66	362
Matsushita					
71ns+	200	200	200	200	800
Vendor Total	200	200	200	200	800
Mitsubishi					
20-29ns	294	375	294	275	1,239
30-44ns	602	509	550	550	2,212
45-70ns	420	389	384	375	1,568
71ns+	84	67	51	50	252
Vendor Total	1,400	1,340	1,280	1,250	5,270
Mosel Vitelic					
45-70ns	253	247	288	238	1,026
71ns+	380	371	431	357	1,539
Vendor Total	633	618	719	595	2,565
Motorola					
10-19ns	262	160	73	253	748
20-29ns	10	12	16	17	56
30-44ns	241	26	314	166	747
Vendor Total	513	198	403	437	1,551
NEC					
45-70ns	241	225	198	180	844
71ns+	389	363	319	290	1,360
71ns+ PSRAM	710	663	583	530	2,486
Vendor Total	1,340	1,250	1,100	1,000	4,690
Oki					
71ns+	35	32	29	23	119
Vendor Total	35	32	29	23	119

Table 2-5 (Continued)
Each Company's Quarterly Shipments of 64K SRAM by Speed to the World, 1996
(Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Rohm					
71ns+	2,051	1,893	1,659	1,375	6,978
Vendor Total	2,051	1,893	1,659	1,375	6,978
Samsung					
20-29ns	52	82	16	-	151
71ns+	1,678	1,288	1,624	1,130	5,720
Vendor Total	1,730	1,370	1,640	1,130	5,870
Sanyo					
71ns+	500	600	500	400	2,000
Vendor Total	500	600	500	400	2,000
Seiko Epson					
71ns+	180	180	170	170	700
Vendor Total	180	180	170	170	700
Sharp					
45-70ns	39	36	32	26	134
71ns+	9,705	8,955	7,847	6,507	33,013
Vendor Total	9,744	8,991	7,879	6,533	33,147
Sony					
30-44ns	45	45	45	45	180
71ns+	105	105	105	105	420
Vendor Total	150	150	150	150	600
Texas Instruments					
10-19ns	335	193	111	64	703
20-29ns	754	434	250	144	1,582
45-70ns	586	338	194	112	1,230
Vendor Total	1,675	965	555	320	3,515
Toshiba					
10-19ns	13	12	10	9	44
20-29ns	222	201	177	145	744
30-44ns	444	389	343	281	1,457
71ns+	627	578	509	417	2,132
Vendor Total	1,307	1,180	1,039	851	4,377
UMC					
20-29ns	400	356	315	256	1,327
30-44ns	801	712	630	511	2,654
71ns+	95	88	77	64	323
Vendor Total	1,296	1,156	1,022	831	4,304

Table 2-5 (Continued)
Each Company's Quarterly Shipments of 64K SRAM by Speed to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Winbond					
45-70ns	947	874	766	635	3,220
Vendor Total	947	874	766	635	3,220
Market Total					
0-9ns	96	70	124	166	456
10-19ns	9,177	7,577	7,338	6,043	30,134
20-29ns	4,565	3,807	3,178	2,751	14,300
30-44ns	4,428	3,753	3,725	3,125	15,033
45-70ns	3,453	2,937	2,742	2,334	11,466
71ns+	30,689	28,042	25,739	21,689	106,160
71ns+ PSRAM	710	663	583	530	2,486
Total	53,118	46,849	43,429	36,639	180,034
Percentage Change from Previous Quarter	-18.6	-11.8	-7.3	-15.6	-
Average Selling Price ($)	2.33	2.21	1.97	1.78	2.10
Revenue ($M)	123,766	103,536	85,554	65,217	378,072
Market Share (% of Units)					
Americas Companies	29.3	26.6	27.2	26.6	27.6
European Companies	0.2	0.2	0.2	0.2	0.2
Japanese Companies	38.6	40.2	39.3	40.3	39.5
Asia/Pacific Companies	31.9	33.0	33.3	32.9	32.7
Total	100.0	100.0	100.0	100.0	100.0

Note: Numbers may not add to totals shown because of rounding.
Source: Dataquest (June 1997)

Table 2-6
Each Company's Quarterly Shipments of 256K SRAM by Configuration to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Alliance					
32Kx8	2,587	2,626	5,671	5,076	15,959
32Kx9	63	64	139	124	391
Vendor Total	2,650	2,690	5,810	5,200	16,350
Cypress					
256Kx1	169	124	121	108	522
64Kx4	454	305	299	257	1,315
32Kx8	10,975	7,334	7,186	6,164	31,659
32Kx9	1,152	997	974	911	4,034
Vendor Total	12,750	8,760	8,580	7,440	37,530
Electronic Designs Inc.					
256Kx1	75	55	55	50	235
Vendor Total	75	55	55	50	235
Fujitsu					
256Kx1	175	152	120	75	522
64Kx4	175	114	90	75	454
32Kx8	3,150	3,534	2,790	2,350	11,824
Vendor Total	3,500	3,800	3,000	2,500	12,800
G-Link					
32Kx8	315	500	350	200	1,365
Vendor Total	315	500	350	200	1,365
Hitachi					
256Kx1	400	360	360	360	1,480
64Kx4	600	540	540	540	2,220
32Kx8	4,000	3,600	3,600	3,600	14,800
Vendor Total	5,000	4,500	4,500	4,500	18,500
Hyundai					
32Kx8	10,246	10,322	10,044	9,804	40,417
Vendor Total	10,246	10,322	10,044	9,804	40,417
Integrated Device Technology					
64Kx4	69	139	61	250	518
32Kx8	6,802	6,788	6,029	8,081	27,701
Vendor Total	6,871	6,927	6,090	8,331	28,219
ISSI					
32Kx8	13,405	13,202	15,432	11,183	53,222
Vendor Total	13,405	13,202	15,432	11,183	53,222
LG Semicon					
32Kx8	2,270	2,500	2,640	2,780	10,190
Vendor Total	2,270	2,500	2,640	2,780	10,190

Table 2-6 (Continued)
Each Company's Quarterly Shipments of 256K SRAM by Configuration to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Matra					
256Kx1	15	19	23	26	83
64Kx4	23	28	34	40	124
32Kx8	30	38	45	53	166
16Kx16	8	9	11	13	41
Vendor Total	75	94	113	132	414
Matsushita					
256Kx1	400	400	400	400	1,600
64Kx4	80	80	80	80	320
32Kx8	320	320	320	320	1,280
Vendor Total	800	800	800	800	3,200
Micron					
32Kx8	96	60	58	36	250
Vendor Total	96	60	58	36	250
Mitsubishi					
256Kx1	80	82	86	93	341
64Kx4	80	82	86	93	341
32Kx8	7,840	8,036	8,428	9,114	33,418
Vendor Total	8,000	8,200	8,600	9,300	34,100
Mosel Vitelic					
32Kx8	471	358	289	226	1,344
Vendor Total	471	358	289	226	1,344
Motorola					
64Kx4	88	99	88	96	371
32Kx8	7,583	3,973	3,658	3,963	19,176
32Kx9	970	596	441	334	2,341
16Kx16	88	199	132	287	706
8Kx20/24	88	99	88	96	371
Vendor Total	8,817	4,966	4,407	4,775	22,965
NEC					
256Kx1	110	110	110	110	440
64Kx4	990	990	990	990	3,960
32Kx8	4,400	4,400	4,400	4,400	17,600
Vendor Total	5,500	5,500	5,500	5,500	22,000
Oki					
32Kx8	152	153	149	146	600
Vendor Total	152	153	149	146	600
Paradigm					
32Kx8	959	676	661	579	2,875
Vendor Total	959	676	661	579	2,875

Table 2-6 (Continued)
Each Company's Quarterly Shipments of 256K SRAM by Configuration to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Rohm					
32Kx8	178	180	175	171	704
Vendor Total	178	180	175	171	704
Samsung					
64Kx4	137	1,410	1,659	1,711	4,917
32Kx8	1,235	10,340	14,929	19,679	46,183
Vendor Total	1,373	11,750	16,588	21,390	51,100
Sanyo					
32Kx8	1,200	1,500	1,200	1,100	5,000
Vendor Total	1,200	1,500	1,200	1,100	5,000
Seiko Epson					
32Kx8	600	350	250	250	1,450
Vendor Total	600	350	250	250	1,450
SGS-Thomson					
32Kx8	600	300	120	35	1,055
Vendor Total	600	300	120	35	1,055
Sharp					
64Kx4	97	97	95	92	381
32Kx8	4,741	4,764	4,635	4,522	18,662
Vendor Total	4,838	4,861	4,730	4,614	19,043
Sony					
256Kx1	375	375	375	375	1,500
64Kx4	375	375	375	375	1,500
32Kx8	6,750	6,750	6,750	6,750	27,000
Vendor Total	7,500	7,500	7,500	7,500	30,000
Toshiba					
64Kx4	210	196	191	183	780
32Kx8	9,663	9,020	8,789	8,413	35,885
32Kx9	630	588	573	549	2,340
Vendor Total	10,503	9,804	9,553	9,145	39,005
UMC					
32Kx8	5,704	4,133	4,042	3,576	17,455
Vendor Total	5,704	4,133	4,042	3,576	17,455
Winbond					
32Kx8	17,843	15,081	14,712	13,697	61,334
Vendor Total	17,843	15,081	14,712	13,697	61,334

Table 2-6 (Continued)
Each Company's Quarterly Shipments of 256K SRAM by Configuration to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Market Total					
256Kx1	1,799	1,677	1,650	1,597	6,723
64Kx4	3,377	4,456	4,587	4,782	17,202
32Kx8	124,116	120,837	127,353	126,268	498,574
32Kx9	2,815	2,245	2,127	1,918	9,106
16Kx16	96	208	144	300	747
8Kx20/24	88	99	88	96	371
Total	132,291	129,522	135,948	134,960	532,722
Percentage Change from Previous Quarter	-31.0	-2.1	5.0	-0.7	-
Average Selling Price ($)	4.00	3.23	2.63	2.44	3.07
Revenue ($M)	529,166	418,356	357,544	329,302	1,634,368
Market Share (% of Units)					
Americas Companies	34.7	29.2	30.5	28.0	30.6
European Companies	0.5	0.3	0.2	0.1	0.3
Japanese Companies	36.1	36.4	33.8	33.7	35.0
Asia/Pacific Companies	28.7	34.1	35.5	38.1	34.1
Total	100.0	100.0	100.0	100.0	100.0

Note: Numbers may not add to totals shown because of rounding.
Source: Dataquest (June 1997)

Table 2-7
Each Company's Quarterly Shipments of 256K SRAM by Speed to the World, 1996
(Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Alliance					
10-19ns	2,173	2,098	4,358	3,900	12,529
20-29ns	159	323	1,453	1,300	3,234
30-44ns	318	269	-	-	587
Vendor Total	2,650	2,690	5,810	5,200	16,350
Cypress					
10-19ns	11,985	8,059	7,894	6,845	34,783
20-29ns	255	175	172	149	751
30-44ns	383	350	343	298	1,374
45-70ns	128	175	172	149	623
Vendor Total	12,750	8,760	8,580	7,440	37,530
Electronic Designs Inc.					
30-44ns	34	25	25	25	108
45-70ns	41	30	30	25	127
Vendor Total	75	55	55	50	235
Fujitsu					
0-9ns	105	76	60	50	291
10-19ns	350	266	210	175	1,001
20-29ns	210	114	90	75	489
30-44ns	210	228	180	150	768
71ns+	2,625	3,116	2,460	2,050	10,251
Vendor Total	3,500	3,800	3,000	2,500	12,800
G-Link					
10-19ns	315	500	350	200	1,365
Vendor Total	315	500	350	200	1,365
Hitachi					
10-19ns	50	45	45	45	185
20-29ns	150	135	135	135	555
30-44ns	350	315	315	315	1,295
20-44ns	-	-	-	-	-
45-70ns	450	405	405	405	1,665
71ns+	3,750	3,375	3,375	3,375	13,875
71ns+ PSRAM	250	225	225	225	925
Vendor Total	5,000	4,500	4,500	4,500	18,500
Hyundai					
71ns+	10,246	10,322	10,044	9,804	40,417
Vendor Total	10,246	10,322	10,044	9,804	40,417

Table 2-7 (Continued)
Each Company's Quarterly Shipments of 256K SRAM by Speed to the World, 1996
(Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Integrated Device Technology					
10-19ns	5,428	4,295	4,385	6,332	20,439
20-29ns	1,305	2,355	1,401	1,583	6,644
30-44ns	69	208	122	167	565
45-70ns	69	69	183	250	571
Vendor Total	6,871	6,927	6,090	8,331	28,219
ISSI					
10-19ns	12,735	12,806	14,815	10,736	51,091
45-70ns	670	396	617	447	2,131
Vendor Total	13,405	13,202	15,432	11,183	53,222
LG Semicon					
71ns+	2,270	2,500	2,640	2,780	10,190
Vendor Total	2,270	2,500	2,640	2,780	10,190
Matra					
20-29ns	19	24	28	33	104
30-44ns	30	38	45	53	166
45-70ns	19	24	28	33	104
71ns+	8	9	11	13	41
Vendor Total	75	94	113	132	414
Matsushita					
71ns+	800	800	800	800	3,200
Vendor Total	800	800	800	800	3,200
Micron					
20-29ns	96	60	58	36	250
Vendor Total	96	60	58	36	250
Mitsubishi					
10-19ns	160	820	1,204	1,488	3,672
20-29ns	400	164	258	279	1,101
30-44ns	400	246	516	558	1,720
20-44ns	-	-	-	-	-
71ns+	7,040	6,970	6,622	6,975	27,607
Vendor Total	8,000	8,200	8,600	9,300	34,100
Mosel Vitelic					
45-70ns	471	358	289	226	1,344
Vendor Total	471	358	289	226	1,344

Table 2-7 (Continued)
Each Company's Quarterly Shipments of 256K SRAM by Speed to the World, 1996
(Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Motorola					
0-9ns	1,675	1,142	529	478	3,824
10-19ns	4,409	2,284	2,115	1,815	10,623
20-29ns	2,204	1,192	1,234	2,149	6,779
30-44ns	265	248	264	287	1,064
45-70ns	265	99	264	48	676
Vendor Total	8,817	4,966	4,407	4,775	22,965
NEC					
20-29ns	110	55	55	55	275
30-44ns	165	55	55	55	330
45-70ns	275	165	165	165	770
71ns+	4,950	5,225	5,225	5,225	20,625
Vendor Total	5,500	5,500	5,500	5,500	22,000
Oki					
71ns+	152	153	149	146	600
Vendor Total	152	153	149	146	600
Paradigm					
10-19ns	812	547	535	460	2,354
20-29ns	49	43	42	40	174
30-44ns	98	86	84	79	347
Vendor Total	959	676	661	579	2,875
Rohm					
71ns+	178	180	175	171	704
Vendor Total	178	180	175	171	704
Samsung					
10-19ns	275	2,585	2,986	2,567	8,412
71ns+	1,098	9,165	13,602	18,823	42,688
Vendor Total	1,373	11,750	16,588	21,390	51,100
Sanyo					
71ns+	1,200	1,500	1,200	1,100	5,000
Vendor Total	1,200	1,500	1,200	1,100	5,000
Seiko Epson					
71ns+	600	350	250	250	1,450
Vendor Total	600	350	250	250	1,450
SGS-Thomson					
10-19ns	500	250	100	35	885
20-29ns	100	50	20	-	170
Vendor Total	600	300	120	35	1,055

Table 2-7 (Continued)
Each Company's Quarterly Shipments of 256K SRAM by Speed to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Sharp					
20-29ns	48	49	47	46	190
30-44ns	48	49	47	46	190
45-70ns	194	194	189	185	762
71ns+	3,096	3,111	3,027	2,953	12,188
71ns+ PSRAM	1,451	1,458	1,419	1,384	5,713
Vendor Total	4,838	4,861	4,730	4,614	19,043
Sony					
30-44ns	750	750	750	750	3,000
45-70ns	1,125	1,125	1,125	1,125	4,500
71ns+	5,625	5,625	5,625	5,625	22,500
Vendor Total	7,500	7,500	7,500	7,500	30,000
Toshiba					
10-19ns	840	588	573	457	2,459
20-29ns	1,365	1,176	1,146	1,097	4,786
30-44ns	2,626	2,353	2,293	2,195	9,466
71ns+	4,096	4,118	4,012	3,932	16,158
71ns+ PSRAM	1,575	1,569	1,528	1,463	6,136
Vendor Total	10,503	9,804	9,553	9,145	39,005
UMC					
10-19ns	4,491	3,024	2,961	2,547	13,023
20-29ns	300	264	258	243	1,065
30-44ns	600	529	516	486	2,131
71ns+	313	316	307	300	1,236
Vendor Total	5,704	4,133	4,042	3,576	17,455
Winbond					
10-19ns	7,984	5,376	5,264	4,528	23,152
20-29ns	600	529	516	486	2,131
30-44ns	1,200	1,057	1,032	972	4,261
45-70ns	7,897	7,956	7,742	7,556	31,151
71ns+	162	163	159	155	639
Vendor Total	17,843	15,081	14,712	13,697	61,334
Market Total					
0-9ns	1,780	1,218	589	528	4,115
10-19ns	52,506	43,543	47,794	42,129	185,972
20-29ns	7,371	6,708	6,913	7,706	28,697
30-44ns	7,544	6,806	6,587	6,435	27,372
45-70ns	11,603	10,997	11,209	10,614	44,423
71ns+	48,210	56,998	59,684	64,477	229,369
71ns+ PSRAM	3,277	3,252	3,172	3,072	12,774
Total	132,291	129,522	135,948	134,960	532,722

Table 2-7 (Continued)
Each Company's Quarterly Shipments of 256K SRAM by Speed to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Percentage Change from Previous Quarter	-31.0	-2.1	5.0	-0.7	-
Average Selling Price ($)	4.00	3.23	2.63	2.44	3.07
Revenue ($M)	529,166	418,356	357,544	329,302	1,634,368
Market Share (% of Units)					
Americas Companies	34.7	29.2	30.5	28.0	30.6
European Companies	0.5	0.3	0.2	0.1	0.3
Japanese Companies	36.1	36.4	33.8	33.7	35.0
Asia/Pacific Companies	28.7	34.1	35.5	38.1	34.1
Total	100.0	100.0	100.0	100.0	100.0

Note: Numbers may not add to totals shown because of rounding.
Source: Dataquest (June 1997)

Table 2-8
Each Company's Quarterly Shipments of 512K SRAM by Configuration to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Alliance					
64Kx8	16	10	14	20	59
32Kx16	2	1	2	2	7
Vendor Total	18	11	15	22	66
G-Link					
64Kx8	355	250	215	55	875
Vendor Total	355	250	215	55	875
Hitachi					
64Kx8	400	250	250	250	1,150
32Kx16	400	250	250	250	1,150
Vendor Total	800	500	500	500	2,300
ISSI					
64Kx8	862	344	515	325	2,046
Vendor Total	862	344	515	325	2,046
Motorola					
32Kx18	579	259	242	261	1,341
Vendor Total	579	259	242	261	1,341
Sanyo					
64Kx8	350	500	350	300	1,500
Vendor Total	350	500	350	300	1,500
Sony					
64Kx8	225	225	225	225	900
32Kx16	225	225	225	225	900
Vendor Total	450	450	450	450	1,800
Market Total					
64Kx8	2,208	1,579	1,569	1,175	6,531
32Kx16	627	476	477	477	2,057
32Kx18	579	259	242	261	1,341
Total	3,414	2,314	2,287	1,913	9,928
Percentage Change from Previous Quarter	26.9	-32.2	-1.2	-16.4	-
Average Selling Price ($)	24.00	21.50	19.00	17.50	20.21
Revenue ($M)	81,936	49,751	43,453	33,477	208,617
Market Share (% of Units)					
Americas Companies	53.1	37.3	43.2	34.6	56.4
European Companies	-	-	-	-	-
Japanese Companies	46.9	62.7	56.8	65.4	43.6
Asia/Pacific Companies	-	-	-	-	-
Total	100.0	100.0	100.0	100.0	100.0

Note: Numbers may not add to totals shown because of rounding.
Source: Dataquest (June 1997)

Table 2-9
Each Company's Quarterly Shipments of 512K SRAM by Speed to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Alliance					
10-19ns	14	9	14	20	57
20-29ns	4	2	2	2	10
Vendor Total	18	11	15	22	66
G-Link					
10-19ns	355	250	215	55	875
Vendor Total	355	250	215	55	875
Hitachi					
45-70ns	240	150	150	150	690
71ns+	560	350	350	350	1,610
Vendor Total	800	500	500	500	2,300
ISSI					
10-19ns	862	344	515	325	2,046
Vendor Total	862	344	515	325	2,046
Motorola					
0-9ns	93	83	22	10	208
10-19ns	486	176	220	251	1,133
Vendor Total	579	259	242	261	1,341
Sanyo					
71ns+	350	500	350	300	1,500
Vendor Total	350	500	350	300	1,500
Sony					
20-29ns	450	450	450	450	1,800
Vendor Total	450	450	450	450	1,800
Market Total					
0-9ns	93	83	22	10	208
10-19ns	1,718	779	964	650	7,032
20-29ns	454	452	452	452	1,810
45-70ns	240	150	150	150	690
71ns+	910	850	700	650	3,110
Total	3,414	2,314	2,287	1,913	9,928
Percentage Change from Previous Quarter	26.9	-32.2	-1.2	-16.4	-
Average Selling Price ($)	24.00	21.50	19.00	17.50	20.21
Revenue ($M)	81,936	49,751	43,453	33,477	208,617
Market Share (% of Units)					
Americas Companies	53.1	37.3	43.2	34.6	56.4
European Companies	-	-	-	-	-
Japanese Companies	46.9	62.7	56.8	65.4	43.6
Asia/Pacific Companies	-	-	-	-	-
Total	100.0	100.0	100.0	100.0	100.0

Note: Numbers may not add to totals shown because of rounding.
Source: Dataquest (June 1997)

Table 2-10
Each Company's Quarterly Shipments of 1Mb SRAM by Configuration to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Alliance					
256Kx4	36	24	9	5	75
128Kx8	564	376	281	165	1,385
Vendor Total	600	400	290	170	1,460
Cypress					
128Kx8	528	473	473	504	1,978
Vendor Total	528	473	473	504	1,978
Electronic Designs Inc.					
256Kx4	119	56	66	84	325
128Kx8	356	169	199	251	975
Vendor Total	475	225	265	335	1,300
Fujitsu					
256Kx4	935	468	234	116	1,752
128Kx8	765	383	191	95	1,433
Vendor Total	1,700	850	425	210	3,185
G-Link					
128Kx8	80	55	40	40	215
Vendor Total	80	55	40	40	215
Hitachi					
1Mbx1	986	1,280	1,120	1,120	4,506
128Kx8	4,814	6,720	6,880	6,880	25,294
Vendor Total	5,800	8,000	8,000	8,000	29,800
IBM Microelectronics					
64Kx18	400	600	800	800	2,600
32Kx32	600	900	1,200	1,200	3,900
Vendor Total	1,000	1,500	2,000	2,000	6,500
Integrated Device Technology					
256Kx4	258	710	218	225	1,411
128Kx8	506	355	672	536	2,069
64Kx16	10	26	54	138	229
32Kx32	181	224	871	830	2,107
Vendor Total	955	1,315	1,815	1,730	5,815
ISSI					
128Kx8	1,107	714	685	734	3,240
32Kx32	123	384	338	600	1,445
Vendor Total	1,230	1,098	1,023	1,334	4,685
LG Semicon					
128Kx8	1,560	1,970	2,230	2,420	8,180
Vendor Total	1,560	1,970	2,230	2,420	8,180

Table 2-10 (Continued)
Each Company's Quarterly Shipments of 1Mb SRAM by Configuration to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Matra					
128Kx8	14	18	21	25	78
Vendor Total	14	18	21	25	78
Micron					
1Mbx1	42	39	42	42	165
256Kx4	25	23	25	25	99
32Kx32	125	117	127	127	495
32Kx36	639	601	651	651	2,541
Vendor Total	830	780	845	845	3,300
Mitsubishi					
1Mbx1	46	50	106	113	314
256Kx4	46	50	212	225	533
128Kx8	4,469	4,890	4,973	5,297	19,628
Vendor Total	4,560	4,990	5,290	5,635	20,475
Motorola					
1Mbx1	32	144	130	73	379
256Kx4	833	721	716	874	3,144
128Kx8	1,603	1,839	1,530	1,456	6,427
128Kx9	32	144	130	146	452
64Kx18	673	721	651	910	2,955
32Kx32	-	-	33	73	105
32Kx36	32	36	65	109	242
Vendor Total	3,205	3,605	3,255	3,640	13,705
NEC					
1Mbx1	335	310	295	410	1,350
128Kx8	3,685	3,410	3,245	4,510	14,850
32Kx32	2,680	2,480	2,360	3,280	10,800
Vendor Total	6,700	6,200	5,900	8,200	27,000
Oki					
128Kx8	544	488	522	565	2,119
Vendor Total	544	488	522	565	2,119
Paradigm					
128Kx8	202	180	175	186	742
Vendor Total	202	180	175	186	742
Rohm					
128Kx8	260	236	250	269	1,015
Vendor Total	260	236	250	269	1,015

Table 2-10 (Continued)
Each Company's Quarterly Shipments of 1Mb SRAM by Configuration to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Samsung					
1Mbx1	684	650	736	864	2,933
256Kx4	2,051	1,950	2,207	2,591	8,798
128Kx8	2,734	2,600	2,943	3,454	11,731
64Kx16	684	650	736	864	2,933
64Kx18	2,051	1,950	2,207	2,591	8,798
32Kx32	4,784	4,550	5,150	6,045	20,529
32Kx36	684	650	736	864	2,933
Vendor Total	13,670	13,000	14,715	17,270	58,655
Sanyo					
128Kx8	600	800	600	500	2,500
Vendor Total	600	800	600	500	2,500
Seiko Epson					
128Kx8	800	600	500	400	2,300
Vendor Total	800	600	500	400	2,300
SGS-Thomson					
256Kx4	125	111	111	118	465
128Kx8	125	111	111	118	465
Vendor Total	249	223	221	236	929
Sharp					
256Kx4	1,066	957	941	1,005	3,969
128Kx8	375	336	366	391	1,468
Vendor Total	1,441	1,293	1,307	1,396	5,437
Sony					
128Kx8	5,805	5,805	5,805	5,805	23,220
128Kx9	484	484	484	484	1,935
32Kx32	3,386	3,386	3,386	3,386	13,545
Vendor Total	9,675	9,675	9,675	9,675	38,700
Toshiba					
256Kx4	742	670	578	619	2,609
128Kx8	10,017	9,162	9,707	10,392	39,279
32Kx32	1,608	1,341	1,271	1,361	5,581
Vendor Total	12,367	11,173	11,556	12,372	47,468
UMC					
32Kx32	1,149	1,008	923	977	4,057
Vendor Total	1,149	1,008	923	977	4,057
Winbond					
32Kx32	345	302	277	293	1,217
Vendor Total	345	302	277	293	1,217

Table 2-10 (Continued)
Each Company's Quarterly Shipments of 1Mb SRAM by Configuration to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Market Total					
1Mbx1	2,124	2,473	2,429	2,621	9,647
256Kx4	6,235	5,741	5,316	5,886	23,178
128Kx8	41,512	41,688	42,398	44,993	170,591
128Kx9	516	628	614	629	2,387
64Kx16	693	676	790	1,002	3,161
64Kx18	3,124	3,271	3,658	4,301	14,353
32Kx32	14,981	14,692	15,936	18,172	63,781
32Kx36	1,355	1,287	1,452	1,623	5,716
Total	70,540	70,457	72,592	79,227	292,816
Percentage Change from Previous Quarter	8.1	-0.1	3.0	9.1	-
Average Selling Price ($)	12.15	9.48	8.07	4.95	8.55
Revenue ($M)	857,057	667,930	585,820	392,173	2,502,980
Market Share (% of Units)					
Americas Companies	12.9	13.7	14.0	13.6	13.6
European Companies	0.4	0.3	0.3	0.3	0.3
Japanese Companies	63.0	62.9	60.6	59.6	61.5
Asia/Pacific Companies	23.7	23.1	25.0	26.5	24.6
Total	100.0	100.0	100.0	100.0	100.0

Note: Numbers may not add to totals shown because of rounding.
Source: Dataquest (June 1997)

Table 2-11
Each Company's Quarterly Shipments of 1Mb SRAM by Speed to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Alliance					
10-19ns	-	60	73	85	218
20-29ns	420	300	218	85	1,023
30-44ns	180	40	-	-	220
Vendor Total	600	400	290	170	1,460
Cypress					
20-29ns	158	141	140	149	588
30-44ns	316	282	280	299	1,177
45-70ns	54	50	53	56	213
Vendor Total	528	473	473	504	1,978
Electronic Designs Inc.					
10-19ns	24	11	27	50	112
20-29ns	143	68	106	151	467
30-44ns	119	56	53	50	278
45-70ns	119	56	40	17	232
71ns+	71	34	40	67	212
Vendor Total	475	225	265	335	1,300
Fujitsu					
45-70ns	1,020	510	255	126	1,911
71ns+	680	340	170	84	1,274
Vendor Total	1,700	850	425	210	3,185
G-Link					
10-19ns	80	55	40	40	215
Vendor Total	80	55	40	40	215
Hitachi					
0-9ns	58	80	80	80	298
10-19ns	870	1,200	1,040	1,040	4,150
20-29ns	174	240	240	240	894
30-44ns	290	400	400	400	1,490
45-70ns	638	880	880	880	3,278
71ns+	3,074	4,240	4,400	4,400	16,114
71ns+ PSRAM	696	960	960	960	3,576
Vendor Total	5,800	8,000	8,000	8,000	29,800
IBM Microelectronics					
0-9ns	1,000	1,500	2,000	2,000	6,500
Vendor Total	1,000	1,500	2,000	2,000	6,500

Table 2-11 (Continued)
Each Company's Quarterly Shipments of 1Mb SRAM by Speed to the World, 1996
(Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Integrated Device Technology					
0-9ns	10	224	871	1,003	2,108
10-19ns	879	868	762	502	3,011
20-29ns	67	224	182	225	697
Vendor Total	955	1,315	1,815	1,730	5,815
ISSI					
0-9ns	123	384	338	600	1,445
10-19ns	1,107	714	685	734	3,240
Vendor Total	1,230	1,098	1,023	1,334	4,685
LG Semicon					
71ns+	1,560	1,970	2,230	2,420	8,180
Vendor Total	1,560	1,970	2,230	2,420	8,180
Matra					
20-29ns	4	5	5	6	20
30-44ns	4	5	5	6	20
45-70ns	7	9	11	13	39
Vendor Total	14	18	21	25	78
Micron					
10-19ns	830	780	845	845	3,300
Vendor Total	830	780	845	845	3,300
Mitsubishi					
45-70ns	91	100	265	338	794
71ns+	4,469	4,890	5,026	5,297	19,681
Vendor Total	4,560	4,990	5,290	5,635	20,475
Motorola					
0-9ns	705	865	814	728	3,112
10-19ns	1,026	1,514	1,204	1,456	5,200
20-29ns	1,378	1,118	1,139	1,383	5,018
30-44ns	32	36	33	36	137
45-70ns	64	72	65	36	238
Vendor Total	3,205	3,605	3,255	3,640	13,705
NEC					
10-19ns	2,680	2,170	1,770	2,870	9,490
20-29ns	134	124	118	164	540
30-44ns	201	186	177	246	810
45-70ns	134	124	118	164	540
71ns+	3,350	3,410	3,481	4,428	14,669
71ns+ PSRAM	201	186	236	328	951
Vendor Total	6,700	6,200	5,900	8,200	27,000

Table 2-11 (Continued)
Each Company's Quarterly Shipments of 1Mb SRAM by Speed to the World, 1996
(Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Oki					
71ns+ PSRAM	544	488	522	565	2,119
Vendor Total	544	488	522	565	2,119
Paradigm					
10-19ns	59	51	47	50	207
20-29ns	48	43	43	45	179
30-44ns	96	86	85	91	357
Vendor Total	202	180	175	186	742
Rohm					
71ns+	260	236	250	269	1,015
Vendor Total	260	236	250	269	1,015
Samsung					
0-9ns	547	650	736	864	2,796
10-19ns	4,374	2,860	2,649	2,936	12,819
20-29ns	2,051	2,990	3,973	5,008	14,022
30-44ns	1,504	910	1,030	864	4,307
71ns+	5,195	5,590	6,327	7,599	24,711
Vendor Total	13,670	13,000	14,715	17,270	58,655
Sanyo					
71ns+	600	800	600	500	2,500
Vendor Total	600	800	600	500	2,500
Seiko Epson					
71ns+	800	600	500	400	2,300
Vendor Total	800	600	500	400	2,300
SGS-Thomson					
10-19ns	249	223	221	236	929
Vendor Total	249	223	221	236	929
Sharp					
20-29ns	216	194	196	209	816
30-44ns	360	323	327	349	1,359
71ns+	865	776	784	838	3,262
Vendor Total	1,441	1,293	1,307	1,396	5,437
Sony					
10-19ns	3,150	3,150	3,150	3,150	12,600
20-29ns	1,575	1,575	1,575	1,575	6,300
30-44ns	3,150	3,150	3,150	3,150	12,600
45-70ns	450	450	450	450	1,800
71ns+	1,350	1,350	1,350	1,350	5,400
Vendor Total	9,675	9,675	9,675	9,675	38,700

Table 2-11 (Continued)
Each Company's Quarterly Shipments of 1Mb SRAM by Speed to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Toshiba					
10-19ns	2,350	2,011	1,849	1,980	8,189
71ns+	6,431	5,810	6,240	6,681	25,162
71ns+ PSRAM	3,586	3,352	3,467	3,712	14,117
Vendor Total	12,367	11,173	11,556	12,372	47,468
UMC					
10-19ns	1,149	1,008	923	977	4,057
Vendor Total	1,149	1,008	923	977	4,057
Winbond					
10-19ns	345	302	277	293	1,217
Vendor Total	345	302	277	293	1,217
Market Total					
0-9ns	2,442	3,703	4,838	5,275	16,259
10-19ns	19,171	16,978	15,562	17,243	68,953
20-29ns	6,366	7,020	7,934	9,241	30,562
30-44ns	6,251	5,474	5,540	5,491	22,755
45-70ns	2,577	2,251	2,135	2,080	9,044
71ns+	28,704	30,046	31,398	34,332	124,480
71ns+ PSRAM	5,027	4,986	5,185	5,565	20,763
Total	70,540	70,457	72,592	79,227	292,816
Percentage Change from Previous Quarter	8.1	-0.1	3.0	9.1	-
Average Selling Price ($)	12.15	9.48	8.07	4.95	8.55
Revenue ($M)	857,057	667,930	585,820	392,173	2,502,980
Market Share (% of Units)					
Americas Companies	12.9	13.7	14.0	13.6	13.6
European Companies	0.4	0.3	0.3	0.3	0.3
Japanese Companies	63.0	62.9	60.6	59.6	61.5
Asia/Pacific Companies	23.7	23.1	25.0	26.5	24.6
Total	100.0	100.0	100.0	100.0	100.0

Note: Numbers may not add to totals shown because of rounding.
Source: Dataquest (June 1997)

Table 2-12
Each Company's Quarterly Shipments of 2Mb SRAM by Configuration to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Electronic Designs Inc.					
256Kx8	75	90	110	160	435
Vendor Total	75	90	110	160	435
Micron					
128Kx16	1	2	3	3	8
128Kx18	-	1	1	1	3
64Kx32	19	42	65	84	209
64Kx36	5	11	17	22	55
Vendor Total	25	55	85	110	275
Samsung					
256Kx8	8	4	8	10	30
128Kx16	8	4	8	10	30
128Kx18	3	1	3	3	10
64Kx32	5	3	5	7	20
64Kx36	3	1	3	3	10
Vendor Total	27	14	25	34	100
Market Total					
256Kx8	83	94	118	170	465
128Kx16	9	6	10	14	38
128Kx18	3	2	3	5	13
64Kx32	24	45	70	90	229
64Kx36	8	12	20	25	65
Total	127	159	220	304	810
Percentage Change from Previous Quarter	NA	25.2	38.4	38.2	-
Average Selling Price ($)	27.25	16.18	14.13	4.60	13.01
Revenue ($M)	3,461	2,573	3,109	1,398	10,540
Market Share (% of Units)					
Americas Companies	78.7	91.2	88.6	88.8	87.7
European Companies	-	-	-	-	-
Japanese Companies	-	-	-	-	-
Asia/Pacific Companies	21.3	8.8	11.4	11.2	12.3
Total	100.0	100.0	100.0	100.0	100.0

NA = Not available
Note: Numbers may not add to totals shown because of rounding.
Source: Dataquest (June 1997)

Table 2-13
Each Company's Quarterly Shipments of 2Mb SRAM by Speed to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Electronic Designs Inc.					
20-29ns	19	23	33	48	122
30-44ns	19	23	22	32	95
45-70ns	38	45	55	80	218
Vendor Total	75	90	110	160	435
Micron					
0-9ns	8	17	30	41	94
10-19ns	18	39	55	69	181
Vendor Total	25	55	85	110	275
Samsung					
10-19ns	5	3	5	7	20
20-29ns	5	3	5	7	20
71ns+	16	8	15	20	60
Vendor Total	27	14	25	34	100
Market Total					
0-9ns	8	17	30	41	94
10-19ns	23	41	60	76	201
20-29ns	24	25	38	55	142
30-44ns	19	23	22	32	95
45-70ns	38	45	55	80	218
71ns+	16	8	15	20	60
Total	127	159	220	304	810
Percentage Change from Previous Quarter	NA	25.2	38.4	38.2	-
Average Selling Price ($)	27.25	16.18	14.13	4.60	13.01
Revenue ($M)	3,461	2,573	3,109	1,398	10,540
Market Share (% of Units)					
Americas Companies	78.7	91.2	88.6	88.8	87.7
European Companies	-	-	-	-	-
Japanese Companies	-	-	-	-	-
Asia/Pacific Companies	21.3	8.8	11.4	11.2	12.3
Total	100.0	100.0	100.0	100.0	100.0

NA = Not available
Note: Numbers may not add to totals shown because of rounding.
Source: Dataquest (June 1997)

Table 2-14
Each Company's Quarterly Shipments of 4Mb SRAM by Configuration to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Electronic Designs Inc.					
512Kx8	146	137	140	143	566
256Kx16	79	74	75	77	305
Vendor Total	225	210	215	220	870
Fujitsu					
1Mbx4	51	18	9	3	81
Vendor Total	51	18	9	3	81
Hitachi					
512Kx8	1,400	1,600	1,600	1,600	6,200
Vendor Total	1,400	1,600	1,600	1,600	6,200
IBM Microelectronics					
128Kx36	*	-	-	2	2
Vendor Total	*	-	-	2	2
Mitsubishi					
512Kx8	80	70	50	50	250
Vendor Total	80	70	50	50	250
Motorola					
2Mbx2	37	20	31	89	176
1Mbx4	33	33	144	151	361
512Kx8	30	90	31	89	240
Vendor Total	99	143	206	329	777
NEC					
1Mbx4	75	150	125	90	440
512Kx8	75	150	125	90	440
Vendor Total	150	300	250	180	880
Oki					
512Kx8	37	47	53	63	200
Vendor Total	37	47	53	63	200
Samsung					
1Mbx4	76	77	78	80	310
512Kx8	243	248	250	257	997
256Kx16	205	209	211	217	842
256Kx18	5	6	6	6	22
128Kx32	8	8	8	9	33
128Kx36	3	3	3	3	11
Vendor Total	540	550	555	570	2,215
Sharp					
512Kx8	135	135	136	137	543
Vendor Total	135	135	136	137	543

Table 2-14 (Continued)
Each Company's Quarterly Shipments of 4Mb SRAM by Configuration to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Sony					
512Kx8	400	400	400	400	1,600
Vendor Total	400	400	400	400	1,600
Toshiba					
512Kx8	1,085	1,234	1,344	1,511	5,174
256Kx16	69	79	86	96	330
Vendor Total	1,154	1,313	1,430	1,607	5,504
Market Total					
2Mbx2	37	20	31	89	176
1Mbx4	234	278	356	324	1,192
512Kx8	3,631	4,110	4,129	4,339	16,209
256Kx16	353	361	372	390	1,476
256Kx18	5	6	6	6	22
128Kx32	8	8	8	9	33
128Kx36	3	3	3	5	13
Total	4,271	4,786	4,904	5,161	19,122
Percentage Change from Previous Quarter	52.9	12.1	2.5	5.2	-
Average Selling Price ($)	54.50	36.41	31.78	19.54	34.71
Revenue ($M)	232,770	174,258	155,849	100,848	663,725
Market Share (% of Units)					
Americas Companies	7.6	7.4	8.6	10.7	8.6
European Companies	-	-	-	-	-
Japanese Companies	79.8	81.1	80.1	78.3	79.8
Asia/Pacific Companies	12.6	11.5	11.3	11.0	11.6
Total	100.0	100.0	100.0	100.0	100.0

Note: Numbers may not add to totals shown because of rounding.
Source: Dataquest (June 1997)

Table 2-15
Each Company's Quarterly Shipments of 4Mb SRAM by Speed to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Electronic Designs Inc.					
20-29ns	68	74	75	77	293
30-44ns	68	74	75	77	293
45-70ns	45	21	22	33	121
71ns+	45	42	43	33	163
Vendor Total	225	210	215	220	870
Fujitsu					
45-70ns	51	18	9	3	81
Vendor Total	51	18	9	3	81
Hitachi					
71ns+	1,344	1,536	1,536	1,536	5,952
71ns+ PSRAM	56	64	64	64	248
Vendor Total	1,400	1,600	1,600	1,600	6,200
IBM Microelectronics					
0-9ns	-	-	-	2	2
Vendor Total	-	-	-	2	2
Mitsubishi					
71ns+	80	70	50	50	250
Vendor Total	80	70	50	50	250
Motorola					
0-9ns	-	-	4	112	116
10-19ns	65	50	80	72	268
20-29ns	27	86	115	135	363
30-44ns	4	1	2	10	17
45-70ns	3	6	4	-	13
Vendor Total	99	143	206	329	777
NEC					
10-19ns	75	150	125	90	440
20-29ns	75	150	125	90	440
Vendor Total	150	300	250	180	880
Oki					
71ns+ PSRAM	37	47	53	63	200
Vendor Total	37	47	53	63	200
Samsung					
10-19ns	11	17	28	23	78
20-29ns	146	149	139	148	581
71ns+	383	385	389	399	1,556
Vendor Total	540	550	555	570	2,215

Table 2-15 (Continued)
Each Company's Quarterly Shipments of 4Mb SRAM by Speed to the World, 1996
(Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Sharp					
71ns+	135	135	136	137	543
Vendor Total	135	135	136	137	543
Sony					
71ns+	400	400	400	400	1,600
Vendor Total	400	400	400	400	1,600
Toshiba					
71ns+	1,085	1,234	1,344	1,511	5,174
71ns+ PSRAM	69	79	86	96	330
Vendor Total	1,154	1,313	1,430	1,607	5,504
Market Total					
0-9ns	-	-	4	114	118
10-19ns	151	217	233	185	786
20-29ns	315	458	454	450	1,677
30-44ns	71	75	77	87	311
45-70ns	99	45	35	36	214
71ns+	3,472	3,802	3,898	4,066	15,238
71ns+ PSRAM	162	190	203	223	778
Total	4,271	4,786	4,904	5,161	19,122
Percentage Change from Previous Quarter	52.9	12.1	2.5	5.2	-
Average Selling Price ($)	54.50	36.41	31.78	19.54	34.71
Revenue ($M)	232,770	174,258	155,849	100,848	663,725
Market Share (% of Units)					
Americas Companies	7.6	7.4	8.6	10.7	8.6
European Companies	-	-	-	-	-
Japanese Companies	79.8	81.1	80.1	78.3	79.8
Asia/Pacific Companies	12.6	11.5	11.3	11.0	11.6
Total	100.0	100.0	100.0	100.0	100.0

Note: Numbers may not add to totals shown because of rounding.
Source: Dataquest (June 1997)

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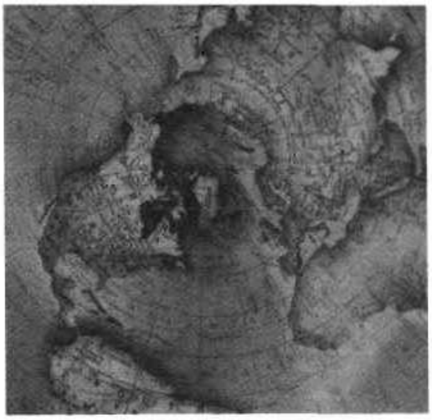

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Dataquest

1996 Nonvolatile Memory Unit Shipments

Market Statistics

Program: Memories Worldwide
Product Code: MMRY-WW-MS-9703
Publication Date: June 23, 1997
Filing: Market Statistics

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Chapter 1
Introduction

This document contains detailed statistics on the 1996 nonvolatile memory market. Analyses of companies' MOS memory shipments provide insight into high-technology markets and reinforce estimates of consumption, production, and company revenue.

Dataquest's Memories Worldwide program provides qualitative analysis of this data as part of a yearly subscription to its service. Clients of this program can find qualitative information in the Dataquest Memories Worldwide binder. Dataquest's client inquiry service can provide historical or more detailed information regarding the MOS memory market on request.

This introduction to the subsequent tables defines the market segments specific to this document. For a complete description of all market segments tracked by Dataquest, please refer to *Final Semiconductor Market Definitions* (SEMI-WW-GU-9701, February 5, 1997). A subscription to any Dataquest semiconductor service includes this guide.

Metric Definitions

Unit Shipments

Dataquest defines unit shipments as "for-revenue transfers of own-branded semiconductor products" from a device manufacturer (for example, Samsung) to an electronic equipment manufacturer (for example, Compaq Computer), subsystem assembler (for example, Kingston or SanDisk), or device reseller (for example, Arrow Electronics). This study counts the volume of devices sold (that is, units) rather than the dollar value of that volume (that is, not sales).

Inclusions for Unit Shipments

For shipments of devices on assembled subsystems (for example, modules), Dataquest counts the devices on the module rather than the module itself. Dataquest considers those devices shipped when the device manufacturer sells the module.

If a company sells any portion of a product category (for example, DRAM or EPROM) outside the company, then Dataquest includes all shipments of that category. For example, company ABC manufactures DRAM and EPROM. ABC's production of PCs consumes 99 percent of its DRAM and 100 percent of its EPROM. Dataquest will include 100 percent of ABC's DRAM shipments and 0 percent of ABC's EPROM shipments. Dataquest considers captive product shipped when the company transfers the product to the electronic equipment business unit or production facility.

Exclusions for Unit Shipments

Dataquest excludes logic devices with embedded memory even if the device manufacturer produces the device with a memory process. Dataquest counts these as microcomponents or ASIC or digital logic.

Dataquest excludes product categories that the company consumes 100 percent internally (totally captive production).

Dataquest excludes devices produced under contract for another device manufacturer to sell under that second manufacturer's brand name (contract manufacturing or foundry).

Dataquest excludes internal transfers from headquarters to sales subsidiaries but counts these parts when the subsidiary invoices them to an end user, to a third party, or to a value-added reseller.

Average Selling Price

At the bottom of each table, Dataquest includes an average selling price (ASP) for each density. Average selling price is the average billing price per unit paid for a product when it leaves the factory, taking into account discounts given to the distribution channel and multiple-purchase discounts. Dataquest averages prices over all companies, package types, lot sizes, speed mixes, and accounts (including military and commercial).

Revenue

Multiplying a product's shipment total by its ASP yields "dollarized units," which Dataquest defines as revenue for this report. These prices are industrywide approximations for each market segment. Dataquest intends use of these prices only as guidelines. Actual negotiated market prices may vary because of manufacturer-specific factors such as product quality, special features, service, delivery performance, volume discount, or other factors that may enhance or detract from the product's value. Therefore, multiplying a company's unit shipments by the industrywide ASP may not yield an accurate revenue figure. For company revenue by product type, please consult *Worldwide Memory Market Share* (MMRY-WW-MS-9701; May 19, 1997). A subscription to Dataquest's Memories Worldwide program includes this report.

Memory Definitions and Categories

Memory IC

A memory IC is an integrated circuit capable of and dedicated to storing retrievable electronic information in binary form. Dataquest limits the scope of this research to MOS (metal oxide semiconductor) DRAM, SRAM, EEPROM, EPROM, flash, and ROM only.

Volatile Memory

A memory IC that loses its contents with power interruption. Volatile memories include DRAM and SRAM. Data on these is published in separate reports, *1996 DRAM Unit Shipments* (MMRY-WW-MS-9702) and *1996 SRAM Unit Shipments* (MMRY-WW-MS-9704).

Nonvolatile Memory

A memory IC that retains its contents with power interruption. Nonvolatile memories include EEPROM, EPROM, and ROM. Dataquest has included these devices in this report.

Density

Dataquest classifies memory ICs by the number of bits the chip is able to store concurrently. Memory devices store bits in memory "cells" laid in rows and columns on the chip. The total number of cells is the density of the chip. Densities usually follow powers of two. For example, a 256-bit memory IC would contain 2^8 bits. Naming conventions have developed to append more dense chips with kilo- (K), mega- (or M), and giga- (G) to simplify references to that density. "Kilobits" (Kb) refers to 2^{10} bits. An 8Kb memory IC will contain 8×2^{10} bits (8,192 bits)—an "eight kilobit" chip. "Megabits" (Mb) refers to 2^{20} bits. A 4Mb memory IC will contain 4×2^{20} bits (4,194,304 bits)—a "four megabit" chip. "Gigabits" (Gb) refers to 2^{30} bits. A 1Gb memory IC will contain 1×2^{30} bits (1,073,741,824 bits)—a "one gigabit" chip. Dataquest limits the densities tracked according to device category. The tracked densities generally include all mainstream and high-volume densities.

This report includes:

- EPROM (densities from 256b through 4Mb)
- EPROM (densities from 16K through 16Mb)
- Flash (densities from 256K through 16Mb)
- ROM (densities from 64K through 64Mb)

Configuration

Along with density, Dataquest classifies memory ICs by their configuration (or organization) of its array of memory cells. The configuration is akin to the length and width of the array, with the product of these equaling the density. Memory IC manufacturers produce many different widths of the same density IC to accommodate each customer's system, data bus, and logic wordwidth needs. Common configurations include x1 (1b wide), x4 (4b wide), x8 (8b wide) and x16 (16b wide).

Device Definitions

EEPROM

EEPROM stands for electrically erasable programmable read-only memory. EEPROM devices are nonvolatile memories with two-transistor (minimum) memory cells that do not require memory cell refreshes. This category also includes nonvolatile RAM (NVRAM), any combination of SRAM and EEPROM technologies in each memory cell, electrically alterable read-only memory (EAROM), and ferroelectric RAM (FRAM). Dataquest subdivides this category into serial interfaces, parallel interfaces, NVRAM, and FRAM.

EPROM

EPROM stands for erasable programmable read-only memory. EPROMs are nonvolatile devices with single-transistor memory cells that do not require cell refreshes. Dataquest subdivides this category into ultraviolet EPROM (UV EPROM) and one-time programmable read-only memory (OTP ROM).

Mask ROM

Mask ROM stands for mask-programmable read-only memory. Mask ROM is a form of memory programmed by the manufacturer to a user specification using a mask step in the lithography process. These devices are nonvolatile.

Flash

Flash memories are nonvolatile products with single-transistor memory cells, electrical programming, and bulk or block (not byte) erasing. Dataquest subdivides the flash category according to the voltages required to program data into the device. Programming voltages include 1.8V, 2V, 2.2V, 2.7V, 3V, 3.3V, 5V, and 12V.

Market Share Methodology

Dataquest uses primary and secondary sources to produce market statistics. The Memories Worldwide program surveys companies once a year to collect shipment data for each quarter of the previous year. Dataquest supplements this survey effort with additional primary and secondary research to verify market size, shipment totals, and pricing information. Dataquest's sources include the following:

- Device manufacturer surveys
- Information published by major industry participants
- Estimates made by knowledgeable and reliable industry spokespersons
- Industry or trade association data (including SIA-WSTS)
- Government data
- Published product literature and price lists
- Interviews with knowledgeable manufacturers, distributors, and users
- Relevant economic data
- Information and data from online or CD-ROM data banks
- Articles in both the general and trade press
- Reports from financial analysts
- End-user surveys

Despite the care taken in gathering, analyzing, and categorizing the data in a meaningful way, differences between Dataquest's data and other available data may exist. Various companies, government agencies, and trade associations may use different product or regional definitions or may include different companies in their summaries. Please keep these differences in mind when comparing data and numbers provided by Dataquest with those provided by other research companies.

Notes to Market Share Tables

To report market data in a more meaningful way, Dataquest sometimes consolidates or revises the numbers for a particular company, model, series, or industry. These notes explain any such changes contained in this document.

1. In 1992, MOSel and Vitelic merged to form Mosel Vitelic, which Dataquest listed as an Asia/Pacific device manufacturer.

2. In 1993, NMB Semiconductor changed its business name to Nittetsu Semiconductor.

3. In 1993, Dataquest included MOS memory shipments from International Business Machines.

4. In 1994, Dataquest changed Nittetsu Semiconductor to Nippon Steel Semiconductor.

5. In 1994, Dataquest included MOS memory shipments from Alliance Semiconductor.

6. In 1995, Dataquest included MOS memory shipments from G-Link.

7. In 1995, Dataquest included MOS memory shipments from Integrated Silicon Solution Inc.

8. In 1995, Dataquest changed Goldstar to LG Semicon.

9. In 1995, Dataquest included MOS memory shipments from Vanguard International.

10. In 1996, Dataquest included MOS memory shipments from Ramtron International.

11. In 1996, Dataquest included MOS memory shipments from Silicon Storage Technology.

12. In 1996, Dataquest included MOS memory shipments from Nan Ya Technology.

Chapter 2
Market Statistics Tables

Table 2-1
Each Company's Quarterly Shipments of Flash by Density to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Advanced Micro Devices					
All 256K	425	450	300	415	1,590
All 512K	235	225	265	565	1,290
All 1Mb	7,710	7,210	9,195	10,325	34,440
All 2Mb	1,475	1,710	2,620	3,615	9,420
All 4Mb	6,370	4,530	6,005	5,430	22,335
All 8Mb	120	170	620	1,950	2,860
All 16Mb	80	110	325	395	910
Vendor Total	16,415	14,405	19,330	22,695	72,845
Atmel					
All 256K	1,000	1,100	1,250	1,350	4,700
All 512K	2,200	2,700	3,200	3,500	11,600
All 1Mb	3,600	4,400	5,500	6,700	20,200
All 2Mb	1,100	1,300	1,600	1,900	5,900
All 4Mb	2,550	2,700	3,100	3,400	11,750
Vendor Total	10,450	12,200	14,650	16,850	54,150
Catalyst					
All 1Mb	860	550	340	140	1,890
All 2Mb	18	19	21	22	79
All 4Mb	17	18	23	24	81
Vendor Total	895	587	383	185	2,050
Fujitsu					
All 2Mb	30	100	500	1,400	2,030
All 4Mb	4,000	4,300	5,300	6,700	20,300
All 8Mb	300	600	1,600	2,300	4,800
All 16Mb	250	250	300	400	1,200
Vendor Total	4,580	5,250	7,700	10,800	28,330
Hitachi					
All 1Mb	200	150	150	150	650
Vendor Total	200	150	150	150	650

Table 2-1 (Continued)
Each Company's Quarterly Shipments of Flash by Density to the World, 1996
(Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Intel					
All 512K	50	30	20	20	120
All 1Mb	7,100	7,200	7,900	8,500	30,700
All 2Mb	3,600	3,700	4,200	4,500	16,000
All 4Mb	4,900	5,500	6,600	7,500	24,500
All 8Mb	7,600	8,800	9,400	10,500	36,300
All 16Mb	1,500	1,600	2,000	2,200	7,300
Vendor Total	24,750	26,830	30,120	33,220	114,920
Macronix					
All 1Mb	1,400	2,800	3,600	4,500	12,300
All 2Mb	-	-	50	100	150
All 4Mb	10	20	30	70	130
Vendor Total	1,410	2,820	3,680	4,670	12,580
Mitsubishi					
All 1Mb	750	750	900	1,200	3,600
All 8Mb	20	25	100	400	545
Vendor Total	770	775	1,000	1,600	4,145
NEC					
All 1Mb	45	50	65	70	230
All 4Mb	550	700	850	1,000	3,100
Vendor Total	595	750	915	1,070	3,330
Samsung					
All 4Mb	145	350	710	930	2,135
All 16Mb	95	105	265	295	760
All 32Mb	25	20	70	110	225
Vendor Total	265	475	1,045	1,335	3,120
Sanyo					
All 1Mb	600	800	600	500	2,500
All 4Mb	500	600	600	800	2,500
Vendor Total	1,100	1,400	1,200	1,300	5,000
SGS-Thomson					
All 256K	495	395	345	495	1,730
All 512K	220	375	585	1,020	2,200
All 1Mb	3,065	2,805	2,925	3,655	12,450
All 2Mb	-	2	8	220	230
All 4Mb	390	410	835	1,620	3,255
Vendor Total	4,170	3,987	4,698	7,010	19,865

Table 2-1 (Continued)
Each Company's Quarterly Shipments of Flash by Density to the World, 1996
(Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Sharp					
All 4Mb	800	1,000	1,100	1,300	4,200
All 8Mb	1,100	1,400	1,600	1,800	5,900
All 16Mb	350	370	380	400	1,500
Vendor Total	2,250	2,770	3,080	3,500	11,600
Silicon Storage Technology					
All 512K	1,675	1,895	2,150	2,435	8,155
All 1Mb	4,030	4,535	5,180	5,750	19,495
All 2Mb	-	76	150	247	473
All 4Mb	140	158	180	200	678
Vendor Total	5,845	6,664	7,660	8,632	28,800
Texas Instruments					
All 512K	124	127	139	144	534
All 1Mb	1,050	1,100	1,250	1,300	4,700
All 2Mb	657	680	755	788	2,880
All 4Mb	10	50	70	110	240
Vendor Total	1,841	1,956	2,214	2,342	8,353
Toshiba					
All 1Mb	717	727	833	870	3,147
All 16Mb	760	872	1,142	1,196	3,970
Vendor Total	1,477	1,599	1,975	2,066	7,117
Market Total					
All 256K	1,920	1,945	1,895	2,260	8,020
All 512K	4,504	5,352	6,359	7,684	23,899
All 1Mb	31,127	33,077	38,438	43,660	146,302
All 2Mb	6,880	7,586	9,904	12,791	37,161
All 4Mb	20,382	20,336	25,403	29,084	95,204
All 8Mb	9,140	10,995	13,320	16,950	50,405
All 16Mb	3,035	3,307	4,412	4,886	15,640
All 32Mb	25	20	70	110	225
Total	77,012	82,618	99,800	117,425	376,855
Percentage Change from Previous Quarter	2.3	7.3	20.8	17.7	-
Average Selling Price ($)	9.71	7.96	6.79	6.25	7.47
Revenue ($M)	747,444	657,863	677,930	739,382	2,186,676
Market Share (% of Units)					
Americas Companies	78.2	75.8	74.5	71.5	74.6
European Companies	5.4	4.8	4.7	6.0	5.3
Japanese Companies	14.2	15.4	16.1	17.4	16.0
Asia/Pacific Companies	2.2	4.0	4.7	5.1	4.2
Total	100.0	100.0	100.0	100.0	100.00

Source: Dataquest (June 1997)

Table 2-2
Each Company's Quarterly Shipments of 256K Flash by Configuration to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Advanced Micro Devices					
32Kx8	425	450	300	415	1,590
Vendor Total	425	450	300	415	1,590
Atmel					
32Kx8	1,000	1,100	1,250	1,350	4,700
Vendor Total	1,000	1,100	1,250	1,350	4,700
SGS-Thomson					
32Kx8	495	395	345	495	1,730
Vendor Total	495	395	345	495	1,730
Market Total					
32Kx8	1,920	1,945	1,895	2,260	8,020
Total	1,920	1,945	1,895	2,260	8,020
Percentage Change from Previous Quarter	37.4	1.3	-2.6	19.3	-
Average Selling Price ($)	2.04	1.92	1.80	1.67	1.85
Revenue ($M)	3,917	3,734	3,411	3,774	14,836
Market Share (% of Units)					
Americas Companies	74.2	79.7	81.8	78.1	78.4
European Companies	25.8	20.3	18.2	21.9	21.6
Japanese Companies	-	-	-	-	-
Asia/Pacific Companies	-	-	-	-	-
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-3
Each Company's Quarterly Shipments of 256K Flash by Voltage to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Advanced Micro Devices					
12V Flash	425	450	300	415	1,590
Vendor Total	425	450	300	415	1,590
Atmel					
2V Flash	200	242	313	338	1,092
3.3V Flash	30	44	50	54	178
5V Flash	770	814	888	959	3,430
Vendor Total	1,000	1,100	1,250	1,350	4,700
SGS-Thomson					
12V Flash	495	395	345	495	1,730
Vendor Total	495	395	345	495	1,730
Market Total					
2V Flash	200	242	313	338	1,092
3.3V Flash	30	44	50	54	178
5V Flash	770	814	888	959	3,430
12V Flash	920	845	645	910	3,320
Total	1,920	1,945	1,895	2,260	8,020
Percentage Change from Previous Quarter	37.4	1.3	-2.6	19.3	-
Average Selling Price ($)	2.04	1.92	1.80	1.67	1.85
Revenue ($M)	3,917	3,734	3,411	3,774	14,836
Market Share (% of Units)					
Americas Companies	74.2	79.7	81.8	78.1	78.4
European Companies	25.8	20.3	18.2	21.9	21.6
Japanese Companies	-	-	-	-	-
Asia/Pacific Companies	-	-	-	-	-
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-4
Each Company's Quarterly Shipments of 512K Flash by Configuration to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Advanced Micro Devices					
64Kx8	235	225	265	565	1,290
Vendor Total	235	225	265	565	1,290
Atmel					
64Kx8	2,200	2,700	3,200	3,500	11,600
Vendor Total	2,200	2,700	3,200	3,500	11,600
Intel					
64Kx8	50	30	20	20	120
Vendor Total	50	30	20	20	120
SGS-Thomson					
64Kx8	220	375	585	1,020	2,200
Vendor Total	220	375	585	1,020	2,200
Silicon Storage Technology					
64Kx8	1,675	1,895	2,150	2,435	8,155
Vendor Total	1,675	1,895	2,150	2,435	8,155
Texas Instruments					
64Kx8	124	127	139	144	534
Vendor Total	124	127	139	144	534
Market Total					
64Kx8	4,504	5,352	6,359	7,684	23,899
Total	4,504	5,352	6,359	7,684	23,899
Percentage Change from Previous Quarter	275.3	18.8	18.8	20.8	-
Average Selling Price ($)	3.58	3.13	2.83	2.63	2.97
Revenue ($M)	16,123	16,750	17,996	20,209	71,079
Market Share (% of Units)					
Americas Companies	95.1	93.0	90.8	86.7	90.8
European Companies	4.9	7.0	9.2	13.3	9.2
Japanese Companies	-	-	-	-	-
Asia/Pacific Companies	-	-	-	-	-
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-5
Each Company's Quarterly Shipments of 512K Flash by Voltage to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Advanced Micro Devices					
12V Flash	235	225	265	565	1,290
Vendor Total	235	225	265	565	1,290
Atmel					
3.3V Flash	44	54	64	70	232
5V Flash	2,156	2,646	3,136	3,430	11,368
Vendor Total	2,200	2,700	3,200	3,500	11,600
Intel					
12V Flash	50	30	20	20	120
Vendor Total	50	30	20	20	120
SGS-Thomson					
12V Flash	220	375	585	1,020	2,200
Vendor Total	220	375	585	1,020	2,200
Silicon Storage Technology					
2.7V Flash	-	-	11	49	59
3V Flash	34	95	204	292	625
5V Flash	1,641	1,800	1,935	2,094	7,471
Vendor Total	1,675	1,895	2,150	2,435	8,155
Texas Instruments					
5V Flash	6	13	21	29	69
12V Flash	118	114	118	115	465
Vendor Total	124	127	139	144	534
Market Total					
2.7V Flash	-	-	11	49	59
3V Flash	34	95	204	292	625
3.3V Flash	44	54	64	70	232
5V Flash	3,804	4,459	5,092	5,553	18,907
12V Flash	623	744	988	1,720	4,075
Total	4,504	5,352	6,359	7,684	23,899
Percentage Change from Previous Quarter	275.3	18.8	18.8	20.8	-
Average Selling Price ($)	3.58	3.13	2.83	2.63	2.97
Revenue ($M)	16,123	16,750	17,996	20,209	71,079
Market Share (% of Units)					
Americas Companies	95.1	93.0	90.8	86.7	90.8
European Companies	4.9	7.0	9.2	13.3	9.2
Japanese Companies	-	-	-	-	-
Asia/Pacific Companies	-	-	-	-	-
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-6
Each Company's Quarterly Shipments of 1Mb Flash by Configuration to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Advanced Micro Devices					
128Kx8	7,247	6,777	8,367	9,706	32,098
64Kx16	463	433	828	620	2,342
Vendor Total	7,710	7,210	9,195	10,325	34,440
Atmel					
128Kx8	3,240	3,960	4,950	6,030	18,180
64Kx16	360	440	550	670	2,020
Vendor Total	3,600	4,400	5,500	6,700	20,200
Catalyst					
128Kx8	860	550	340	140	1,890
Vendor Total	860	550	340	140	1,890
Hitachi					
128Kx8	200	150	150	150	650
Vendor Total	200	150	150	150	650
Intel					
128Kx8	7,100	7,200	7,900	8,500	30,700
Vendor Total	7,100	7,200	7,900	8,500	30,700
Macronix					
128Kx8	1,400	2,800	3,600	4,500	12,300
Vendor Total	1,400	2,800	3,600	4,500	12,300
Mitsubishi					
128Kx8	407	407	489	651	1,954
64Kx16	343	343	411	549	1,646
Vendor Total	750	750	900	1,200	3,600
NEC					
128Kx8	45	50	65	70	230
Vendor Total	45	50	65	70	230
Sanyo					
128Kx8	600	800	600	500	2,500
Vendor Total	600	800	600	500	2,500
SGS-Thomson					
128Kx8	2,513	2,104	2,340	2,814	9,771
64Kx16	552	701	585	841	2,679
Vendor Total	3,065	2,805	2,925	3,655	12,450
Silicon Storage Technology					
128Kx8	4,030	4,535	5,180	5,750	19,495
Vendor Total	4,030	4,535	5,180	5,750	19,495

Table 2-6 (Continued)
Each Company's Quarterly Shipments of 1Mb Flash by Configuration to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Texas Instruments					
128Kx8	703	737	838	871	3,149
64Kx16	347	363	412	429	1,551
Vendor Total	1,050	1,100	1,250	1,300	4,700
Toshiba					
128Kx8	717	727	833	870	3,147
Vendor Total	717	727	833	870	3,147
Market Total					
128Kx8	29,063	30,797	35,652	40,552	136,064
64Kx16	2,064	2,280	2,786	3,108	10,238
Total	31,127	33,077	38,438	43,660	146,302
Percentage Change from Previous Quarter	-1.1	6.3	16.2	13.6	-
Average Selling Price ($)	4.13	3.80	3.36	3.13	3.55
Revenue ($M)	128,555	125,693	129,152	136,656	520,055
Market Share (% of Units)					
Americas Companies	78.2	75.6	76.4	74.9	76.2
European Companies	9.8	8.5	7.6	8.4	8.5
Japanese Companies	7.4	7.5	6.6	6.4	6.9
Asia/Pacific Companies	4.5	8.5	9.4	10.3	8.4
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-7
Each Company's Quarterly Shipments of 1Mb Flash by Voltage by Device to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Advanced Micro Devices					
5V Flash	6,091	5,480	7,448	7,641	26,659
12V Flash	1,619	1,730	1,747	2,685	7,781
Vendor Total	7,710	7,210	9,195	10,325	34,440
Atmel					
2.7V Flash	144	176	220	268	808
3.3V Flash	1,548	1,892	2,365	2,881	8,686
5V Flash	1,908	2,332	2,915	3,551	10,706
Vendor Total	3,600	4,400	5,500	6,700	20,200
Catalyst					
5V Flash	50	34	21	9	113
12V Flash	810	516	319	131	1,777
Vendor Total	860	550	340	140	1,890
Hitachi					
5V Flash	200	150	150	150	650
Vendor Total	200	150	150	150	650
Intel					
12V Flash	7,100	7,200	7,900	8,500	30,700
Vendor Total	7,100	7,200	7,900	8,500	30,700
Macronix					
5V Flash	-	280	540	900	1,720
12V Flash	1,400	2,520	3,060	3,600	10,580
Vendor Total	1,400	2,800	3,600	4,500	12,300
Mitsubishi					
5V Flash	750	750	900	1,200	3,600
Vendor Total	750	750	900	1,200	3,600
NEC					
12V Flash	45	50	65	70	230
Vendor Total	45	50	65	70	230
Sanyo					
12V Flash	600	800	600	500	2,500
Vendor Total	600	800	600	500	2,500
SGS-Thomson					
12V Flash	3,065	2,805	2,925	3,655	12,450
Vendor Total	3,065	2,805	2,925	3,655	12,450
Silicon Storage Technology					
2.7V Flash	20	23	39	43	125
3V Flash	101	125	181	201	608
5V Flash	3,909	4,388	4,960	5,506	18,762
Vendor Total	4,030	4,535	5,180	5,750	19,495

Table 2-7 (Continued)
Each Company's Quarterly Shipments of 1Mb Flash by Voltage by Device to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Texas Instruments					
5V Flash	105	220	375	520	1,220
12V Flash	945	880	875	780	3,480
Vendor Total	1,050	1,100	1,250	1,300	4,700
Toshiba					
12V Flash	717	727	833	870	3,147
Vendor Total	717	727	833	870	3,147
Market Total					
2.7V Flash	164	199	259	311	933
3V Flash	101	125	181	201	608
3.3V Flash	1,548	1,892	2,365	2,881	8,686
5V Flash	13,013	13,633	17,309	19,476	63,430
12V Flash	16,301	17,229	18,324	20,791	72,645
Total	31,127	33,077	38,438	43,660	146,302
Percentage Change from Previous Quarter	-1.1	6.3	16.2	13.6	-
Average Selling Price ($)	4.13	3.80	3.36	3.13	3.55
Revenue ($M)	128,555	125,693	129,152	136,656	520,055
Market Share (% of Units)					
Americas Companies	78.2	75.6	76.4	74.9	76.2
European Companies	9.8	8.5	7.6	8.4	8.5
Japanese Companies	7.4	7.5	6.6	6.4	6.9
Asia/Pacific Companies	4.5	8.5	9.4	10.3	8.4
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-8
Each Company's Quarterly Shipments of 2Mb Flash by Configuration to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Advanced Micro Devices					
256Kx8	1,195	1,488	2,306	2,531	7,519
128Kx16	15	308	1,703	2,711	4,737
Vendor Total	1,475	1,710	2,620	3,615	9,420
Atmel					
256Kx8	1,100	1,300	1,600	1,900	5,900
Vendor Total	1,100	1,300	1,600	1,900	5,900
Catalyst					
256Kx8	18	19	21	22	79
Vendor Total	18	19	21	22	79
Fujitsu					
256Kx8	-	-	-	280	280
128Kx16	21	70	350	980	1,421
Vendor Total	30	100	500	1,400	2,030
Intel					
256Kx8	360	370	420	450	1,600
128Kx16	3,492	3,589	4,074	4,365	15,520
Vendor Total	3,600	3,700	4,200	4,500	16,000
Macronix					
256Kx8	-	-	50	100	150
Vendor Total	-	-	50	100	150
SGS-Thomson					
256Kx8	-	2	8	220	230
Vendor Total	-	2	8	220	230
Silicon Storage Technology					
256Kx8	-	76	150	247	473
Vendor Total	-	76	150	247	473
Texas Instruments					
256Kx8	493	510	566	591	2,160
Vendor Total	657	680	755	788	2,880
Market Total					
256Kx8	3,165	3,764	5,120	6,340	18,390
128Kx16	3,528	3,967	6,127	8,056	21,678
Total	6,880	7,586	9,904	12,791	37,161

Table 2-8
Each Company's Quarterly Shipments of 2Mb Flash by Configuration to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Percentage Change from Previous Quarter	-39.8	10.3	30.5	29.2	-
Average Selling Price ($)	9.10	6.53	6.44	5.57	6.65
Revenue ($M)	62,607	49,538	63,779	71,248	247,171
Market Share (% of Units)					
Americas Companies	99.6	98.7	94.4	86.6	93.5
European Companies	-	-	0.1	1.7	0.6
Japanese Companies	0.4	1.3	5.0	10.9	5.5
Asia/Pacific Companies	-	-	0.5	0.8	0.4
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-9
Each Company's Quarterly Shipments of 2Mb Flash by Voltage to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Advanced Micro Devices					
5V Flash	118	257	472	1,301	2,148
12V Flash	1,357	1,454	2,148	2,314	7,272
Vendor Total	1,475	1,710	2,620	3,615	9,420
Atmel					
2.7V Flash	275	325	400	475	1,475
3.3V Flash	165	195	240	285	885
5V Flash	660	780	960	1,140	3,540
Vendor Total	1,100	1,300	1,600	1,900	5,900
Catalyst					
12V Flash	18	19	21	22	79
Vendor Total	18	19	21	22	79
Fujitsu					
5V Flash	30	100	500	1,400	2,030
Vendor Total	30	100	500	1,400	2,030
Intel					
5V Flash	360	555	840	1,125	2,880
12V Flash	3,240	3,145	3,360	3,375	13,120
Vendor Total	3,600	3,700	4,200	4,500	16,000
Macronix					
5V Flash	-	-	5	15	20
12V Flash	-	-	45	85	130
Vendor Total	-	-	50	100	150
SGS-Thomson					
12V Flash	-	2	8	220	230
Vendor Total	-	2	8	220	230
Silicon Storage Technology					
2.7V Flash	-	-	-	15	15
3V Flash	-	-	1	2	3
5V Flash	-	76	149	230	455
Vendor Total	-	76	150	247	473
Texas Instruments					
3.3V Flash	-	-	38	79	117
5V Flash	657	680	717	709	2,763
Vendor Total	657	680	755	788	2,880

Table 2-9 (Continued)
Each Company's Quarterly Shipments of 2Mb Flash by Voltage to the World, 1996
(Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Market Total					
2.7V Flash	275	325	400	490	1,490
3V Flash	-	-	1	2	3
3.3V Flash	165	195	278	364	1,002
5V Flash	1,825	2,447	3,643	5,921	13,836
12V Flash	4,615	4,619	5,582	6,015	20,831
Total	6,880	7,586	9,904	12,791	37,161
Percentage Change from Previous Quarter	-39.8	10.3	30.5	29.2	-
Average Selling Price ($)	9.10	6.53	6.44	5.57	6.65
Revenue ($M)	62,607	49,538	63,779	71,248	247,171
Market Share (% of Units)					
Americas Companies	99.6	98.7	94.4	86.6	93.5
European Companies	-	-	0.1	1.7	0.6
Japanese Companies	0.4	1.3	5.0	10.9	5.5
Asia/Pacific Companies	-	-	0.5	0.8	0.4
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-10
Each Company's Quarterly Shipments of 4Mb Flash by Configuration to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Advanced Micro Devices					
512Kx8	5,223	3,715	4,624	4,616	18,177
256Kx16	1,147	815	1,381	815	4,158
Vendor Total	6,370	4,530	6,005	5,430	22,335
Atmel					
512Kx8	2,550	2,700	3,100	3,400	11,750
Vendor Total	2,550	2,700	3,100	3,400	11,750
Catalyst					
512Kx8	17	18	23	24	81
Vendor Total	17	18	23	24	81
Fujitsu					
512Kx8	1,600	1,720	2,120	2,881	8,321
256Kx16	2,400	2,580	3,180	3,819	11,979
Vendor Total	4,000	4,300	5,300	6,700	20,300
Intel					
512Kx8	245	275	330	375	1,225
256Kx16	4,655	5,225	6,270	7,125	23,275
Vendor Total	4,900	5,500	6,600	7,500	24,500
Macronix					
512Kx8	10	20	30	70	130
Vendor Total	10	20	30	70	130
NEC					
256Kx16	550	700	850	1,000	3,100
Vendor Total	550	700	850	1,000	3,100
Samsung					
512Kx8	145	350	710	930	2,135
Vendor Total	145	350	710	930	2,135
Sanyo					
256Kx16	500	600	600	800	2,500
Vendor Total	500	600	600	800	2,500
SGS-Thomson					
512Kx8	328	381	818	1,523	3,050
256Kx16	62	29	17	97	205
Vendor Total	390	410	835	1,620	3,255
Sharp					
256Kx16	800	1,000	1,100	1,300	4,200
Vendor Total	800	1,000	1,100	1,300	4,200
Silicon Storage Technology					
512Kx8	140	158	180	200	678
Vendor Total	140	158	180	200	678

Table 2-10 (Continued)
Each Company's Quarterly Shipments of 4Mb Flash by Configuration to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Texas Instruments					
512Kx8	8	38	49	72	166
256Kx16	2	13	21	39	74
Vendor Total	10	50	70	110	240
Market Total					
512Kx8	10,266	9,374	11,984	14,089	45,713
256Kx16	10,116	10,962	13,419	14,994	49,491
Total	20,382	20,336	25,403	29,084	95,204
Percentage Change from Previous Quarter	-3.7	-0.2	24.9	14.5	-
Average Selling Price ($)	13.33	10.93	8.19	7.66	9.71
Revenue ($M)	271,689	222,271	208,046	222,780	924,788
Market Share (% of Units)					
Americas Companies	68.6	63.7	62.9	57.3	62.6
European Companies	1.9	2.0	3.3	5.6	3.4
Japanese Companies	28.7	32.5	30.9	33.7	31.6
Asia/Pacific Companies	0.8	1.8	2.9	3.4	2.4
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-11
Each Company's Quarterly Shipments of 4Mb Flash by Voltage to the World, 1996
(Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Advanced Micro Devices					
2.7V Flash	-	-	6	217	223
5V Flash	6,370	4,530	5,999	5,213	22,112
Vendor Total	6,370	4,530	6,005	5,430	22,335
Atmel					
2.7V Flash	638	675	775	850	2,938
3.3V Flash	306	324	372	408	1,410
5V Flash	1,606	1,701	1,953	2,142	7,402
Vendor Total	2,550	2,700	3,100	3,400	11,750
Catalyst					
12V Flash	17	18	23	24	81
Vendor Total	17	18	23	24	81
Fujitsu					
5V Flash	4,000	4,300	5,300	6,700	20,300
Vendor Total	4,000	4,300	5,300	6,700	20,300
Intel					
3.3V Flash	1,470	1,925	2,640	3,750	9,785
5V Flash	2,940	3,025	3,300	3,000	12,265
12V Flash	490	550	660	750	2,450
Vendor Total	4,900	5,500	6,600	7,500	24,500
Macronix					
3V Flash	2	6	12	35	55
5V Flash	8	14	18	35	75
Vendor Total	10	20	30	70	130
NEC					
12V Flash	550	700	850	1,000	3,100
Vendor Total	550	700	850	1,000	3,100
Samsung					
3.3V Flash	15	70	213	372	670
5V Flash	131	280	497	558	1,466
Vendor Total	145	350	710	930	2,135
Sanyo					
12V Flash	500	600	600	800	2,500
Vendor Total	500	600	600	800	2,500
SGS-Thomson					
12V Flash	390	410	835	1,620	3,255
Vendor Total	390	410	835	1,620	3,255
Sharp					
5V Flash	800	1,000	1,100	1,300	4,200
Vendor Total	800	1,000	1,100	1,300	4,200

Table 2-11 (Continued)
Each Company's Quarterly Shipments of 4Mb Flash by Voltage to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Silicon Storage Technology					
2.7V Flash	3	6	8	11	28
3V Flash	1	1	1	2	5
5V Flash	137	150	171	187	645
Vendor Total	140	158	180	200	678
Texas Instruments					
3.3V Flash	-	2	4	8	13
5V Flash	5	29	46	80	159
12V Flash	5	20	21	22	68
Vendor Total	10	50	70	110	240
Market Total					
2.7V Flash	640	681	789	1,078	3,189
3V Flash	3	7	13	37	60
3.3V Flash	1,791	2,321	3,229	4,538	11,877
5V Flash	15,996	15,029	18,383	19,216	68,624
12V Flash	1,952	2,298	2,989	4,216	11,454
Total	20,382	20,336	25,403	29,084	95,204
Percentage Change from Previous Quarter	-3.7	-0.2	24.9	14.5	-
Average Selling Price ($)	13.33	10.93	8.19	7.66	9.71
Revenue ($M)	271,689	222,271	208,046	222,780	924,788
Market Share (% of Units)					
Americas Companies	68.6	63.7	62.9	57.3	62.6
European Companies	1.9	2.0	3.3	5.6	3.4
Japanese Companies	28.7	32.5	30.9	33.7	31.6
Asia/Pacific Companies	0.8	1.8	2.9	3.4	2.4
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-12
Each Company's Quarterly Shipments of 8Mb Flash by Configuration to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	
Advanced Micro Devices					
1Mbx8	119	139	217	488	963
1Mbx8/512Kx16	1	31	403	1,463	1,898
Vendor Total	120	170	620	1,950	2,860
Fujitsu					
1Mbx8	90	180	480	690	1,440
1Mbx8/512Kx16	210	420	1,120	1,610	3,360
Vendor Total	300	600	1,600	2,300	4,800
Intel					
1Mbx8	228	264	282	315	1,089
1Mbx8/512Kx16	7,372	8,536	9,118	10,185	35,211
Vendor Total	7,600	8,800	9,400	10,500	36,300
Mitsubishi					
1Mbx8	20	25	100	400	545
Vendor Total	20	25	100	400	545
Sharp					
1Mbx8	220	280	320	360	1,180
1Mbx8/512Kx16	880	1,120	1,280	1,440	4,720
Vendor Total	1,100	1,400	1,600	1,800	5,900
Market Total					
1Mbx8	657	863	1,299	1,853	4,672
1Mbx8/512Kx16	8,483	10,132	12,021	15,097	45,733
Total	9,140	10,995	13,320	16,950	50,405
Percentage Change from Previous Quarter	128.5	20.3	21.1	27.3	-
Average Selling Price ($)	17.19	12.18	10.75	10.41	12.12
Revenue ($M)	157,117	133,919	143,190	176,450	610,675
Market Share (% of Units)					
Americas Companies	84.5	81.6	75.2	73.5	77.7
European Companies	-	-	-	-	-
Japanese Companies	15.5	18.4	24.8	26.5	22.3
Asia/Pacific Companies	-	-	-	-	-
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-13
Each Company's Quarterly Shipments of 8Mb Flash by Voltage by Device to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Advanced Micro Devices					
2.7V Flash	1	3	136	722	863
5V Flash	119	167	484	1,229	1,998
Vendor Total	120	170	620	1,950	2,860
Fujitsu					
5V Flash	300	600	1,600	2,300	4,800
Vendor Total	300	600	1,600	2,300	4,800
Intel					
3.3V Flash	2,660	3,520	4,230	5,775	16,185
5V Flash	3,420	3,960	4,230	4,200	15,810
12V Flash	1,520	1,320	940	525	4,305
Vendor Total	7,600	8,800	9,400	10,500	36,300
Mitsubishi					
5V Flash	20	25	100	400	545
Vendor Total	20	25	100	400	545
Sharp					
5V Flash	550	700	800	900	2,950
12V Flash	550	700	800	900	2,950
Vendor Total	1,100	1,400	1,600	1,800	5,900
Market Total					
2.7V Flash	1	3	136	722	863
3.3V Flash	2,660	3,520	4,230	5,775	16,185
5V Flash	4,409	5,452	7,214	9,029	26,102
12V Flash	2,070	2,020	1,740	1,425	7,255
Total	9,140	10,995	13,320	16,950	50,405
Percentage Change from Previous Quarter	128.5	20.3	21.1	27.3	-
Average Selling Price ($)	17.19	12.18	10.75	10.41	12.12
Revenue ($M)	157,117	133,919	143,190	176,450	610,675
Market Share (% of Units)					
Americas Companies	84.5	81.6	75.2	73.5	77.7
European Companies	-	-	-	-	-
Japanese Companies	15.5	18.4	24.8	26.5	22.3
Asia/Pacific Companies	-	-	-	-	-
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-14
Each Company's Quarterly Shipments of 16Mb Flash by Configuration to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Advanced Micro Devices					
2Mbx8	80	110	325	395	910
Vendor Total	80	110	325	395	910
Fujitsu					
2Mbx8	250	250	300	400	1,200
Vendor Total	250	250	300	400	1,200
Intel					
2Mbx8	105	80	60	22	267
1Mbx16	1,395	1,520	1,940	2,178	7,033
Vendor Total	1,500	1,600	2,000	2,200	7,300
Samsung					
2Mbx8	95	105	265	295	760
Vendor Total	95	105	265	295	760
Sharp					
2Mbx8	350	370	380	400	1,500
Vendor Total	350	370	380	400	1,500
Toshiba					
2Mbx8	760	872	1,142	1,196	3,970
Vendor Total	760	872	1,142	1,196	3,970
Market Total					
2Mbx8	1,640	1,787	2,472	2,708	8,607
1Mbx16	1,395	1,520	1,940	2,178	7,033
Total	3,035	3,307	4,412	4,886	15,640
Percentage Change from Previous Quarter	-34.0	9.0	33.4	10.7	-
Average Selling Price ($)	35.40	32.04	25.31	21.08	27.37
Revenue ($M)	107,439	105,956	111,668	102,997	428,060
Market Share (% of Units)					
Americas Companies	52.1	51.7	52.7	53.1	52.5
European Companies	-	-	-	-	-
Japanese Companies	44.8	45.1	41.3	40.9	42.6
Asia/Pacific Companies	3.1	3.2	6.0	6.0	4.9
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-15
Each Company's Quarterly Shipments of 16Mb Flash by Voltage to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Advanced Micro Devices					
5V Flash	80	110	325	395	910
Vendor Total	80	110	325	395	910
Fujitsu					
5V Flash	250	250	300	400	1,200
Vendor Total	250	250	300	400	1,200
Intel					
3.3V Flash	675	800	1,100	1,320	3,895
5V Flash	720	720	840	858	3,138
12V Flash	105	80	60	22	267
Vendor Total	1,500	1,600	2,000	2,200	7,300
Samsung					
3.3V Flash	19	32	106	148	304
5V Flash	76	74	159	148	456
Vendor Total	95	105	265	295	760
Sharp					
5V Flash	175	185	190	200	750
12V Flash	175	185	190	200	750
Vendor Total	350	370	380	400	1,500
Toshiba					
5V Flash	760	872	1,142	1,196	3,970
Vendor Total	760	872	1,142	1,196	3,970
Market Total					
3.3V Flash	694	832	1,206	1,468	4,199
5V Flash	2,061	2,211	2,956	3,197	10,424
12V Flash	280	265	250	222	1,017
Total	3,035	3,307	4,412	4,886	15,640
Percentage Change from Previous Quarter	-34.0	9.0	33.4	10.7	-
Average Selling Price ($)	35.40	32.04	25.31	21.08	27.37
Revenue ($M)	107,439	105,956	111,668	102,997	428,060
Market Share (% of Units)					
Americas Companies	52.1	51.7	52.7	53.1	52.5
European Companies	-	-	-	-	-
Japanese Companies	44.8	45.1	41.3	40.9	42.6
Asia/Pacific Companies	3.1	3.2	6.0	6.0	4.9
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-16
Each Company's Quarterly Shipments of 32Mb Flash by Configuration to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Samsung					
4Mbx8	25	20	70	110	225
Vendor Total	25	20	70	110	225
Market Total					
4Mbx8	25	20	70	110	225
Total	25	20	70	110	225
Percentage Change from Previous Quarter	-	-20.0	250.0	57.1	-
Average Selling Price ($)	63.69	57.90	52.63	47.85	51.99
Revenue ($M)	2	1	4	5	12
Market Share (% of Units)					
Americas Companies	-	-	-	-	-
European Companies	-	-	-	-	-
Japanese Companies	-	-	-	-	-
Asia/Pacific Companies	100.0	100.0	100.0	100.0	100.0
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-17
Each Company's Quarterly Shipments of 32Mb Flash by Voltage to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Samsung					
3.3V Flash	8	8	35	66	117
5V Flash	18	12	35	44	109
Vendor Total	25	20	70	110	225
Market Total					
3.3V Flash	8	8	35	66	117
5V Flash	18	12	35	44	109
Total	25	20	70	110	225
Percentage Change from Previous Quarter	NA	-20.0	250.0	57.1	-
Average Selling Price ($)	63.69	57.90	52.63	47.85	51.99
Revenue ($M)	2	1	4	5	12
Market Share (% of Units)					
Americas Companies	-	-	-	-	-
European Companies	-	-	-	-	-
Japanese Companies	-	-	-	-	-
Asia/Pacific Companies	100.0	100.0	100.0	100.0	100.0
Total	100.0	100.0	100.0	100.0	100.0

NA = Not available
Source: Dataquest (June 1997)

Table 2-18
Each Company's Quarterly Shipments of EEPROM by Density to the World, 1996
(Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Atmel					
All 1K	19,130	19,580	15,700	22,450	76,860
All 2K	8,800	10,210	9,800	12,000	40,810
All 4K	5,815	9,285	8,870	11,590	35,560
All 8K	3,375	2,705	3,685	1,620	11,385
All 16K	5,485	6,300	5,320	5,670	22,775
All 32K	740	1,185	1,520	2,230	5,675
All 64K	8,425	9,720	10,380	10,330	38,855
All 256K	1,065	1,450	1,580	1,720	5,815
All 1Mb	105	115	125	145	490
All 4Mb	-	3	3	2	8
Vendor Total	52,940	60,553	56,983	67,757	238,233
Catalyst					
All 256b	585	565	545	525	2,220
All 1K	8,070	8,390	8,725	9,060	34,245
All 2K	1,700	1,850	2,020	2,200	7,770
All 4K	2,430	2,630	2,830	3,025	10,915
All 16K	320	335	345	360	1,360
All 64K	1,375	1,475	1,580	1,680	6,110
All 256K	46	47	48	49	189
Vendor Total	14,526	15,292	16,093	16,899	62,809
Fujitsu					
All 1K	190	190	195	195	770
All 16K	115	75	90	70	350
All 64K	13	7	7	20	47
Vendor Total	318	272	292	285	1,167
ISSI					
All 1K	805	690	615	985	3,095
All 2K	610	85	430	535	1,660
All 4K	1,200	1,400	1,550	1,750	5,900
Vendor Total	2,615	2,175	2,595	3,270	10,655
Microchip					
All 256b	995	1,550	1,755	2,040	6,340
All 1K	20,325	18,825	21,375	22,110	82,635
All 2K	7,210	7,560	7,710	8,155	30,635
All 4K	6,915	7,855	8,050	11,890	34,710
All 8K	1,800	3,175	1,625	4,070	10,670
All 16K	4,270	3,455	4,295	5,080	17,100
All 32K	820	1,085	1,125	1,015	4,045
All 64K	1,850	2,135	3,485	4,215	11,685
Vendor Total	44,185	45,640	49,420	58,575	197,820

Table 2-18 (Continued)
Each Company's Quarterly Shipments of EEPROM by Density to the World, 1996
(Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
National Semiconductor					
All 256b	3,455	3,350	2,340	2,370	11,515
All 1K	10,955	10,800	11,900	13,200	46,855
All 2K	6,160	8,230	7,860	7,620	29,870
All 4K	4,845	4,115	4,160	5,730	18,850
All 8K	330	305	320	490	1,445
All 16K	1,285	2,205	1,565	2,200	7,255
Vendor Total	27,030	29,005	28,145	31,610	115,790
NEC					
All 64K	1,100	1,150	1,200	1,050	4,500
All 256K	100	100	110	100	410
Vendor Total	1,200	1,250	1,310	1,150	4,910
Oki					
All 1K	1,060	1,100	1,150	1,200	4,510
All 16K	30	31	32	34	127
All 64K	32	35	37	39	143
Vendor Total	1,122	1,166	1,219	1,273	4,780
Ramtron International					
All 4K	140	192	73	115	520
All 16K	40	70	33	62	205
All 64K	-	1	3	3	7
Vendor Total	180	263	109	180	732
Rohm					
All 1K	5,200	6,000	7,000	7,800	26,000
All 2K	1,800	2,000	2,500	2,700	9,000
All 4K	1,650	2,000	2,150	2,500	8,300
All 16K	700	850	900	1,050	3,500
All 64K	200	230	265	300	995
Vendor Total	9,550	11,080	12,815	14,350	47,795
Samsung					
All 1K	1,645	1,710	1,780	1,850	6,985
Vendor Total	1,645	1,710	1,780	1,850	6,985
SGS-Thomson					
All 256b	2,300	2,030	1,485	1,270	7,085
All 1K	23,450	19,780	16,400	18,325	77,955
All 2K	14,880	14,490	13,090	14,640	57,100
All 4K	4,920	5,780	5,885	9,110	25,695
All 8K	2,760	3,520	4,055	4,355	14,690
All 16K	1,710	3,655	4,075	6,050	15,490

Table 2-18 (Continued)
Each Company's Quarterly Shipments of EEPROM by Density to the World, 1996
(Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
All 32K	400	920	1,490	1,550	4,360
All 64K	562	510	1,110	2,595	4,777
Vendor Total	50,982	50,685	47,590	57,895	207,152
Xicor					
All 256b	315	310	310	305	1,240
All 1K	3,600	3,750	3,900	4,040	15,290
All 2K	4,400	4,840	5,280	5,720	20,240
All 4K	4,400	4,760	5,120	5,480	19,760
All 16K	3,805	4,125	4,445	4,770	17,145
All 64K	1,440	1,545	1,655	1,760	6,400
All 256K	475	485	500	505	1,965
All 512K	30	30	30	30	120
All 1Mb	25	25	25	25	100
Vendor Total	18,490	19,870	21,265	22,635	82,260
Market Total					
All 256b	7,650	7,805	6,435	6,510	28,400
All 1K	94,430	90,815	88,740	101,215	375,200
All 2K	45,560	49,265	48,690	53,570	197,085
All 4K	32,315	38,017	38,688	51,190	160,210
All 8K	8,265	9,705	9,685	10,535	38,190
All 16K	17,760	21,101	21,100	25,346	85,307
All 32K	1,960	3,190	4,135	4,795	14,080
All 64K	14,997	16,808	19,722	21,992	73,519
All 256K	1,686	2,082	2,238	2,374	8,379
All 512K	30	30	30	30	120
All 1Mb	130	140	150	170	590
All 4Mb	-	3	3	2	8
Total	224,783	238,960	239,615	277,729	981,087
Percentage Change from Previous Quarter	5.9	6.8	-0.2	15.9	-
Average Selling Price ($)	0.98	1.12	0.87	0.79	0.93
Revenue ($M)	220,085	225,510	208,898	218,287	872,780
Market Share (% of Units)					
Americas Companies	71.2	72.4	72.9	72.3	72.2
European Companies	22.7	21.1	19.9	20.8	21.1
Japanese Companies	5.4	5.7	6.5	6.1	6.0
Asia/Pacific Companies	0.7	0.7	0.7	0.7	0.7
Total	100.0	100.0	100.0	100.0	100.00

Source: Dataquest (June 1997)

Table 2-19
Each Company's Quarterly Shipments of 256-Bit EEPROM to the World, 1996
(Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Catalyst					
16bx16					
Serial EEPROM	585	565	545	525	2,220
Total	585	565	545	525	2,220
Vendor Total					
Serial EEPROM	585	565	545	525	2,220
Total	585	565	545	525	2,220
Microchip					
16bx16					
Serial EEPROM	995	1,550	1,755	2,040	6,340
Total	995	1,550	1,755	2,040	6,340
Vendor Total					
Serial EEPROM	995	1,550	1,755	2,040	6,340
Total	995	1,550	1,755	2,040	6,340
National Semiconductor					
16bx16					
Serial EEPROM	3,455	3,350	2,340	2,370	11,515
Total	3,455	3,350	2,340	2,370	11,515
Vendor Total					
Serial EEPROM	3,455	3,350	2,340	2,370	11,515
Total	3,455	3,350	2,340	2,370	11,515
SGS-Thomson					
16bx16					
Serial EEPROM	2,300	2,030	1,485	1,270	7,085
Total	2,300	2,030	1,485	1,270	7,085
Vendor Total					
Serial EEPROM	2,300	2,030	1,485	1,270	7,085
Total	2,300	2,030	1,485	1,270	7,085
Xicor					
16bx16					
Parallel EEPROM	315	310	310	305	1,240
Total	315	310	310	305	1,240
Vendor Total					
Parallel EEPROM	315	310	310	305	1,240
Total	315	310	310	305	1,240

Table 2-19 (Continued)
Each Company's Quarterly Shipments of 256-Bit EEPROM to the World, 1996
(Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Market Total					
16bx16					
Parallel EEPROM	315	310	310	305	1,240
Serial EEPROM	7,335	7,495	6,125	6,205	27,160
Total	7,650	7,805	6,435	6,510	28,400
All 256b					
Parallel EEPROM	315	310	310	305	1,240
Serial EEPROM	7,335	7,495	6,125	6,205	27,160
Total	7,650	7,805	6,435	6,510	28,400
% Change from Previous Quarter	20.5	2.0	-17.6	1.2	-
Average Selling Price ($)	0.57	0.48	0.42	0.34	0.46
Revenue ($M)	4,377	3,709	2,678	2,207	12,972
Market Share (% of Units)					
Americas Companies	69.9	74.0	76.9	80.5	75.1
European Companies	30.1	26.0	23.1	19.5	24.9
Japanese Companies	-	-	-	-	-
Asia/Pacific Companies	-	-	-	-	-
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-20
Each Company's Quarterly Shipments of 1K EEPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Atmel					
128bx8					
Serial EEPROM	16,380	17,970	13,950	20,200	68,500
Total	16,380	17,970	13,950	20,200	68,500
64bx16					
Serial EEPROM	2,750	1,610	1,750	2,250	8,360
Total	2,750	1,610	1,750	2,250	8,360
Vendor Total					
Serial EEPROM	19,130	19,580	15,700	22,450	76,860
Total	19,130	19,580	15,700	22,450	76,860
Catalyst					
128bx8					
Serial EEPROM	7,960	8,280	8,610	8,940	33,790
Total	7,960	8,280	8,610	8,940	33,790
64bx16					
Serial EEPROM	110	110	115	120	455
Total	110	110	115	120	455
Vendor Total					
Serial EEPROM	8,070	8,390	8,725	9,060	34,245
Total	8,070	8,390	8,725	9,060	34,245
Fujitsu					
256bx4					
Parallel EEPROM	190	190	195	195	770
Total	190	190	195	195	770
Vendor Total					
Parallel EEPROM	190	190	195	195	770
Total	190	190	195	195	770
64bx16					
Serial EEPROM	805	690	615	985	3,095
Total	805	690	615	985	3,095
Vendor Total					
Serial EEPROM	805	690	615	985	3,095
Total	805	690	615	985	3,095
Microchip					
128bx8					
Serial EEPROM	20,325	18,825	21,375	22,110	82,635
Total	20,325	18,825	21,375	22,110	82,635
Vendor Total					
Serial EEPROM	20,325	18,825	21,375	22,110	82,635
Total	20,325	18,825	21,375	22,110	82,635

Table 2-20 (Continued)
Each Company's Quarterly Shipments of 1K EEPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
National Semiconductor					
128bx8					
Serial EEPROM	10,955	10,800	11,900	13,200	46,855
Total	10,955	10,800	11,900	13,200	46,855
Vendor Total					
Serial EEPROM	10,955	10,800	11,900	13,200	46,855
Total	10,955	10,800	11,900	13,200	46,855
Oki					
128bx8					
Serial EEPROM	530	550	575	600	2,255
Total	530	550	575	600	2,255
64bx16					
Serial EEPROM	530	550	575	600	2,255
Total	530	550	575	600	2,255
Vendor Total					
Serial EEPROM	1,060	1,100	1,150	1,200	4,510
Total	1,060	1,100	1,150	1,200	4,510
Rohm					
64bx16					
Parallel EEPROM	5,200	6,000	7,000	7,800	26,000
Total	5,200	6,000	7,000	7,800	26,000
Vendor Total					
Parallel EEPROM	5,200	6,000	7,000	7,800	26,000
Total	5,200	6,000	7,000	7,800	26,000
Samsung					
64bx16					
Serial EEPROM	1,645	1,710	1,780	1,850	6,985
Total	1,645	1,710	1,780	1,850	6,985
Vendor Total					
Serial EEPROM	1,645	1,710	1,780	1,850	6,985
Total	1,645	1,710	1,780	1,850	6,985
SGS-Thomson					
128bx8					
Serial EEPROM	10,550	8,900	7,380	8,250	35,080
Total	10,550	8,900	7,380	8,250	35,080
64bx16					
Serial EEPROM	12,900	10,880	9,020	10,075	42,875
Total	12,900	10,880	9,020	10,075	42,875

Table 2-20 (Continued)
Each Company's Quarterly Shipments of 1K EEPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Vendor Total					
Serial EEPROM	23,450	19,780	16,400	18,325	77,955
Total	23,450	19,780	16,400	18,325	77,955
Xicor					
128bx8					
Serial EEPROM	3,600	3,750	3,900	4,040	15,290
Total	3,600	3,750	3,900	4,040	15,290
Vendor Total					
Serial EEPROM	3,600	3,750	3,900	4,040	15,290
Total	3,600	3,750	3,900	4,040	15,290
Market Total					
256bx4					
Parallel EEPROM	190	190	195	195	770
Total	190	190	195	195	770
128bx8					
Serial EEPROM	70,300	69,075	67,690	77,340	284,405
Total	70,300	69,075	67,690	77,340	284,405
64bx16					
Parallel EEPROM	5,200	6,000	7,000	7,800	26,000
Serial EEPROM	18,740	15,550	13,855	15,880	64,025
Total	23,940	21,550	20,855	23,680	90,025
All 1K					
Parallel EEPROM	5,390	6,190	7,195	7,995	26,770
Serial EEPROM	89,040	84,625	81,545	93,220	348,430
Total	94,430	90,815	88,740	101,215	375,200
% Change from Previous Quarter	19.4	-3.8	-2.3	14.1	-
Average Selling Price ($)	0.63	0.55	0.50	0.42	0.52
Revenue ($M)	59,088	49,618	44,034	42,643	195,383
Market Share (% of Units)					
Americas Companies	66.6	68.3	70.1	71.0	69.0
European Companies	24.8	21.8	18.5	18.1	20.8
Japanese Companies	6.8	8.0	9.4	9.1	8.3
Asia/Pacific Companies	1.7	1.9	2.0	1.8	1.9
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-21
Each Company's Quarterly Shipments of 2K EEPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Atmel					
256bx8					
Serial EEPROM	8,800	10,210	9,800	12,000	40,810
Total	8,800	10,210	9,800	12,000	40,810
Vendor Total					
Serial EEPROM	8,800	10,210	9,800	12,000	40,810
Total	8,800	10,210	9,800	12,000	40,810
Catalyst					
256bx8					
Serial EEPROM	850	925	1,010	1,100	3,885
Total	850	925	1,010	1,100	3,885
128bx16					
Serial EEPROM	850	925	1,010	1,100	3,885
Total	850	925	1,010	1,100	3,885
Vendor Total					
Serial EEPROM	1,700	1,850	2,020	2,200	7,770
Total	1,700	1,850	2,020	2,200	7,770
ISSI					
128bx16					
Serial EEPROM	610	85	430	535	1,660
Total	610	85	430	535	1,660
Vendor Total					
Serial EEPROM	610	85	430	535	1,660
Total	610	85	430	535	1,660
Microchip					
256bx8					
Serial EEPROM	7,210	7,560	7,710	8,155	30,635
Total	7,210	7,560	7,710	8,155	30,635
Vendor Total					
Serial EEPROM	7,210	7,560	7,710	8,155	30,635
Total	7,210	7,560	7,710	8,155	30,635
National Semiconductor					
256bx8					
Serial EEPROM	2,460	3,290	3,145	3,050	11,945
Total	2,460	3,290	3,145	3,050	11,945
128bx16					
Serial EEPROM	3,700	4,940	4,715	4,570	17,925
Total	3,700	4,940	4,715	4,570	17,925

Table 2-21 (Continued)
Each Company's Quarterly Shipments of 2K EEPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Vendor Total					
Serial EEPROM	6,160	8,230	7,860	7,620	29,870
Total	6,160	8,230	7,860	7,620	29,870
Rohm					
128bx16					
Parallel EEPROM	1,800	2,000	2,500	2,700	9,000
Total	1,800	2,000	2,500	2,700	9,000
Vendor Total					
Parallel EEPROM	1,800	2,000	2,500	2,700	9,000
Total	1,800	2,000	2,500	2,700	9,000
SGS-Thomson					
256bx8					
Serial EEPROM	4,465	4,350	3,930	4,390	17,135
Total	4,465	4,350	3,930	4,390	17,135
128bx16					
Serial EEPROM	10,415	10,140	9,160	10,250	39,965
Total	10,415	10,140	9,160	10,250	39,965
Vendor Total					
Serial EEPROM	14,880	14,490	13,090	14,640	57,100
Total	14,880	14,490	13,090	14,640	57,100
Xicor					
256bx8					
Serial EEPROM	4,400	4,840	5,280	5,720	20,240
Total	4,400	4,840	5,280	5,720	20,240
Vendor Total					
Serial EEPROM	4,400	4,840	5,280	5,720	20,240
Total	4,400	4,840	5,280	5,720	20,240
Market Total					
256bx8					
Serial EEPROM	28,185	31,175	30,875	34,415	124,650
Total	28,185	31,175	30,875	34,415	124,650
128bx16					
Parallel EEPROM	1,800	2,000	2,500	2,700	9,000
Serial EEPROM	15,575	16,090	15,315	16,455	63,435
Total	17,375	18,090	17,815	19,155	72,435
All 2K					
Parallel EEPROM	1,800	2,000	2,500	2,700	9,000
Serial EEPROM	43,760	47,265	46,190	50,870	188,085
Total	45,560	49,265	48,690	53,570	197,085

Table 2-21 (Continued)
Each Company's Quarterly Shipments of 2K EEPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
% Change from Previous Quarter	-13.5	8.1	-1.2	10.0	-
Average Selling Price ($)	0.79	0.77	0.69	0.63	0.71
Revenue ($M)	35,872	37,767	33,383	33,637	140,659
Market Share (% of Units)					
Americas Companies	63.4	66.5	68.0	67.6	66.5
European Companies	32.7	29.4	26.9	27.3	29.0
Japanese Companies	4.0	4.1	5.1	5.0	4.6
Asia/Pacific Companies	-	-	-	-	-
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-22
Each Company's Quarterly Shipments of 4K EEPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Atmel					
512bx8					
Serial EEPROM	5,815	9,285	8,870	11,590	35,560
Total	5,815	9,285	8,870	11,590	35,560
Vendor Total					
Serial EEPROM	5,815	9,285	8,870	11,590	35,560
Total	5,815	9,285	8,870	11,590	35,560
Catalyst					
512bx8					
Serial EEPROM	800	870	930	1,000	3,600
Total	800	870	930	1,000	3,600
256bx16					
Serial EEPROM	1,630	1,760	1,900	2,025	7,315
Total	1,630	1,760	1,900	2,025	7,315
Vendor Total					
Serial EEPROM	2,430	2,630	2,830	3,025	10,915
Total	2,430	2,630	2,830	3,025	10,915
ISSI					
256bx16					
Serial EEPROM	1,200	1,400	1,550	1,750	5,900
Total	1,200	1,400	1,550	1,750	5,900
Vendor Total					
Serial EEPROM	1,200	1,400	1,550	1,750	5,900
Total	1,200	1,400	1,550	1,750	5,900
Microchip					
512bx8					
Parallel EEPROM	15	15	20	25	75
Serial EEPROM	6,900	7,840	8,030	11,865	34,635
Total	6,915	7,855	8,050	11,890	34,710
Vendor Total					
Parallel EEPROM	15	15	20	25	75
Serial EEPROM	6,900	7,840	8,030	11,865	34,635
Total	6,915	7,855	8,050	11,890	34,710
National Semiconductor					
512bx8					
Serial EEPROM	3,390	2,880	2,910	4,010	13,190
Total	3,390	2,880	2,910	4,010	13,190
256bx16					
Serial EEPROM	1,455	1,235	1,250	1,720	5,660
Total	1,455	1,235	1,250	1,720	5,660

Table 2-22 (Continued)
Each Company's Quarterly Shipments of 4K EEPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Vendor Total					
Serial EEPROM	4,845	4,115	4,160	5,730	18,850
Total	4,845	4,115	4,160	5,730	18,850
Ramtron International					
512bx8					
Parallel FRAM	120	162	63	100	445
Serial FRAM	20	30	10	15	75
Total	140	192	73	115	520
Vendor Total					
Parallel FRAM	120	162	63	100	445
Serial FRAM	20	30	10	15	75
Total	140	192	73	115	520
Rohm					
256bx16					
Parallel EEPROM	1,650	2,000	2,150	2,500	8,300
Total	1,650	2,000	2,150	2,500	8,300
Vendor Total					
Parallel EEPROM	1,650	2,000	2,150	2,500	8,300
Total	1,650	2,000	2,150	2,500	8,300
SGS-Thomson					
512bx8					
Serial EEPROM	1,870	2,200	2,235	3,460	9,765
Total	1,870	2,200	2,235	3,460	9,765
256bx16					
Serial EEPROM	3,050	3,580	3,650	5,650	15,930
Total	3,050	3,580	3,650	5,650	15,930
Vendor Total					
Serial EEPROM	4,920	5,780	5,885	9,110	25,695
Total	4,920	5,780	5,885	9,110	25,695
Xicor					
512bx8					
Serial EEPROM	4,400	4,760	5,120	5,480	19,760
Total	4,400	4,760	5,120	5,480	19,760
Vendor Total					
Serial EEPROM	4,400	4,760	5,120	5,480	19,760
Total	4,400	4,760	5,120	5,480	19,760

Table 2-22 (Continued)
Each Company's Quarterly Shipments of 4K EEPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Market Total					
512bx8					
Parallel EEPROM	15	15	20	25	75
Parallel FRAM	120	162	63	100	445
Serial EEPROM	23,175	27,835	28,095	37,405	116,510
Serial FRAM	20	30	10	15	75
Total	23,330	28,042	28,188	37,545	117,105
256bx16					
Parallel EEPROM	1,650	2,000	2,150	2,500	8,300
Serial EEPROM	7,335	7,975	8,350	11,145	34,805
Total	8,985	9,975	10,500	13,645	43,105
All 4K					
Parallel EEPROM	1,665	2,015	2,170	2,525	8,375
Parallel FRAM	120	162	63	100	445
Serial EEPROM	30,510	35,810	36,445	48,550	151,315
Serial FRAM	20	30	10	15	75
Total	32,315	38,017	38,688	51,190	160,210
% Change from Previous Quarter	13.7	17.6	1.8	32.3	-
Average Selling Price ($)	1.00	0.89	0.84	0.79	0.87
Revenue ($M)	32,337	33,962	32,610	40,229	139,138
Market Share (% of Units)					
Americas Companies	79.7	79.5	79.2	77.3	78.8
European Companies	15.2	15.2	15.2	17.8	16.0
Japanese Companies	5.1	5.3	5.6	4.9	5.2
Asia/Pacific Companies	-	-	-	-	-
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-23
Each Company's Quarterly Shipments of 8K EEPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Atmel					
1Kx8					
Serial EEPROM	3,375	2,705	3,685	1,620	11,385
Total	3,375	2,705	3,685	1,620	11,385
Vendor Total					
Serial EEPROM	3,375	2,705	3,685	1,620	11,385
Total	3,375	2,705	3,685	1,620	11,385
Microchip					
1Kx8					
Serial EEPROM	1,800	3,175	1,625	4,070	10,670
Total	1,800	3,175	1,625	4,070	10,670
Vendor Total					
Serial EEPROM	1,800	3,175	1,625	4,070	10,670
Total	1,800	3,175	1,625	4,070	10,670
National Semiconductor					
1Kx8					
Serial EEPROM	330	305	320	490	1,445
Total	330	305	320	490	1,445
Vendor Total					
Serial EEPROM	330	305	320	490	1,445
Total	330	305	320	490	1,445
SGS-Thomson					
1Kx8					
Serial EEPROM	2,760	3,520	4,055	4,355	14,690
Total	2,760	3,520	4,055	4,355	14,690
Vendor Total					
Serial EEPROM	2,760	3,520	4,055	4,355	14,690
Total	2,760	3,520	4,055	4,355	14,690
Market Total					
1Kx8					
Serial EEPROM	8,265	9,705	9,685	10,535	38,190
Total	8,265	9,705	9,685	10,535	38,190
All 8K					
Serial EEPROM	8,265	9,705	9,685	10,535	38,190
Total	8,265	9,705	9,685	10,535	38,190
% Change from Previous Quarter	-5.0	17.4	-0.2	8.8	-
Average Selling Price ($)	1.02	1.02	0.96	0.91	0.97
Revenue ($M)	8,430	9,899	9,298	9,587	37,214

Table 2-23 (Continued)
Each Company's Quarterly Shipments of 8K EEPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Market Share (% of Units)					-
Americas Companies	66.6	63.7	58.1	58.7	61.5
European Companies	33.4	36.3	41.9	41.3	38.5
Japanese Companies	-	-	-	-	-
Asia/Pacific Companies	-	-	-	-	-
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-24
Each Company's Quarterly Shipments of 16K EEPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Atmel					
2Kx8					
Parallel EEPROM	1,140	1,200	1,310	1,320	4,970
Serial EEPROM	4,345	5,100	4,010	4,350	17,805
Total	5,485	6,300	5,320	5,670	22,775
Vendor Total					
Parallel EEPROM	1,140	1,200	1,310	1,320	4,970
Serial EEPROM	4,345	5,100	4,010	4,350	17,805
Total	5,485	6,300	5,320	5,670	22,775
Catalyst					
2Kx8					
Parallel EEPROM	80	85	85	90	340
Total	80	85	85	90	340
1Kx16					
Parallel EEPROM	240	250	260	270	1,020
Total	240	250	260	270	1,020
Vendor Total					
Parallel EEPROM	320	335	345	360	1,360
Total	320	335	345	360	1,360
Fujitsu					
2Kx8					
Parallel EEPROM	115	75	90	70	350
Total	115	75	90	70	350
Vendor Total					
Parallel EEPROM	115	75	90	70	350
Total	115	75	90	70	350
Microchip					
2Kx8					
Parallel EEPROM	260	370	355	540	1,525
Serial EEPROM	4,010	3,085	3,940	4,540	15,575
Total	4,270	3,455	4,295	5,080	17,100
Vendor Total					
Parallel EEPROM	260	370	355	540	1,525
Serial EEPROM	4,010	3,085	3,940	4,540	15,575
Total	4,270	3,455	4,295	5,080	17,100
National Semiconductor					
2Kx8					
Serial EEPROM	925	1,545	1,175	1,585	5,230
Total	925	1,545	1,175	1,585	5,230

Table 2-24 (Continued)
Each Company's Quarterly Shipments of 16K EEPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
1Kx16					
Serial EEPROM	360	660	390	615	2,025
Total	360	660	390	615	2,025
Vendor Total					
Serial EEPROM	1,285	2,205	1,565	2,200	7,255
Total	1,285	2,205	1,565	2,200	7,255
Oki					
2Kx8					
Parallel EEPROM	30	31	32	34	127
Total	30	31	32	34	127
Vendor Total					
Parallel EEPROM	30	31	32	34	127
Total	30	31	32	34	127
Ramtron International					
2Kx8					
Parallel FRAM	40	70	33	62	205
Total	40	70	33	62	205
Vendor Total					
Parallel FRAM	40	70	33	62	205
Total	40	70	33	62	205
Rohm					
2Kx8					
Parallel EEPROM	700	850	900	1,050	3,500
Total	700	850	900	1,050	3,500
Vendor Total					
Parallel EEPROM	700	850	900	1,050	3,500
Total	700	850	900	1,050	3,500
SGS-Thomson					
2Kx8					
Serial EEPROM	1,660	3,470	3,790	5,445	14,365
Total	1,660	3,470	3,790	5,445	14,365
1Kx16					
Serial EEPROM	50	185	285	605	1,125
Total	50	185	285	605	1,125
Vendor Total					
Serial EEPROM	1,710	3,655	4,075	6,050	15,490
Total	1,710	3,655	4,075	6,050	15,490

Table 2-24 (Continued)
Each Company's Quarterly Shipments of 16K EEPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Xicor					
2Kx8					
Parallel EEPROM	740	775	805	840	3,160
Serial EEPROM	3,065	3,350	3,640	3,930	13,985
Total	3,805	4,125	4,445	4,770	17,145
Vendor Total					
Parallel EEPROM	740	775	805	840	3,160
Serial EEPROM	3,065	3,350	3,640	3,930	13,985
Total	3,805	4,125	4,445	4,770	17,145
Market Total					
2Kx8					
Parallel EEPROM	3,065	3,386	3,577	3,944	13,972
Parallel FRAM	40	70	33	62	205
Serial EEPROM	14,005	16,550	16,555	19,850	66,960
Total	17,110	20,006	20,165	23,856	81,137
1Kx16					
Parallel EEPROM	240	250	260	270	1,020
Serial EEPROM	410	845	675	1,220	3,150
Total	650	1,095	935	1,490	4,170
All 16K					
Parallel EEPROM	3,305	3,636	3,837	4,214	14,992
Parallel FRAM	40	70	33	62	205
Serial EEPROM	14,415	17,395	17,230	21,070	70,110
Total	17,760	21,101	21,100	25,346	85,307
% Change from Previous Quarter	-6.7	18.8	-	20.1	-
Average Selling Price ($)	1.34	1.32	1.04	0.94	1.14
Revenue ($M)	23,732	27,872	21,984	23,744	97,332
Market Share (% of Units)					
Americas Companies	85.6	78.1	75.8	71.6	77.2
European Companies	9.6	17.3	19.3	23.9	18.2
Japanese Companies	4.8	4.5	4.8	4.6	4.7
Asia/Pacific Companies	-	-	-	-	-
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-25
Each Company's Quarterly Shipments of 32K EEPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Atmel					
4Kx8					
Serial EEPROM	740	1,185	1,520	2,230	5,675
Total	740	1,185	1,520	2,230	5,675
Vendor Total					
Serial EEPROM	740	1,185	1,520	2,230	5,675
Total	740	1,185	1,520	2,230	5,675
Microchip					
4Kx8					
Serial EEPROM	820	1,085	1,125	1,015	4,045
Total	820	1,085	1,125	1,015	4,045
Vendor Total					
Serial EEPROM	820	1,085	1,125	1,015	4,045
Total	820	1,085	1,125	1,015	4,045
SGS-Thomson					
4Kx8					
Serial EEPROM	400	920	1,490	1,550	4,360
Total	400	920	1,490	1,550	4,360
Vendor Total					
Serial EEPROM	400	920	1,490	1,550	4,360
Total	400	920	1,490	1,550	4,360
Market Total					
4Kx8					
Serial EEPROM	1,960	3,190	4,135	4,795	14,080
Total	1,960	3,190	4,135	4,795	14,080
All 32K					
Serial EEPROM	1,960	3,190	4,135	4,795	14,080
Total	1,960	3,190	4,135	4,795	14,080
% Change from Previous Quarter	32.9	62.8	29.6	16.0	-
Average Selling Price ($)	1.91	1.81	1.71	1.63	1.73
Revenue ($M)	3,744	5,774	7,071	7,816	24,404
Market Share (% of Units)					
Americas Companies	79.6	71.2	64.0	67.7	69.0
European Companies	20.4	28.8	36.0	32.3	31.0
Japanese Companies	-	-	-	-	-
Asia/Pacific Companies	-	-	-	-	-
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-26
Each Company's Quarterly Shipments of 64K EEPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Atmel					
8Kx8					
Parallel EEPROM	7,100	7,200	7,415	7,500	29,215
Serial EEPROM	1,325	2,520	2,965	2,830	9,640
Total	8,425	9,720	10,380	10,330	38,855
Vendor Total					
Parallel EEPROM	7,100	7,200	7,415	7,500	29,215
Serial EEPROM	1,325	2,520	2,965	2,830	9,640
Total	8,425	9,720	10,380	10,330	38,855
Catalyst					
8Kx8					
Parallel EEPROM	920	990	1,060	1,125	4,095
Total	920	990	1,060	1,125	4,095
4Kx16					
Parallel EEPROM	455	485	520	555	2,015
Total	455	485	520	555	2,015
Vendor Total					
Parallel EEPROM	1,375	1,475	1,580	1,680	6,110
Total	1,375	1,475	1,580	1,680	6,110
Fujitsu					
8Kx8					
Parallel EEPROM	13	7	7	20	47
Total	13	7	7	20	47
Vendor Total					
Parallel EEPROM	13	7	7	20	47
Total	13	7	7	20	47
Microchip					
8Kx8					
Parallel EEPROM	530	540	525	740	2,335
Serial EEPROM	1,320	1,595	2,960	3,475	9,350
Total	1,850	2,135	3,485	4,215	11,685
Vendor Total					
Parallel EEPROM	530	540	525	740	2,335
Serial EEPROM	1,320	1,595	2,960	3,475	9,350
Total	1,850	2,135	3,485	4,215	11,685
NEC					
8Kx8					
Parallel EEPROM	1,100	1,150	1,200	1,050	4,500
Total	1,100	1,150	1,200	1,050	4,500

Table 2-26 (Continued)
Each Company's Quarterly Shipments of 64K EEPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Vendor Total					
Parallel EEPROM	1,100	1,150	1,200	1,050	4,500
Total	1,100	1,150	1,200	1,050	4,500
Oki					
8Kx8					
Parallel EEPROM	32	35	37	39	143
Total	32	35	37	39	143
Vendor Total					
Parallel EEPROM	32	35	37	39	143
Total	32	35	37	39	143
Ramtron International					
8Kx8					
Parallel FRAM	-	1	3	3	7
Total	-	1	3	3	7
Vendor Total					
Parallel FRAM	-	1	3	3	7
Total	-	1	3	3	7
Rohm					
8Kx8					
Parallel EEPROM	200	230	265	300	995
Total	200	230	265	300	995
Vendor Total					
Parallel EEPROM	200	230	265	300	995
Total	200	230	265	300	995
SGS-Thomson					
8Kx8					
Parallel EEPROM	560	420	710	1,620	3,310
Serial EEPROM	2	90	400	975	1,467
Total	562	510	1,110	2,595	4,777
Vendor Total					
Parallel EEPROM	560	420	710	1,620	3,310
Serial EEPROM	2	90	400	975	1,467
Total	562	510	1,110	2,595	4,777
Xicor					
8Kx8					
Parallel EEPROM	1,440	1,545	1,655	1,760	6,400
Total	1,440	1,545	1,655	1,760	6,400
Vendor Total					
Parallel EEPROM	1,440	1,545	1,655	1,760	6,400
Total	1,440	1,545	1,655	1,760	6,400

Table 2-26 (Continued)
Each Company's Quarterly Shipments of 64K EEPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Market Total					
8Kx8					
Parallel EEPROM	11,895	12,117	12,874	14,154	51,040
Parallel FRAM	-	1	3	3	7
Serial EEPROM	2,647	4,205	6,325	7,280	20,457
Total	14,542	16,323	19,202	21,437	71,504
4Kx16					
Parallel EEPROM	455	485	520	555	2,015
Total	455	485	520	555	2,015
All 64K					
Parallel EEPROM	12,350	12,602	13,394	14,709	53,055
Parallel FRAM	-	1	3	3	7
Serial EEPROM	2,647	4,205	6,325	7,280	20,457
Total	14,997	16,808	19,722	21,992	73,519
% Change from Previous Quarter	-0.9	12.1	17.3	11.5	-
Average Selling Price ($)	2.16	1.97	1.80	1.63	1.86
Revenue ($M)	32,394	33,112	35,500	35,847	136,852
Market Share (% of Units)					
Americas Companies	87.3	88.5	86.7	81.8	85.8
European Companies	3.7	3.0	5.6	11.8	6.5
Japanese Companies	9.0	8.5	7.7	6.4	7.7
Asia/Pacific Companies	-	-	-	-	-
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-27
Each Company's Quarterly Shipments of 256K EEPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Atmel					
32Kx8					
Parallel EEPROM	1,065	1,450	1,580	1,720	5,815
Total	1,065	1,450	1,580	1,720	5,815
Vendor Total					
Parallel EEPROM	1,065	1,450	1,580	1,720	5,815
Total	1,065	1,450	1,580	1,720	5,815
Catalyst					
32Kx8					
Parallel EEPROM	46	47	48	49	189
Total	46	47	48	49	189
Vendor Total					
Parallel EEPROM	46	47	48	49	189
Total	46	47	48	49	189
NEC					
32Kx8					
Parallel EEPROM	100	100	110	100	410
Total	100	100	110	100	410
Vendor Total					
Parallel EEPROM	100	100	110	100	410
Total	100	100	110	100	410
Xicor					
32Kx8					
Parallel EEPROM	475	485	500	505	1,965
Total	475	485	500	505	1,965
Vendor Total					
Parallel EEPROM	475	485	500	505	1,965
Total	475	485	500	505	1,965
Market Total					
32Kx8					
Parallel EEPROM	1,686	2,082	2,238	2,374	8,379
Total	1,686	2,082	2,238	2,374	8,379
All 256K					
Parallel EEPROM	1,686	2,082	2,238	2,374	8,379
Total	1,686	2,082	2,238	2,374	8,379
% Change from Previous Quarter	26.1	23.5	7.5	6.1	-
Average Selling Price ($)	7.82	7.35	6.94	6.57	7.11
Revenue ($M)	13,182	15,300	15,529	15,594	59,606

Table 2-27 (Continued)
Each Company's Quarterly Shipments of 256K EEPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Market Share (% of Units)					
Americas Companies	94.1	95.2	95.1	95.8	95.1
European Companies	-	-	-	-	-
Japanese Companies	5.9	4.8	4.9	4.2	4.9
Asia/Pacific Companies	-	-	-	-	-
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-28
Each Company's Quarterly Shipments of 512K EEPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Xicor					
64Kx8					
Parallel EEPROM	30	30	30	30	120
Total	30	30	30	30	120
Vendor Total					
Parallel EEPROM	30	30	30	30	120
Total	30	30	30	30	120
Market Total					
64Kx8					
Parallel EEPROM	30	30	30	30	120
Total	30	30	30	30	120
All 512K					
Parallel EEPROM	30	30	30	30	120
Total	30	30	30	30	120
% Change from Previous Quarter	-	-	-	-	-
Average Selling Price ($)	23.47	22.05	20.78	19.66	21.49
Revenue ($M)	704	662	623	590	2,579
Market Share (% of Units)					
Americas Companies	100.0	100.0	100.0	100.0	100.0
European Companies	-	-	-	-	-
Japanese Companies	-	-	-	-	-
Asia/Pacific Companies	-	-	-	-	-
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-29
Each Company's Quarterly Shipments of 1Mb EEPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Atmel					
128Kx8					
Parallel EEPROM	105	115	125	145	490
Total	105	115	125	145	490
Vendor Total					
Parallel EEPROM	105	115	125	145	490
Total	105	115	125	145	490
Xicor					
128Kx8					
Parallel EEPROM	25	25	25	25	100
Total	25	25	25	25	100
Vendor Total					
Parallel EEPROM	25	25	25	25	100
Total	25	25	25	25	100
Market Total					
128Kx8					
Parallel EEPROM	130	175	150	170	625
Total	130	175	150	170	625
All 1Mb					
Parallel EEPROM	130	175	150	170	625
Total	130	175	150	170	625
% Change from Previous Quarter	113.1	175.0	-87.2	13.3	-
Average Selling Price ($)	47.78	43.79	40.13	36.77	44.31
Revenue ($M)	6,211	7,663	6,020	6,251	26,145
Market Share (% of Units)					
Americas Companies	100.0	100.0	100.0	100.0	100.0
European Companies	-	-	-	-	-
Japanese Companies	-	-	-	-	-
Asia/Pacific Companies	-	-	-	-	-
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-30
Each Company's Quarterly Shipments of 4Mb EEPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Atmel					
512Kx8					
Parallel EEPROM	-	3	3	2	8
Total	-	3	3	2	8
Vendor Total					
Parallel EEPROM	-	3	3	2	8
Total	-	3	3	2	8
Market Total					
512Kx8					
Parallel EEPROM	-	3	3	2	8
Total	-	3	3	2	8
All 4Mb					
Parallel EEPROM	-	3	3	2	8
Total	-	3	3	2	8
% Change from Previous Quarter	NA	1,150.0	4.0	-11.5	-
Average Selling Price ($)	72.74	68.65	65.06	61.89	65.48
Revenue ($M)	15	172	169	142	498
Market Share (% of Units)					
Americas Companies	100.0	100.0	100.0	100.0	100.0
European Companies	-	-	-	-	-
Japanese Companies	-	-	-	-	-
Asia/Pacific Companies	-	-	-	-	-
Total	100.0	100.0	100.0	100.0	100.0

NA = Not available
Source: Dataquest (June 1997)

Table 2-31
Each Company's Quarterly Shipments of EPROM by Density to the World, 1996
(Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Advanced Micro Devices					
All 64K	600	625	620	1,160	3,005
All 128K	435	750	650	470	2,305
All 256K	4,220	3,605	2,690	3,230	13,745
All 512K	1,876	2,456	1,622	1,773	7,727
All 1Mb	3,775	4,130	2,950	3,350	14,205
All 2Mb	1,390	2,165	1,620	1,540	6,715
All 4Mb	1,765	2,160	1,425	1,120	6,470
Vendor Total	14,061	15,891	11,577	12,643	54,172
Atmel					
All 256K	6,700	7,600	7,800	7,700	29,800
All 512K	4,300	6,000	7,700	9,400	27,400
All 1Mb	5,100	5,200	4,700	5,000	20,000
All 2Mb	1,900	2,000	2,100	2,100	8,100
All 4Mb	1,100	1,100	1,150	1,200	4,550
All 8Mb	55	105	145	215	520
Vendor Total	19,155	22,005	23,595	25,615	90,370
Cypress					
All 16K	410	400	290	295	1,395
All 64K	480	470	340	350	1,640
All 128K	185	180	130	135	630
All 256K	180	185	130	130	625
All 512K	710	700	415	510	2,335
All 1Mb	210	215	160	215	800
Vendor Total	2,175	2,150	1,465	1,635	7,425
Fujitsu					
All 32K	14	7	-	4	25
All 64K	155	140	165	120	580
All 128K	95	100	70	55	320
All 256K	390	380	360	180	1,310
All 512K	270	155	140	135	700
All 1Mb	30	40	30	60	160
All 2Mb	2	-	-	-	2
All 4Mb	26	-	1	-	27
Vendor Total	982	822	766	554	3,124

Table 2-31 (Continued)
Each Company's Quarterly Shipments of EPROM by Density to the World, 1996
(Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Hitachi					
All 128K	60	50	50	50	210
All 256K	700	500	500	500	2,200
All 512K	60	50	50	50	210
All 1Mb	800	700	700	700	2,900
All 4Mb	600	850	850	850	3,150
Vendor Total	2,220	2,150	2,150	2,150	8,670
ISSI					
All 256K	1	1	1	5	7
All 512K	3	2	208	146	358
All 1Mb	920	1,130	1,280	1,320	4,650
Vendor Total	923	1,132	1,489	1,471	5,015
Macronix					
All 256K	1,200	1,110	910	800	4,020
All 512K	1,500	1,750	2,475	3,425	9,150
All 1Mb	3,175	4,175	1,750	2,175	11,275
All 2Mb	-	-	4	20	24
All 4Mb	1,500	1,700	1,400	1,300	5,900
All 8Mb	-	1	3	15	19
Vendor Total	7,375	8,736	6,542	7,735	30,388
Microchip					
All 64K	210	360	260	260	1,090
All 128K	125	50	80	210	465
All 256K	2,260	2,160	930	1,300	6,650
All 512K	125	65	255	120	565
Vendor Total	2,720	2,635	1,525	1,890	8,770
Mitsubishi					
All 256K	480	200	310	310	1,300
All 512K	150	200	150	150	650
All 1Mb	200	200	200	200	800
All 2Mb	450	300	200	200	1,150
All 4Mb	40	100	60	60	260
Vendor Total	1,320	1,000	920	920	4,160
National Semiconductor					
All 16K	50	40	40	100	230
All 32K	100	130	205	225	660
All 64K	690	1,500	240	560	2,990
All 128K	360	440	220	220	1,240
All 256K	2,220	2,900	1,480	2,700	9,300

Table 2-31 (Continued)
Each Company's Quarterly Shipments of EPROM by Density to the World, 1996
(Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
All 512K	2,650	2,100	770	2,840	8,360
All 1Mb	450	170	300	285	1,205
All 2Mb	70	20	20	25	135
All 4Mb	130	150	100	130	510
Vendor Total	6,720	7,450	3,375	7,085	24,630
NEC					
All 512K	75	145	215	290	725
All 1Mb	300	250	200	145	895
All 2Mb	300	300	450	450	1,500
All 4Mb	960	950	920	900	3,730
Vendor Total	1,635	1,645	1,785	1,785	6,850
Oki					
All 128K	2	2	1	1	5
All 1Mb	71	72	53	72	267
All 4Mb	208	241	186	186	822
Vendor Total	281	314	240	260	1,094
SGS-Thomson					
All 16K	115	95	150	75	435
All 32K	120	200	220	135	675
All 64K	2,050	2,130	1,910	1,560	7,650
All 128K	210	210	165	180	765
All 256K	9,590	9,180	5,910	8,650	33,330
All 512K	10,100	9,540	5,550	8,010	33,200
All 1Mb	5,840	6,180	4,875	5,720	22,615
All 2Mb	2,450	2,470	2,000	2,200	9,120
All 4Mb	3,800	4,100	3,730	3,730	15,360
All 8Mb	270	520	530	405	1,725
All 16Mb	3	18	32	67	120
Vendor Total	34,548	34,643	25,072	30,732	124,995
Sharp					
All 64K	215	210	150	155	730
All 128K	85	85	59	60	289
All 256K	160	155	115	115	545
All 512K	115	110	70	80	375
All 1Mb	60	60	45	60	225
Vendor Total	635	620	439	470	2,164

Table 2-31 (Continued)
Each Company's Quarterly Shipments of EPROM by Density to the World, 1996
(Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Texas Instruments					
All 32K	105	105	75	75	360
All 64K	350	345	245	250	1,190
All 128K	365	320	290	285	1,260
All 256K	3,100	2,850	2,550	2,400	10,900
All 512K	6,880	6,800	4,040	4,930	22,650
All 1Mb	4,250	4,950	2,700	3,100	15,000
All 2Mb	2,400	2,600	2,800	2,800	10,600
All 4Mb	925	1,875	2,500	3,250	8,550
Vendor Total	18,375	19,845	15,200	17,090	70,510
Toshiba					
All 1Mb	295	295	220	295	1,105
All 4Mb	680	800	620	615	2,715
Vendor Total	975	1,095	840	910	3,820
WaferScale Integration					
All 16K	135	135	95	100	465
All 64K	160	160	115	115	550
All 128K	215	210	150	155	730
All 256K	240	235	170	175	820
All 512K	105	100	60	75	340
All 1Mb	232	237	175	237	881
Vendor Total	1,087	1,077	765	857	3,786
Market Total					
All 16K	710	670	575	570	2,525
All 32K	339	442	500	439	1,720
All 64K	4,910	5,940	4,045	4,530	19,425
All 128K	2,137	2,397	1,865	1,821	8,219
All 256K	31,441	31,061	23,856	28,195	114,552
All 512K	28,919	30,173	23,720	31,934	114,745
All 1Mb	25,708	28,004	20,338	22,934	96,983
All 2Mb	8,962	9,855	9,194	9,335	37,346
All 4Mb	11,734	14,026	12,942	13,341	52,044
All 8Mb	325	626	678	635	2,264
All 16Mb	3	18	32	67	120
Total	115,187	123,210	97,745	113,802	449,943
Percentage Change from Previous Quarter	-4.8	7.0	-20.7	16.4	-
Average Selling Price ($)	3.02	3.05	3.21	2.72	2.99
Revenue ($M)	347,312	375,637	314,009	309,844	1,346,803

Table 2-31 (Continued)
Each Company's Quarterly Shipments of EPROM by Density to the World, 1996
(Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Market Share (% of Units)					
Americas Companies	56.6	58.6	60.4	60.0	58.8
European Companies	30.0	28.1	25.7	27.0	27.8
Japanese Companies	7.0	6.2	7.3	6.2	6.6
Asia/Pacific Companies	6.4	7.1	6.7	6.8	6.8
Total	100.0	100.0	100.0	100.0	100.00

Source: Dataquest (June 1997)

Table 2-32
Each Company's Quarterly Shipments of 16K EPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Cypress					
2Kx8					
UV EPROM	410	400	290	295	1,395
Total	410	400	290	295	1,395
Vendor Total					
UV EPROM	410	400	290	295	1,395
Total	410	400	290	295	1,395
National Semiconductor					
2Kx8					
UV EPROM	50	40	40	100	230
Total	50	40	40	100	230
Vendor Total					
UV EPROM	50	40	40	100	230
Total	50	40	40	100	230
SGS-Thomson					
2Kx8					
UV EPROM	115	95	150	75	435
Total	115	95	150	75	435
Vendor Total					
UV EPROM	115	95	150	75	435
Total	115	95	150	75	435
WaferScale Integration					
2Kx8					
UV EPROM	135	135	95	100	465
Total	135	135	95	100	465
Vendor Total					
UV EPROM	135	135	95	100	465
Total	135	135	95	100	465
Market Total					
2Kx8					
UV EPROM	710	670	575	570	2,525
Total	710	670	575	570	2,525
All 16K					
UV EPROM	710	670	575	570	2,525
Total	710	670	575	570	2,525
% Change from Previous Quarter	-2.8	-5.6	-14.2	-0.9	-
Average Selling Price ($)	0.58	0.58	0.59	0.57	0.58
Revenue ($M)	412	389	339	325	1,465

Table 2-32 (Continued)
Each Company's Quarterly Shipments of 16K EPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Market Share (% of Units)					
Americas Companies	83.8	85.8	73.9	86.8	82.8
European Companies	16.2	14.2	26.1	13.2	17.2
Japanese Companies	-	-	-	-	-
Asia/Pacific Companies	-	-	-	-	-
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-33
Each Company's Quarterly Shipments of 32K EPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Fujitsu					
4Kx8					
UV EPROM	14	7	-	4	25
Total	14	7	-	4	25
Vendor Total					
UV EPROM	14	7	-	4	25
Total	14	7	-	4	25
National Semiconductor					
4Kx8					
OTP EPROM	-	-	-	5	5
UV EPROM	100	130	205	220	655
Total	100	130	205	225	660
Vendor Total					
OTP EPROM	-	-	-	5	5
UV EPROM	100	130	205	220	655
Total	100	130	205	225	660
SGS-Thomson					
4Kx8					
UV EPROM	120	200	220	135	675
Total	120	200	220	135	675
Vendor Total					
UV EPROM	120	200	220	135	675
Total	120	200	220	135	675
Texas Instruments					
4Kx8					
UV EPROM	105	105	75	75	360
Total	105	105	75	75	360
Vendor Total					
UV EPROM	105	105	75	75	360
Total	105	105	75	75	360
Market Total					
4Kx8					
OTP EPROM	-	-	-	5	5
UV EPROM	339	442	500	434	1,715
Total	339	442	500	439	1,720
All 32K					
OTP EPROM	-	-	-	5	5
UV EPROM	339	442	500	434	1,715
Total	339	442	500	439	1,720

Table 2-33 (Continued)
Each Company's Quarterly Shipments of 32K EPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
% Change from Previous Quarter	-21.9	30.4	13.1	-12.2	-
Average Selling Price ($)	0.67	0.67	0.68	0.65	0.67
Revenue ($M)	227	296	340	285	1,149
Market Share (% of Units)					
Americas Companies	60.5	53.2	56.0	68.3	59.3
European Companies	35.4	45.2	44.0	30.8	39.2
Japanese Companies	4.1	1.6	-	0.9	1.5
Asia/Pacific Companies	-	-	-	-	-
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-34
Each Company's Quarterly Shipments of 64K EPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Advanced Micro Devices					
8Kx8					
OTP EPROM	120	132	136	270	658
UV EPROM	480	493	484	890	2,347
Total	600	625	620	1,160	3,005
Vendor Total					
OTP EPROM	120	132	136	270	658
UV EPROM	480	493	484	890	2,347
Total	600	625	620	1,160	3,005
Cypress					
8Kx8					
UV EPROM	480	470	340	350	1,640
Total	480	470	340	350	1,640
Vendor Total					
UV EPROM	480	470	340	350	1,640
Total	480	470	340	350	1,640
Fujitsu					
8Kx8					
UV EPROM	155	140	165	120	580
Total	155	140	165	120	580
Vendor Total					
UV EPROM	155	140	165	120	580
Total	155	140	165	120	580
Microchip					
8Kx8					
OTP EPROM	210	360	260	260	1,090
Total	210	360	260	260	1,090
Vendor Total					
OTP EPROM	210	360	260	260	1,090
Total	210	360	260	260	1,090
National Semiconductor					
8Kx8					
OTP EPROM	110	60	-	-	170
UV EPROM	580	1,440	240	560	2,820
Total	690	1,500	240	560	2,990
Vendor Total					
OTP EPROM	110	60	-	-	170
UV EPROM	580	1,440	240	560	2,820
Total	690	1,500	240	560	2,990

Table 2-34 (Continued)
Each Company's Quarterly Shipments of 64K EPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
SGS-Thomson					
8Kx8					
OTP EPROM	440	490	540	440	1,910
UV EPROM	1,610	1,640	1,370	1,120	5,740
Total	2,050	2,130	1,910	1,560	7,650
Vendor Total					
OTP EPROM	440	490	540	440	1,910
UV EPROM	1,610	1,640	1,370	1,120	5,740
Total	2,050	2,130	1,910	1,560	7,650
Sharp					
8Kx8					
OTP EPROM	120	115	85	85	405
UV EPROM	95	95	65	70	325
Total	215	210	150	155	730
Vendor Total					
OTP EPROM	120	115	85	85	405
UV EPROM	95	95	65	70	325
Total	215	210	150	155	730
Texas Instruments					
8Kx8					
OTP EPROM	100	100	70	70	340
UV EPROM	250	245	175	180	850
Total	350	345	245	250	1,190
Vendor Total					
OTP EPROM	100	100	70	70	340
UV EPROM	250	245	175	180	850
Total	350	345	245	250	1,190
WaferScale Integration					
8Kx8					
UV EPROM	160	160	115	115	550
Total	160	160	115	115	550
Vendor Total					
UV EPROM	160	160	115	115	550
Total	160	160	115	115	550
Market Total					
8Kx8					
OTP EPROM	1,100	1,257	1,091	1,125	4,573
UV EPROM	3,810	4,683	2,954	3,405	14,852
Total	4,910	5,940	4,045	4,530	19,425

Table 2-34 (Continued)
Each Company's Quarterly Shipments of 64K EPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
All 64K					
OTP EPROM	1,100	1,257	1,091	1,125	4,573
UV EPROM	3,810	4,683	2,954	3,405	14,852
Total	4,910	5,940	4,045	4,530	19,425
% Change from Previous Quarter	-9.1	21.0	-31.9	12.0	-
Average Selling Price ($)	1.02	1.02	1.06	0.98	1.02
Revenue ($M)	5,008	6,059	4,288	4,439	19,794
Market Share (% of Units)					
Americas Companies	50.7	58.2	45.0	59.5	53.9
European Companies	41.8	35.9	47.2	34.4	39.4
Japanese Companies	7.5	5.9	7.8	6.1	6.7
Asia/Pacific Companies	-	-	-	-	-
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-35
Each Company's Quarterly Shipments of 128K EPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Advanced Micro Devices					
16Kx8					
OTP EPROM	35	60	50	40	185
UV EPROM	400	690	600	430	2,120
Total	435	750	650	470	2,305
Vendor Total					
OTP EPROM	35	60	50	40	185
UV EPROM	400	690	600	430	2,120
Total	435	750	650	470	2,305
Cypress					
16Kx8					
UV EPROM	185	180	130	135	630
Total	185	180	130	135	630
Vendor Total					
UV EPROM	185	180	130	135	630
Total	185	180	130	135	630
Fujitsu					
16Kx8					
UV EPROM	95	100	70	55	320
Total	95	100	70	55	320
Vendor Total					
UV EPROM	95	100	70	55	320
Total	95	100	70	55	320
Hitachi					
16Kx8					
UV EPROM	60	50	50	50	210
Total	60	50	50	50	210
Vendor Total					
UV EPROM	60	50	50	50	210
Total	60	50	50	50	210
Microchip					
16Kx8					
OTP EPROM	125	50	80	210	465
Total	125	50	80	210	465
Vendor Total					
OTP EPROM	125	50	80	210	465
Total	125	50	80	210	465

Table 2-35 (Continued)
Each Company's Quarterly Shipments of 128K EPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
National Semiconductor					
16Kx8					
OTP EPROM	-	50	50	-	100
UV EPROM	360	390	170	220	1,140
Total	360	440	220	220	1,240
Vendor Total					
OTP EPROM	-	50	50	-	100
UV EPROM	360	390	170	220	1,140
Total	360	440	220	220	1,240
Oki					
16Kx8					
OTP EPROM	2	2	1	1	5
Total	2	2	1	1	5
Vendor Total					
OTP EPROM	2	2	1	1	5
Total	2	2	1	1	5
SGS-Thomson					
16Kx8					
UV EPROM	210	210	165	180	765
Total	210	210	165	180	765
Vendor Total					
UV EPROM	210	210	165	180	765
Total	210	210	165	180	765
Sharp					
16Kx8					
OTP EPROM	20	20	14	15	69
UV EPROM	65	65	45	45	220
Total	85	85	59	60	289
Vendor Total					
OTP EPROM	20	20	14	15	69
UV EPROM	65	65	45	45	220
Total	85	85	59	60	289
Texas Instruments					
16Kx8					
UV EPROM	365	320	290	285	1,260
Total	365	320	290	285	1,260
Vendor Total					
UV EPROM	365	320	290	285	1,260
Total	365	320	290	285	1,260

Table 2-35 (Continued)
Each Company's Quarterly Shipments of 128K EPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
WaferScale Integration					
16Kx8					
UV EPROM	215	210	150	155	730
Total	215	210	150	155	730
Vendor Total					
UV EPROM	215	210	150	155	730
Total	215	210	150	155	730
Market Total					
16Kx8					
OTP EPROM	182	182	195	266	824
UV EPROM	1,955	2,215	1,670	1,555	7,395
Total	2,137	2,397	1,865	1,821	8,219
All 128K					
OTP EPROM	182	182	195	266	824
UV EPROM	1,955	2,215	1,670	1,555	7,395
Total	2,137	2,397	1,865	1,821	8,219
% Change from Previous Quarter	-36.9	12.2	-22.2	-2.4	-
Average Selling Price ($)	1.29	1.29	1.36	1.21	1.29
Revenue ($M)	2,756	3,092	2,537	2,204	10,588
Market Share (% of Units)					
Americas Companies	78.9	81.4	81.5	81.0	80.7
European Companies	9.8	8.8	8.8	9.9	9.3
Japanese Companies	11.3	9.9	9.7	9.1	10.0
Asia/Pacific Companies	-	-	-	-	-
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-36
Each Company's Quarterly Shipments of 256K EPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Advanced Micro Devices					
32Kx8					
OTP EPROM	1,645	1,440	1,100	1,357	5,542
UV EPROM	2,575	2,165	1,590	1,873	8,203
Total	4,220	3,605	2,690	3,230	13,745
Vendor Total					
OTP EPROM	1,645	1,440	1,100	1,357	5,542
UV EPROM	2,575	2,165	1,590	1,873	8,203
Total	4,220	3,605	2,690	3,230	13,745
Atmel					
32Kx8					
OTP EPROM	6,700	7,600	7,800	7,700	29,800
Total	6,700	7,600	7,800	7,700	29,800
Vendor Total					
OTP EPROM	6,700	7,600	7,800	7,700	29,800
Total	6,700	7,600	7,800	7,700	29,800
Cypress					
32Kx8					
UV EPROM	180	185	130	130	625
Total	180	185	130	130	625
Vendor Total					
UV EPROM	180	185	130	130	625
Total	180	185	130	130	625
Fujitsu					
32Kx8					
UV EPROM	390	380	360	180	1,310
Total	390	380	360	180	1,310
Vendor Total					
UV EPROM	390	380	360	180	1,310
Total	390	380	360	180	1,310
Hitachi					
32Kx8					
OTP EPROM	200	150	150	150	650
UV EPROM	500	350	350	350	1,550
Total	700	500	500	500	2,200
Vendor Total					
OTP EPROM	200	150	150	150	650
UV EPROM	500	350	350	350	1,550
Total	700	500	500	500	2,200

Table 2-36 (Continued)
Each Company's Quarterly Shipments of 256K EPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
ISSI					
32Kx8					
OTP EPROM	1	1	1	5	7
Total	1	1	1	5	7
Vendor Total					
OTP EPROM	1	1	1	5	7
Total	1	1	1	5	7
Macronix					
32Kx8					
OTP EPROM	300	280	230	200	1,010
UV EPROM	900	830	680	600	3,010
Total	1,200	1,110	910	800	4,020
Vendor Total					
OTP EPROM	300	280	230	200	1,010
UV EPROM	900	830	680	600	3,010
Total	1,200	1,110	910	800	4,020
Microchip					
32Kx8					
OTP EPROM	2,260	2,160	930	1,300	6,650
Total	2,260	2,160	930	1,300	6,650
Vendor Total					
OTP EPROM	2,260	2,160	930	1,300	6,650
Total	2,260	2,160	930	1,300	6,650
Mitsubishi					
32Kx8					
OTP EPROM	300	80	250	250	880
UV EPROM	180	120	60	60	420
Total	480	200	310	310	1,300
Vendor Total					
OTP EPROM	300	80	250	250	880
UV EPROM	180	120	60	60	420
Total	480	200	310	310	1,300
National Semiconductor					
32Kx8					
OTP EPROM	1,040	1,910	630	1,000	4,580
UV EPROM	1,180	990	850	1,700	4,720
Total	2,220	2,900	1,480	2,700	9,300

Table 2-36 (Continued)
Each Company's Quarterly Shipments of 256K EPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Vendor Total					
OTP EPROM	1,040	1,910	630	1,000	4,580
UV EPROM	1,180	990	850	1,700	4,720
Total	2,220	2,900	1,480	2,700	9,300
SGS-Thomson					
32Kx8					
OTP EPROM	1,450	1,700	1,160	1,750	6,060
UV EPROM	8,140	7,480	4,750	6,900	27,270
Total	9,590	9,180	5,910	8,650	33,330
Vendor Total					
OTP EPROM	1,450	1,700	1,160	1,750	6,060
UV EPROM	8,140	7,480	4,750	6,900	27,270
Total	9,590	9,180	5,910	8,650	33,330
Sharp					
32Kx8					
OTP EPROM	90	85	65	65	305
UV EPROM	70	70	50	50	240
Total	160	155	115	115	545
Vendor Total					
OTP EPROM	90	85	65	65	305
UV EPROM	70	70	50	50	240
Total	160	155	115	115	545
Texas Instruments					
32Kx8					
OTP EPROM	850	750	650	550	2,800
UV EPROM	2,250	2,100	1,900	1,850	8,100
Total	3,100	2,850	2,550	2,400	10,900
Vendor Total					
OTP EPROM	850	750	650	550	2,800
UV EPROM	2,250	2,100	1,900	1,850	8,100
Total	3,100	2,850	2,550	2,400	10,900
WaferScale Integration					
32Kx8					
UV EPROM	240	235	170	175	820
Total	240	235	170	175	820
Vendor Total					
UV EPROM	240	235	170	175	820
Total	240	235	170	175	820

Table 2-36 (Continued)
Each Company's Quarterly Shipments of 256K EPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Market Total					
32Kx8					
OTP EPROM	14,836	16,156	12,966	14,327	58,284
UV EPROM	16,605	14,905	10,890	13,868	56,268
Total	31,441	31,061	23,856	28,195	114,552
All 256K					
OTP EPROM	14,836	16,156	12,966	14,327	58,284
UV EPROM	16,605	14,905	10,890	13,868	56,268
Total	31,441	31,061	23,856	28,195	114,552
% Change from Previous Quarter	-7.2	-1.2	-23.2	18.2	-
Average Selling Price ($)	1.83	1.82	1.96	1.67	1.82
Revenue ($M)	57,600	56,529	46,855	47,169	208,154
Market Share (% of Units)					
Americas Companies	60.2	62.9	66.0	62.6	62.7
European Companies	30.5	29.6	24.8	30.7	29.1
Japanese Companies	5.5	4.0	5.4	3.9	4.7
Asia/Pacific Companies	3.8	3.6	3.8	2.8	3.5
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-37
Each Company's Quarterly Shipments of 512K EPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Advanced Micro Devices					
64Kx8					
OTP EPROM	619	835	568	656	2,678
UV EPROM	1,257	1,621	1,054	1,117	5,049
Total	1,876	2,456	1,622	1,773	7,727
Vendor Total					
OTP EPROM	619	835	568	656	2,678
UV EPROM	1,257	1,621	1,054	1,117	5,049
Total	1,876	2,456	1,622	1,773	7,727
Atmel					
64Kx8					
OTP EPROM	4,300	6,000	7,700	9,400	27,400
Total	4,300	6,000	7,700	9,400	27,400
Vendor Total					
OTP EPROM	4,300	6,000	7,700	9,400	27,400
Total	4,300	6,000	7,700	9,400	27,400
Cypress					
64Kx8					
UV EPROM	710	700	415	510	2,335
Total	710	700	415	510	2,335
Vendor Total					
UV EPROM	710	700	415	510	2,335
Total	710	700	415	510	2,335
Fujitsu					
64Kx8					
UV EPROM	270	155	140	135	700
Total	270	155	140	135	700
Vendor Total					
UV EPROM	270	155	140	135	700
Total	270	155	140	135	700
Hitachi					
64Kx8					
UV EPROM	60	50	50	50	210
Total	60	50	50	50	210
Vendor Total					
UV EPROM	60	50	50	50	210
Total	60	50	50	50	210

Table 2-37 (Continued)
Each Company's Quarterly Shipments of 512K EPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
ISSI					
64Kx8					
OTP EPROM	3	2	208	146	358
Total	3	2	208	146	358
Vendor Total					
OTP EPROM	3	2	208	146	358
Total	3	2	208	146	358
Macronix					
64Kx8					
OTP EPROM	300	350	500	675	1,825
UV EPROM	1,200	1,400	1,975	2,750	7,325
Total	1,500	1,750	2,475	3,425	9,150
Vendor Total					
OTP EPROM	300	350	500	675	1,825
UV EPROM	1,200	1,400	1,975	2,750	7,325
Total	1,500	1,750	2,475	3,425	9,150
Microchip					
64Kx8					
OTP EPROM	125	65	255	120	565
Total	125	65	255	120	565
Vendor Total					
OTP EPROM	125	65	255	120	565
Total	125	65	255	120	565
Mitsubishi					
64Kx8					
UV EPROM	150	200	150	150	650
Total	150	200	150	150	650
Vendor Total					
UV EPROM	150	200	150	150	650
Total	150	200	150	150	650
National Semiconductor					
64Kx8					
OTP EPROM	1,640	1,000	430	940	4,010
UV EPROM	1,010	1,100	340	1,900	4,350
Total	2,650	2,100	770	2,840	8,360
Vendor Total					
OTP EPROM	1,640	1,000	430	940	4,010
UV EPROM	1,010	1,100	340	1,900	4,350
Total	2,650	2,100	770	2,840	8,360

Table 2-37 (Continued)
Each Company's Quarterly Shipments of 512K EPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
NEC					
64Kx8					
UV EPROM	75	145	215	290	725
Total	75	145	215	290	725
Vendor Total					
UV EPROM	75	145	215	290	725
Total	75	145	215	290	725
SGS-Thomson					
64Kx8					
OTP EPROM	2,900	3,290	2,700	2,650	11,540
UV EPROM	7,200	6,250	2,850	5,360	21,660
Total	10,100	9,540	5,550	8,010	33,200
Vendor Total					
OTP EPROM	2,900	3,290	2,700	2,650	11,540
UV EPROM	7,200	6,250	2,850	5,360	21,660
Total	10,100	9,540	5,550	8,010	33,200
Sharp					
64Kx8					
OTP EPROM	30	30	20	20	100
UV EPROM	85	80	50	60	275
Total	115	110	70	80	375
Vendor Total					
OTP EPROM	30	30	20	20	100
UV EPROM	85	80	50	60	275
Total	115	110	70	80	375
Texas Instruments					
64Kx8					
OTP EPROM	2,830	2,800	1,665	2,030	9,325
UV EPROM	4,050	4,000	2,375	2,900	13,325
Total	6,880	6,800	4,040	4,930	22,650
Vendor Total					
OTP EPROM	2,830	2,800	1,665	2,030	9,325
UV EPROM	4,050	4,000	2,375	2,900	13,325
Total	6,880	6,800	4,040	4,930	22,650
WaferScale Integration					
64Kx8					
UV EPROM	105	100	60	75	340
Total	105	100	60	75	340

Table 2-37 (Continued)
Each Company's Quarterly Shipments of 512K EPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Vendor Total					
UV EPROM	105	100	60	75	340
Total	105	100	60	75	340
Market Total					
64Kx8					
OTP EPROM	12,747	14,372	14,046	16,637	57,801
UV EPROM	16,172	15,801	9,674	15,297	56,944
Total	28,919	30,173	23,720	31,934	114,745
All 512K					
OTP EPROM	12,747	14,372	14,046	16,637	57,801
UV EPROM	16,172	15,801	9,674	15,297	56,944
Total	28,919	30,173	23,720	31,934	114,745
% Change from Previous Quarter	-13.7	4.3	-21.4	34.6	-
Average Selling Price ($)	2.04	2.03	2.05	1.77	1.96
Revenue ($M)	58,988	61,278	48,673	56,515	225,454
Market Share (% of Units)					
Americas Companies	57.6	60.4	63.5	62.0	60.8
European Companies	34.9	31.6	23.4	25.1	28.9
Japanese Companies	2.3	2.2	2.6	2.2	2.3
Asia/Pacific Companies	5.2	5.8	10.4	10.7	8.0
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-38
Each Company's Quarterly Shipments of 1Mb EPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Advanced Micro Devices					
128Kx8					
UV EPROM	3,415	3,480	2,625	3,030	12,550
Total	3,415	3,480	2,625	3,030	12,550
64Kx16					
UV EPROM	360	650	325	320	1,655
Total	360	650	325	320	1,655
Vendor Total					
UV EPROM	3,775	4,130	2,950	3,350	14,205
Total	3,775	4,130	2,950	3,350	14,205
Atmel					
128Kx8					
OTP EPROM	4,580	4,450	4,130	4,400	17,560
Total	4,580	4,450	4,130	4,400	17,560
64Kx16					
OTP EPROM	520	750	570	600	2,440
Total	520	750	570	600	2,440
Vendor Total					
OTP EPROM	5,100	5,200	4,700	5,000	20,000
Total	5,100	5,200	4,700	5,000	20,000
Cypress					
128Kx8					
UV EPROM	210	215	160	215	800
Total	210	215	160	215	800
Vendor Total					
UV EPROM	210	215	160	215	800
Total	210	215	160	215	800
Fujitsu					
128Kx8					
UV EPROM	30	40	30	60	160
Total	30	40	30	60	160
Vendor Total					
UV EPROM	30	40	30	60	160
Total	30	40	30	60	160
Hitachi					
128Kx8					
UV EPROM	500	450	450	450	1,850
Total	500	450	450	450	1,850

Table 2-38 (Continued)
Each Company's Quarterly Shipments of 1Mb EPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
64Kx16					
UV EPROM	300	250	250	250	1,050
Total	300	250	250	250	1,050
Vendor Total					
UV EPROM	800	700	700	700	2,900
Total	800	700	700	700	2,900
ISSI					
128Kx8					
OTP EPROM	920	1,130	1,280	1,320	4,650
Total	920	1,130	1,280	1,320	4,650
Vendor Total					
OTP EPROM	920	1,130	1,280	1,320	4,650
Total	920	1,130	1,280	1,320	4,650
Macronix					
128Kx8					
OTP EPROM	300	400	175	225	1,100
UV EPROM	1,800	2,300	1,000	1,225	6,325
Total	2,100	2,700	1,175	1,450	7,425
64Kx16					
OTP EPROM	100	175	75	75	425
UV EPROM	975	1,300	500	650	3,425
Total	1,075	1,475	575	725	3,850
Vendor Total					
OTP EPROM	400	575	250	300	1,525
UV EPROM	2,775	3,600	1,500	1,875	9,750
Total	3,175	4,175	1,750	2,175	11,275
Mitsubishi					
128Kx8					
UV EPROM	80	80	80	80	320
Total	80	80	80	80	320
64Kx16					
OTP EPROM	85	85	85	85	340
UV EPROM	35	35	35	35	140
Total	120	120	120	120	480
Vendor Total					
OTP EPROM	85	85	85	85	340
UV EPROM	115	115	115	115	460
Total	200	200	200	200	800

Table 2-38 (Continued)
Each Company's Quarterly Shipments of 1Mb EPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
National Semiconductor					
128Kx8					
OTP EPROM	170	80	200	155	605
UV EPROM	280	90	100	130	600
Total	450	170	300	285	1,205
Vendor Total					
OTP EPROM	170	80	200	155	605
UV EPROM	280	90	100	130	600
Total	450	170	300	285	1,205
NEC					
128Kx8					
UV EPROM	260	90	75	50	475
Total	260	90	75	50	475
64Kx16					
UV EPROM	40	160	125	95	420
Total	40	160	125	95	420
Vendor Total					
UV EPROM	300	250	200	145	895
Total	300	250	200	145	895
Oki					
128Kx8					
OTP EPROM	71	72	53	72	267
Total	71	72	53	72	267
Vendor Total					
OTP EPROM	71	72	53	72	267
Total	71	72	53	72	267
SGS-Thomson					
128Kx8					
OTP EPROM	1,530	1,630	1,115	1,510	5,785
UV EPROM	3,500	3,460	3,150	3,020	13,130
Total	5,030	5,090	4,265	4,530	18,915
64Kx16					
OTP EPROM	260	760	255	580	1,855
UV EPROM	550	330	355	610	1,845
Total	810	1,090	610	1,190	3,700
Vendor Total					
OTP EPROM	1,790	2,390	1,370	2,090	7,640
UV EPROM	4,050	3,790	3,505	3,630	14,975
Total	5,840	6,180	4,875	5,720	22,615

Table 2-38 (Continued)
Each Company's Quarterly Shipments of 1Mb EPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Sharp					
128Kx8					
OTP EPROM	20	20	15	20	75
UV EPROM	40	40	30	40	150
Total	60	60	45	60	225
Vendor Total					
OTP EPROM	20	20	15	20	75
UV EPROM	40	40	30	40	150
Total	60	60	45	60	225
Texas Instruments					
128Kx8					
OTP EPROM	600	735	200	350	1,885
UV EPROM	1,750	1,905	1,350	1,250	6,255
Total	2,350	2,640	1,550	1,600	8,140
64Kx16					
OTP EPROM	750	995	450	600	2,795
UV EPROM	1,150	1,315	700	900	4,065
Total	1,900	2,310	1,150	1,500	6,860
Vendor Total					
OTP EPROM	1,350	1,730	650	950	4,680
UV EPROM	2,900	3,220	2,050	2,150	10,320
Total	4,250	4,950	2,700	3,100	15,000
Toshiba					
128Kx8					
OTP EPROM	70	70	55	70	265
UV EPROM	90	90	65	90	335
Total	160	160	120	160	600
64Kx16					
OTP EPROM	50	50	35	50	185
UV EPROM	85	85	65	85	320
Total	135	135	100	135	505
Vendor Total					
OTP EPROM	120	120	90	120	450
UV EPROM	175	175	130	175	655
Total	295	295	220	295	1,105

Table 2-38 (Continued)
Each Company's Quarterly Shipments of 1Mb EPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
WaferScale Integration					
128Kx8					
UV EPROM	225	230	170	230	855
Total	225	230	170	230	855
64Kx16					
UV EPROM	7	7	5	7	26
Total	7	7	5	7	26
Vendor Total					
UV EPROM	232	237	175	237	881
Total	232	237	175	237	881
Market Total					
128Kx8					
OTP EPROM	8,261	8,587	7,223	8,122	32,192
UV EPROM	12,180	12,470	9,285	9,870	43,805
Total	20,441	21,057	16,508	17,992	75,997
64Kx16					
OTP EPROM	1,765	2,815	1,470	1,990	8,040
UV EPROM	3,502	4,132	2,360	2,952	12,946
Total	5,267	6,947	3,830	4,942	20,986
All 1Mb					
OTP EPROM	10,026	11,402	8,693	10,112	40,232
UV EPROM	15,682	16,602	11,645	12,822	56,751
Total	25,708	28,004	20,338	22,934	96,983
% Change from Previous Quarter	11.2	8.9	-27.4	12.8	-
Average Selling Price ($)	2.79	2.58	2.58	2.37	2.59
Revenue ($M)	71,676	72,380	52,377	54,332	250,766
Market Share (% of Units)					
Americas Companies	58.1	57.2	60.3	58.9	58.5
European Companies	22.7	22.1	24.0	24.9	23.3
Japanese Companies	6.8	5.8	7.1	6.7	6.5
Asia/Pacific Companies	12.4	14.9	8.6	9.5	11.6
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-39
Each Company's Quarterly Shipments of 2Mb EPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Advanced Micro Devices					
256Kx8					
UV EPROM	1,080	1,165	790	1,120	4,155
Total	1,080	1,165	790	1,120	4,155
128Kx16					
UV EPROM	310	1,000	830	420	2,560
Total	310	1,000	830	420	2,560
Vendor Total					
UV EPROM	1,390	2,165	1,620	1,540	6,715
Total	1,390	2,165	1,620	1,540	6,715
Atmel					
256Kx8					
OTP EPROM	1,900	2,000	2,100	2,100	8,100
Total	1,900	2,000	2,100	2,100	8,100
Vendor Total					
OTP EPROM	1,900	2,000	2,100	2,100	8,100
Total	1,900	2,000	2,100	2,100	8,100
Fujitsu					
256Kx8					
UV EPROM	2	-	-	-	2
Total	2	-	-	-	2
Vendor Total					
UV EPROM	2	-	-	-	2
Total	2	-	-	-	2
Macronix					
256Kx8					
UV EPROM	-	-	4	20	24
Total	-	-	4	20	24
Vendor Total					
UV EPROM	-	-	4	20	24
Total	-	-	4	20	24
Mitsubishi					
256Kx8					
OTP EPROM	100	70	50	50	270
UV EPROM	100	50	40	40	230
Total	200	120	90	90	500
128Kx16					
OTP EPROM	100	70	50	50	270
UV EPROM	150	110	60	60	380
Total	250	180	110	110	650

Table 2-39 (Continued)
Each Company's Quarterly Shipments of 2Mb EPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Vendor Total					
OTP EPROM	200	140	100	100	540
UV EPROM	250	160	100	100	610
Total	450	300	200	200	1,150
National Semiconductor					
256Kx8					
OTP EPROM	30	10	-	-	40
UV EPROM	40	10	20	25	95
Total	70	20	20	25	135
Vendor Total					
OTP EPROM	30	10	-	-	40
UV EPROM	40	10	20	25	95
Total	70	20	20	25	135
NEC					
256Kx8					
UV EPROM	300	300	450	450	1,500
Total	300	300	450	450	1,500
Vendor Total					
UV EPROM	300	300	450	450	1,500
Total	300	300	450	450	1,500
SGS-Thomson					
256Kx8					
OTP EPROM	490	640	290	420	1,840
UV EPROM	1,960	1,830	1,710	1,780	7,280
Total	2,450	2,470	2,000	2,200	9,120
Vendor Total					
OTP EPROM	490	640	290	420	1,840
UV EPROM	1,960	1,830	1,710	1,780	7,280
Total	2,450	2,470	2,000	2,200	9,120
Texas Instruments					
256Kx8					
OTP EPROM	600	750	900	900	3,150
UV EPROM	1,800	1,850	1,900	1,900	7,450
Total	2,400	2,600	2,800	2,800	10,600
Vendor Total					
OTP EPROM	600	750	900	900	3,150
UV EPROM	1,800	1,850	1,900	1,900	7,450
Total	2,400	2,600	2,800	2,800	10,600

Table 2-39 (Continued)
Each Company's Quarterly Shipments of 2Mb EPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Market Total					
256Kx8					
OTP EPROM	3,120	3,470	3,340	3,470	13,400
UV EPROM	5,282	5,205	4,914	5,335	20,736
Total	8,402	8,675	8,254	8,805	34,136
128Kx16					
OTP EPROM	100	70	50	50	270
UV EPROM	460	1,110	890	480	2,940
Total	560	1,180	940	530	3,210
All 2Mb					
OTP EPROM	3,220	3,540	3,390	3,520	13,670
UV EPROM	5,742	6,315	5,804	5,815	23,676
Total	8,962	9,855	9,194	9,335	37,346
% Change from Previous Quarter	-7.3	10.0	-6.7	1.5	-
Average Selling Price ($)	4.65	4.41	4.27	3.73	4.26
Revenue ($M)	41,631	43,439	39,270	34,773	159,113
Market Share (% of Units)					
Americas Companies	64.3	68.8	71.1	69.3	68.4
European Companies	27.3	25.1	21.8	23.6	24.4
Japanese Companies	8.4	6.1	7.1	7.0	7.1
Asia/Pacific Companies	-	-	-	0.2	0.1
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-40
Each Company's Quarterly Shipments of 4Mb EPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Advanced Micro Devices					
512Kx8					
UV EPROM	1,225	1,140	1,060	860	4,285
Total	1,225	1,140	1,060	860	4,285
256Kx16					
UV EPROM	540	1,020	365	260	2,185
Total	540	1,020	365	260	2,185
Vendor Total					
UV EPROM	1,765	2,160	1,425	1,120	6,470
Total	1,765	2,160	1,425	1,120	6,470
Atmel					
512Kx8					
OTP EPROM	455	500	400	380	1,735
Total	455	500	400	380	1,735
256Kx16					
OTP EPROM	645	600	750	820	2,815
Total	645	600	750	820	2,815
Vendor Total					
OTP EPROM	1,100	1,100	1,150	1,200	4,550
Total	1,100	1,100	1,150	1,200	4,550
Fujitsu					
512Kx8					
UV EPROM	26	-	1	-	27
Total	26	-	1	-	27
Vendor Total					
UV EPROM	26	-	1	-	27
Total	26	-	1	-	27
Hitachi					
256Kx16					
UV EPROM	600	850	850	850	3,150
Total	600	850	850	850	3,150
Vendor Total					
UV EPROM	600	850	850	850	3,150
Total	600	850	850	850	3,150
Macronix					
512Kx8					
OTP EPROM	110	125	105	100	440
UV EPROM	990	1,125	945	900	3,960
Total	1,100	1,250	1,050	1,000	4,400

Table 2-40 (Continued)
Each Company's Quarterly Shipments of 4Mb EPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
256Kx16					
OTP EPROM	20	23	18	15	75
UV EPROM	380	428	333	285	1,425
Total	400	450	350	300	1,500
Vendor Total					
OTP EPROM	130	148	123	115	515
UV EPROM	1,370	1,553	1,278	1,185	5,385
Total	1,500	1,700	1,400	1,300	5,900
Mitsubishi					
512Kx8					
UV EPROM	20	50	30	10	110
Total	20	50	30	10	110
256Kx16					
UV EPROM	20	50	30	50	150
Total	20	50	30	50	150
Vendor Total					
UV EPROM	40	100	60	60	260
Total	40	100	60	60	260
National Semiconductor					
512Kx8					
OTP EPROM	-	20	-	-	20
UV EPROM	130	130	100	130	490
Total	130	150	100	130	510
Vendor Total					
OTP EPROM	-	20	-	-	20
UV EPROM	130	130	100	130	490
Total	130	150	100	130	510
NEC					
512Kx8					
UV EPROM	645	635	615	600	2,495
Total	645	635	615	600	2,495
256Kx16					
UV EPROM	315	315	305	300	1,235
Total	315	315	305	300	1,235
Vendor Total					
UV EPROM	960	950	920	900	3,730
Total	960	950	920	900	3,730

Table 2-40 (Continued)
Each Company's Quarterly Shipments of 4Mb EPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Oki					
512Kx8					
OTP EPROM	7	8	6	6	27
Total	7	8	6	6	27
256Kx16					
OTP EPROM	202	233	180	180	795
Total	202	233	180	180	795
Vendor Total					
OTP EPROM	208	241	186	186	822
Total	208	241	186	186	822
SGS-Thomson					
512Kx8					
OTP EPROM	680	405	360	515	1,960
UV EPROM	1,760	1,920	1,900	2,420	8,000
Total	2,440	2,325	2,260	2,935	9,960
256Kx16					
OTP EPROM	350	840	220	115	1,525
UV EPROM	1,010	935	1,250	680	3,875
Total	1,360	1,775	1,470	795	5,400
Vendor Total					
OTP EPROM	1,030	1,245	580	630	3,485
UV EPROM	2,770	2,855	3,150	3,100	11,875
Total	3,800	4,100	3,730	3,730	15,360
Texas Instruments					
512Kx8					
OTP EPROM	25	75	200	250	550
UV EPROM	600	1,000	1,200	1,300	4,100
Total	625	1,075	1,400	1,550	4,650
256Kx16					
OTP EPROM	100	200	300	500	1,100
UV EPROM	200	600	800	1,200	2,800
Total	300	800	1,100	1,700	3,900
Vendor Total					
OTP EPROM	125	275	500	750	1,650
UV EPROM	800	1,600	2,000	2,500	6,900
Total	925	1,875	2,500	3,250	8,550

Table 2-40 (Continued)
Each Company's Quarterly Shipments of 4Mb EPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Toshiba					
512Kx8					
UV EPROM	230	250	220	215	915
Total	230	250	220	215	915
256Kx16					
UV EPROM	450	550	400	400	1,800
Total	450	550	400	400	1,800
Vendor Total					
UV EPROM	680	800	620	615	2,715
Total	680	800	620	615	2,715
Market Total					
512Kx8					
OTP EPROM	1,277	1,133	1,071	1,251	4,732
UV EPROM	5,626	6,250	6,071	6,435	24,382
Total	6,903	7,383	7,142	7,686	29,114
256Kx16					
OTP EPROM	1,317	1,896	1,468	1,630	6,310
UV EPROM	3,515	4,748	4,333	4,025	16,620
Total	4,832	6,643	5,800	5,655	22,930
All 4Mb					
OTP EPROM	2,593	3,028	2,539	2,881	11,042
UV EPROM	9,141	10,998	10,404	10,460	41,002
Total	11,734	14,026	12,942	13,341	52,044
% Change from Previous Quarter	13.9	19.5	-7.7	3.1	-
Average Selling Price ($)	8.92	8.84	8.56	7.60	8.47
Revenue ($M)	104,630	124,033	110,797	101,385	440,846
Market Share (% of Units)					
Americas Companies	33.4	37.7	40.0	42.7	38.6
European Companies	32.4	29.2	28.8	28.0	29.5
Japanese Companies	21.4	21.0	20.4	19.6	20.6
Asia/Pacific Companies	12.8	12.1	10.8	9.7	11.3
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-41
Each Company's Quarterly Shipments of 8Mb EPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Atmel					
1Mbx8					
OTP EPROM	10	21	30	30	91
UV EPROM	45	84	115	185	429
Total	55	105	145	215	520
Vendor Total					
OTP EPROM	10	21	30	30	91
UV EPROM	45	84	115	185	429
Total	55	105	145	215	520
Macronix					
1Mbx8					
UV EPROM	-	1	3	12	16
Total	-	1	3	12	16
512Kx16					
UV EPROM	-	-	-	3	3
Total	-	-	-	3	3
Vendor Total					
UV EPROM	-	1	3	15	19
Total	-	1	3	15	19
SGS-Thomson					
1Mbx8					
OTP EPROM	-	-	15	25	40
UV EPROM	270	520	510	290	1,590
Total	270	520	525	315	1,630
512Kx16					
UV EPROM	-	-	5	90	95
Total	-	-	5	90	95
Vendor Total					
OTP EPROM	-	-	15	25	40
UV EPROM	270	520	515	380	1,685
Total	270	520	530	405	1,725
Market Total					
1Mbx8					
OTP EPROM	10	21	45	55	131
UV EPROM	315	605	628	487	2,035
Total	325	626	673	542	2,166
512Kx16					
UV EPROM	-	-	5	93	98
Total	-	-	5	93	98

Table 2-41 (Continued)
Each Company's Quarterly Shipments of 8Mb EPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
All 8Mb					
OTP EPROM	10	21	45	55	131
UV EPROM	315	605	633	580	2,133
Total	325	626	678	635	2,264
% Change from Previous Quarter	-40.9	92.6	8.3	-6.3	-
Average Selling Price ($)	13.29	12.42	11.65	11.23	11.98
Revenue ($M)	4,319	7,773	7,899	7,133	27,124
Market Share (% of Units)					
Americas Companies	16.9	16.8	21.4	33.9	23.0
European Companies	83.1	83.1	78.2	63.8	76.2
Japanese Companies	-	-	-	-	-
Asia/Pacific Companies	-	0.2	0.4	2.4	0.8
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-42
Each Company's Quarterly Shipments of 16Mb EPROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
SGS-Thomson					
2Mbx8					
OTP EPROM	-	-	1	1	2
UV EPROM	3	18	31	66	118
Total	3	18	32	67	120
Vendor Total					
OTP EPROM	-	-	1	1	2
UV EPROM	3	18	31	66	118
Total	3	18	32	67	120
Market Total					
2Mbx8					
OTP EPROM	-	-	1	1	2
UV EPROM	3	18	31	66	118
Total	3	18	32	67	120
All 16Mb					
OTP EPROM	-	-	1	1	2
UV EPROM	3	18	31	66	118
Total	3	18	32	67	120
% Change from Previous Quarter	-70.0	500.0	77.8	109.4	-
Average Selling Price ($)	21.31	20.60	19.85	19.15	19.61
Revenue ($M)	64	371	635	1,283	2,353
Market Share (% of Units)					
Americas Companies	-	-	-	-	-
European Companies	100.0	100.0	100.0	100.0	100.0
Japanese Companies	-	-	-	-	-
Asia/Pacific Companies	-	-	-	-	-
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-43
Each Company's Quarterly Shipments of ROM by Density to the World, 1996
(Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Fujitsu					
All 64K	16	12	18	20	66
All 128K	11	3	8	7	29
All 256K	80	70	60	25	235
All 512K	40	45	45	35	165
All 1Mb	30	30	30	20	110
All 2Mb	12	12	4	9	37
All 4Mb	250	220	250	280	1,000
All 8Mb	180	100	130	385	795
All 16Mb	155	125	145	175	600
Vendor Total	774	617	690	956	3,037
Hitachi					
All 256K	20	50	50	50	170
All 1Mb	300	165	165	165	795
All 2Mb	200	200	200	200	800
All 4Mb	1,700	1,300	1,300	1,300	5,600
All 8Mb	2,800	1,500	2,100	3,500	9,900
All 16Mb	1,600	1,200	1,300	1,900	6,000
Vendor Total	6,620	4,415	5,115	7,115	23,265
Hualon Microelectronics					
All 128K	9	8	8	7	32
All 256K	7	7	7	6	27
All 512K	6	5	4	5	20
All 1Mb	395	380	375	380	1,530
All 2Mb	3,100	2,800	2,600	2,500	11,000
Vendor Total	3,517	3,200	2,994	2,898	12,609
LG Semicon					
All 1Mb	240	165	115	115	635
All 4Mb	1,300	1,050	1,000	1,000	4,350
All 8Mb	1,300	1,000	1,100	1,400	4,800
All 16Mb	900	500	900	1,300	3,600
Vendor Total	3,740	2,715	3,115	3,815	13,385
Macronix					
All 1Mb	170	160	155	165	650
All 2Mb	485	470	450	475	1,880
All 4Mb	820	845	885	865	3,415
All 8Mb	1,400	1,100	1,300	1,400	5,200
All 16Mb	4,300	3,100	3,700	5,900	17,000
Vendor Total	7,175	5,675	6,490	8,805	28,145

Table 2-43 (Continued)
Each Company's Quarterly Shipments of ROM by Density to the World, 1996
(Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Matsushita					
All 2Mb	20	19	18	19	76
All 4Mb	215	220	230	230	895
All 8Mb	230	190	200	230	850
All 16Mb	205	135	170	170	680
Vendor Total	670	564	618	649	2,501
NEC					
All 128K	10	10	10	10	40
All 512K	70	70	70	70	280
All 1Mb	320	195	195	65	775
All 2Mb	450	470	430	400	1,750
All 4Mb	1,700	1,700	1,900	2,200	7,500
All 8Mb	2,700	2,400	2,500	2,900	10,500
All 16Mb	1,500	1,300	1,400	2,200	6,400
All 32Mb	1,400	1,200	1,600	4,000	8,200
Vendor Total	8,150	7,345	8,105	11,845	35,445
Oki					
All 4Mb	810	840	880	860	3,390
All 8Mb	890	725	885	790	3,290
All 16Mb	975	635	810	810	3,230
Vendor Total	2,675	2,200	2,575	2,460	9,910
Ricoh					
All 64K	22	21	11	8	62
All 128K	27	21	17	14	79
All 256K	120	80	55	45	300
All 1Mb	60	30	10	5	105
All 2Mb	105	65	40	25	235
All 4Mb	95	50	25	5	175
All 8Mb	60	30	15	5	110
Vendor Total	489	297	173	107	1,066
Samsung					
All 256K	20	-	-	-	20
All 512K	400	165	25	-	590
All 1Mb	445	280	260	200	1,185
All 2Mb	200	190	190	160	740
All 4Mb	3,760	3,130	4,000	3,120	14,010
All 8Mb	3,080	2,730	3,130	3,010	11,950
All 16Mb	2,190	2,010	2,020	2,210	8,430
Vendor Total	10,095	8,505	9,625	8,700	36,925

Table 2-43 (Continued)
Each Company's Quarterly Shipments of ROM by Density to the World, 1996
(Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Sharp					
All 64K	7	7	8	8	30
All 128K	22	22	23	25	92
All 256K	770	805	815	830	3,220
All 512K	460	480	485	495	1,920
All 1Mb	1,845	1,930	1,960	2,000	7,735
All 2Mb	2,790	2,900	2,935	2,985	11,610
All 4Mb	7,200	7,100	7,100	7,000	28,400
All 8Mb	3,665	3,065	3,305	3,690	13,725
All 16Mb	5,300	2,000	3,800	6,800	17,900
All 32Mb	4,600	2,150	3,200	5,400	15,350
Vendor Total	26,659	20,459	23,631	29,233	99,982
Toshiba					
All 1Mb	1,140	980	860	760	3,740
All 2Mb	90	90	85	90	355
All 4Mb	1,400	1,210	1,060	940	4,610
All 8Mb	1,680	1,300	1,470	1,960	6,410
All 16Mb	1,890	640	1,100	3,260	6,890
Vendor Total	6,200	4,220	4,575	7,010	22,005
UMC					
All 512K	22	21	20	22	85
All 1Mb	52	51	50	51	204
All 2Mb	65	64	61	64	254
All 4Mb	2,500	2,550	2,580	2,600	10,230
All 8Mb	1,000	385	670	1,440	3,495
Vendor Total	3,639	3,071	3,381	4,177	14,268
Market Total					
All 64K	45	40	37	36	158
All 128K	79	64	66	63	272
All 256K	1,017	1,012	987	956	3,972
All 512K	998	786	649	627	3,060
All 1Mb	4,997	4,366	4,175	3,926	17,464
All 2Mb	7,517	7,280	7,013	6,927	28,737
All 4Mb	21,750	20,215	21,210	20,400	83,575
All 8Mb	18,985	14,525	16,805	20,710	71,025
All 16Mb	19,015	11,645	15,345	24,725	70,730
All 32Mb	6,000	3,350	4,800	9,400	23,550
Total	80,403	63,283	71,087	87,770	302,543

Table 2-43 (Continued)
Each Company's Quarterly Shipments of ROM by Density to the World, 1996
(Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Percentage Change from Previous Quarter	-32.3	-21.3	12.3	23.5	-
Average Selling Price ($)	4.75	4.28	4.47	4.98	4.65
Revenue ($M)	381,569	270,843	317,765	436,728	1,406,905
Market Share (% of Units)					
Americas Companies	-	-	-	-	-
European Companies	-	-	-	-	-
Japanese Companies	65.0	63.4	64.0	67.6	65.2
Asia/Pacific Companies	35.0	36.6	36.0	32.4	34.8
Total	100.0	100.0	100.0	100.0	100.00

Source: Dataquest (June 1997)

Table 2-44
Each Company's Quarterly Shipments of 64K ROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Fujitsu					
8Kx8					
ROM	16	12	18	20	66
Total	16	12	18	20	66
Vendor Total					
ROM	16	12	18	20	66
Total	16	12	18	20	66
Ricoh					
8Kx8					
ROM	22	21	11	8	62
Total	22	21	11	8	62
Vendor Total					
ROM	22	21	11	8	62
Total	22	21	11	8	62
Sharp					
8Kx8					
ROM	7	7	8	8	30
Total	7	7	8	8	30
Vendor Total					
ROM	7	7	8	8	30
Total	7	7	8	8	30
Market Total					
8Kx8					
ROM	45	40	37	36	158
Total	45	40	37	36	158
All 64K					
ROM	45	40	37	36	158
Total	45	40	37	36	158
% Change from Previous Quarter	-4.5	-11.1	-8.8	-1.4	-
Average Selling Price ($)	1.43	1.39	1.39	1.39	1.40
Revenue ($M)	64	56	51	50	221
Market Share (% of Units)					
Americas Companies	-	-	-	-	-
European Companies	-	-	-	-	-
Japanese Companies	100.0	100.0	100.0	100.0	100.0
Asia/Pacific Companies	-	-	-	-	-
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-45
Each Company's Quarterly Shipments of 128K ROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Fujitsu					
16Kx8					
ROM	11	3	8	7	29
Total	11	3	8	7	29
Vendor Total					
ROM	11	3	8	7	29
Total	11	3	8	7	29
Hualon Microelectronics					
16Kx8					
ROM	9	8	8	7	32
Total	9	8	8	7	32
Vendor Total					
ROM	9	8	8	7	32
Total	9	8	8	7	32
NEC					
16Kx8					
ROM	10	10	10	10	40
Total	10	10	10	10	40
Vendor Total					
ROM	10	10	10	10	40
Total	10	10	10	10	40
Ricoh					
16Kx8					
ROM	27	21	17	14	79
Total	27	21	17	14	79
Vendor Total					
ROM	27	21	17	14	79
Total	27	21	17	14	79
Sharp					
16Kx8					
ROM	22	22	23	25	92
Total	22	22	23	25	92
Vendor Total					
ROM	22	22	23	25	92
Total	22	22	23	25	92

Table 2-45 (Continued)
Each Company's Quarterly Shipments of 128K ROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Market Total					
16Kx8					
ROM	79	64	66	63	272
Total	79	64	66	63	272
All 128K					
ROM	79	64	66	63	272
Total	79	64	66	63	272
% Change from Previous Quarter	-6.7	-19.0	3.1	-4.5	-
Average Selling Price ($)	1.47	1.43	1.43	1.43	1.44
Revenue ($M)	116	92	95	90	393
Market Share (% of Units)					
Americas Companies	-	-	-	-	-
European Companies	-	-	-	-	-
Japanese Companies	88.6	87.5	87.9	88.9	88.2
Asia/Pacific Companies	11.4	12.5	12.1	11.1	11.8
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-46
Each Company's Quarterly Shipments of 256K ROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Fujitsu					
32Kx8					
ROM	80	70	60	25	235
Total	80	70	60	25	235
Vendor Total					
ROM	80	70	60	25	235
Total	80	70	60	25	235
Hitachi					
32Kx8					
ROM	20	50	50	50	170
Total	20	50	50	50	170
Vendor Total					
ROM	20	50	50	50	170
Total	20	50	50	50	170
Hualon Microelectronics					
32Kx8					
ROM	7	7	7	6	27
Total	7	7	7	6	27
Vendor Total					
ROM	7	7	7	6	27
Total	7	7	7	6	27
Ricoh					
32Kx8					
ROM	120	80	55	45	300
Total	120	80	55	45	300
Vendor Total					
ROM	120	80	55	45	300
Total	120	80	55	45	300
Samsung					
32Kx8					
ROM	20	-	-	-	20
Total	20	-	-	-	20
Vendor Total					
ROM	20	-	-	-	20
Total	20	-	-	-	20

Table 2-46 (Continued)
Each Company's Quarterly Shipments of 256K ROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Sharp					
32Kx8					
ROM	770	805	815	830	3,220
Total	770	805	815	830	3,220
Vendor Total					
ROM	770	805	815	830	3,220
Total	770	805	815	830	3,220
Market Total					
32Kx8					
ROM	1,017	1,012	987	956	3,972
Total	1,017	1,012	987	956	3,972
All 256K					
ROM	1,017	1,012	987	956	3,972
Total	1,017	1,012	987	956	3,972
% Change from Previous Quarter	-37.3	-0.5	-2.5	-3.1	-
Average Selling Price ($)	1.56	1.52	1.52	1.52	1.53
Revenue ($M)	1,588	1,539	1,501	1,454	6,082
Market Share (% of Units)					
Americas Companies	-	-	-	-	-
European Companies	-	-	-	-	-
Japanese Companies	97.3	99.3	99.3	99.4	98.8
Asia/Pacific Companies	2.7	0.7	0.7	0.6	1.2
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-47
Each Company's Quarterly Shipments of 512K ROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Fujitsu					
64Kx8					
ROM	40	45	45	35	165
Total	40	45	45	35	165
Vendor Total					
ROM	40	45	45	35	165
Total	40	45	45	35	165
Hualon Microelectronics					
64Kx8					
ROM	6	5	4	5	20
Total	6	5	4	5	20
Vendor Total					
ROM	6	5	4	5	20
Total	6	5	4	5	20
NEC					
64Kx8					
ROM	70	70	70	70	280
Total	70	70	70	70	280
Vendor Total					
ROM	70	70	70	70	280
Total	70	70	70	70	280
Samsung					
64Kx8					
ROM	400	165	25	-	590
Total	400	165	25	-	590
Vendor Total					
ROM	400	165	25	-	590
Total	400	165	25	-	590
Sharp					
64Kx8					
ROM	460	480	485	495	1,920
Total	460	480	485	495	1,920
Vendor Total					
ROM	460	480	485	495	1,920
Total	460	480	485	495	1,920

Table 2-47 (Continued)
Each Company's Quarterly Shipments of 512K ROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
UMC					
64Kx8					
ROM	22	21	20	22	85
Total	22	21	20	22	85
Vendor Total					
ROM	22	21	20	22	85
Total	22	21	20	22	85
Market Total					
64Kx8					
ROM	998	786	649	627	3,060
Total	998	786	649	627	3,060
All 512K					
ROM	998	786	649	627	3,060
Total	998	786	649	627	3,060
% Change from Previous Quarter	-18.2	-21.2	-17.4	-3.4	-
Average Selling Price ($)	1.74	1.70	1.70	1.70	1.71
Revenue ($M)	1,741	1,336	1,103	1,066	5,247
Market Share (% of Units)					
Americas Companies	-	-	-	-	-
European Companies	-	-	-	-	-
Japanese Companies	57.1	75.7	92.4	95.7	77.3
Asia/Pacific Companies	42.9	24.3	7.6	4.3	22.7
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-48
Each Company's Quarterly Shipments of 1Mb ROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Fujitsu					
128Kx8					
ROM	30	30	30	20	110
Total	30	30	30	20	110
Vendor Total					
ROM	30	30	30	20	110
Total	30	30	30	20	110
Hitachi					
128Kx8					
ROM	300	165	165	165	795
Total	300	165	165	165	795
Vendor Total					
ROM	300	165	165	165	795
Total	300	165	165	165	795
Hualon Microelectronics					
128Kx8					
ROM	395	380	375	380	1,530
Total	395	380	375	380	1,530
Vendor Total					
ROM	395	380	375	380	1,530
Total	395	380	375	380	1,530
LG Semicon					
128Kx8					
ROM	240	165	115	115	635
Total	240	165	115	115	635
Vendor Total					
ROM	240	165	115	115	635
Total	240	165	115	115	635
Macronix					
128Kx8					
ROM	170	160	155	165	650
Total	170	160	155	165	650
Vendor Total					
ROM	170	160	155	165	650
Total	170	160	155	165	650
NEC					
128Kx8					
ROM	320	195	195	65	775
Total	320	195	195	65	775

Table 2-48 (Continued)
Each Company's Quarterly Shipments of 1Mb ROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Vendor Total					
ROM	320	195	195	65	775
Total	320	195	195	65	775
Ricoh					
128Kx8					
ROM	60	30	10	5	105
Total	60	30	10	5	105
Vendor Total					
ROM	60	30	10	5	105
Total	60	30	10	5	105
Samsung					
128Kx8					
ROM	445	280	260	200	1,185
Total	445	280	260	200	1,185
Vendor Total					
ROM	445	280	260	200	1,185
Total	445	280	260	200	1,185
Sharp					
128Kx8					
ROM	1,845	1,930	1,960	2,000	7,735
Total	1,845	1,930	1,960	2,000	7,735
Vendor Total					
ROM	1,845	1,930	1,960	2,000	7,735
Total	1,845	1,930	1,960	2,000	7,735
Toshiba					
128Kx8					
ROM	1,140	980	860	760	3,740
Total	1,140	980	860	760	3,740
Vendor Total					
ROM	1,140	980	860	760	3,740
Total	1,140	980	860	760	3,740
UMC					
128Kx8					
ROM	52	51	50	51	204
Total	52	51	50	51	204
Vendor Total					
ROM	52	51	50	51	204
Total	52	51	50	51	204

Table 2-48 (Continued)
Each Company's Quarterly Shipments of 1Mb ROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Market Total					
128Kx8					
ROM	4,997	4,366	4,175	3,926	17,464
Total	4,997	4,366	4,175	3,926	17,464
All 1Mb					
ROM	4,997	4,366	4,175	3,926	17,464
Total	4,997	4,366	4,175	3,926	17,464
% Change from Previous Quarter	-29.9	-12.6	-4.4	-6.0	-
Average Selling Price ($)	1.95	1.90	1.90	1.90	1.91
Revenue ($M)	9,744	8,295	7,933	7,459	33,431
Market Share (% of Units)					
Americas Companies	-	-	-	-	-
European Companies	-	-	-	-	-
Japanese Companies	73.9	76.3	77.1	76.8	75.9
Asia/Pacific Companies	26.1	23.7	22.9	23.2	24.1
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-49
Each Company's Quarterly Shipments of 2Mb ROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Fujitsu					
256Kx8					
ROM	12	12	4	9	37
Total	12	12	4	9	37
Vendor Total					
ROM	12	12	4	9	37
Total	12	12	4	9	37
Hitachi					
256Kx8					
ROM	200	200	200	200	800
Total	200	200	200	200	800
Vendor Total					
ROM	200	200	200	200	800
Total	200	200	200	200	800
Hualon Microelectronics					
256Kx8					
ROM	3,100	2,800	2,600	2,500	11,000
Total	3,100	2,800	2,600	2,500	11,000
Vendor Total					
ROM	3,100	2,800	2,600	2,500	11,000
Total	3,100	2,800	2,600	2,500	11,000
Macronix					
256Kx8					
ROM	485	470	450	475	1,880
Total	485	470	450	475	1,880
Vendor Total					
ROM	485	470	450	475	1,880
Total	485	470	450	475	1,880
Matsushita					
256Kx8					
ROM	20	19	18	19	76
Total	20	19	18	19	76
Vendor Total					
ROM	20	19	18	19	76
Total	20	19	18	19	76

Table 2-49 (Continued)
Each Company's Quarterly Shipments of 2Mb ROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
NEC					
256Kx8					
ROM	450	470	430	400	1,750
Total	450	470	430	400	1,750
Vendor Total					
ROM	450	470	430	400	1,750
Total	450	470	430	400	1,750
Ricoh					
256Kx8					
ROM	105	65	40	25	235
Total	105	65	40	25	235
Vendor Total					
ROM	105	65	40	25	235
Total	105	65	40	25	235
Samsung					
256Kx8					
ROM	200	190	190	160	740
Total	200	190	190	160	740
Vendor Total					
ROM	200	190	190	160	740
Total	200	190	190	160	740
Sharp					
256Kx8					
ROM	2,790	2,900	2,935	2,985	11,610
Total	2,790	2,900	2,935	2,985	11,610
Vendor Total					
ROM	2,790	2,900	2,935	2,985	11,610
Total	2,790	2,900	2,935	2,985	11,610
Toshiba					
256Kx8					
ROM	90	90	85	90	355
Total	90	90	85	90	355
Vendor Total					
ROM	90	90	85	90	355
Total	90	90	85	90	355

Table 2-49 (Continued)
Each Company's Quarterly Shipments of 2Mb ROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
UMC					
256Kx8					
ROM	65	64	61	64	254
Total	65	64	61	64	254
Vendor Total					
ROM	65	64	61	64	254
Total	65	64	61	64	254
Market Total					
256Kx8					
ROM	7,517	7,280	7,013	6,927	28,737
Total	7,517	7,280	7,013	6,927	28,737
All 2Mb					
ROM	7,517	7,280	7,013	6,927	28,737
Total	7,517	7,280	7,013	6,927	28,737
% Change from Previous Quarter	-35.5	-3.2	-3.7	-1.2	-
Average Selling Price ($)	2.25	2.25	2.25	2.25	2.25
Revenue ($M)	16,913	16,380	15,779	15,586	64,658
Market Share (% of Units)					
Americas Companies	-	-	-	-	-
European Companies	-	-	-	-	-
Japanese Companies	48.8	51.6	52.9	53.8	51.7
Asia/Pacific Companies	51.2	48.4	47.1	46.2	48.3
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-50
Each Company's Quarterly Shipments of 4Mb ROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Fujitsu					
512Kx8					
ROM	100	100	120	130	450
Total	100	100	120	130	450
256Kx16					
ROM	150	120	130	150	550
Total	150	120	130	150	550
Vendor Total					
ROM	250	220	250	280	1,000
Total	250	220	250	280	1,000
Hitachi					
512Kx8					
ROM	1,700	1,300	1,300	1,300	5,600
Total	1,700	1,300	1,300	1,300	5,600
Vendor Total					
ROM	1,700	1,300	1,300	1,300	5,600
Total	1,700	1,300	1,300	1,300	5,600
LG Semicon					
512Kx8					
ROM	1,300	1,050	1,000	1,000	4,350
Total	1,300	1,050	1,000	1,000	4,350
Vendor Total					
ROM	1,300	1,050	1,000	1,000	4,350
Total	1,300	1,050	1,000	1,000	4,350
Macronix					
512Kx8					
ROM	820	845	885	865	3,415
Total	820	845	885	865	3,415
Vendor Total					
ROM	820	845	885	865	3,415
Total	820	845	885	865	3,415
Matsushita					
512Kx8					
ROM	215	220	230	230	895
Total	215	220	230	230	895
Vendor Total					
ROM	215	220	230	230	895
Total	215	220	230	230	895

Table 2-50 (Continued)
Each Company's Quarterly Shipments of 4Mb ROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
NEC					
512Kx8					
ROM	1,700	1,700	1,900	2,200	7,500
Total	1,700	1,700	1,900	2,200	7,500
Vendor Total					
ROM	1,700	1,700	1,900	2,200	7,500
Total	1,700	1,700	1,900	2,200	7,500
Oki					
512Kx8					
ROM	370	380	400	390	1,540
Total	370	380	400	390	1,540
256Kx16					
ROM	440	460	480	470	1,850
Total	440	460	480	470	1,850
Vendor Total					
ROM	810	840	880	860	3,390
Total	810	840	880	860	3,390
Ricoh					
512Kx8					
ROM	95	50	25	5	175
Total	95	50	25	5	175
Vendor Total					
ROM	95	50	25	5	175
Total	95	50	25	5	175
Samsung					
512Kx8					
ROM	2,520	2,100	2,700	2,100	9,420
Total	2,520	2,100	2,700	2,100	9,420
256Kx16					
ROM	1,240	1,030	1,300	1,020	4,590
Total	1,240	1,030	1,300	1,020	4,590
Vendor Total					
ROM	3,760	3,130	4,000	3,120	14,010
Total	3,760	3,130	4,000	3,120	14,010
Sharp					
512Kx8					
ROM	7,200	7,100	7,100	7,000	28,400
Total	7,200	7,100	7,100	7,000	28,400

Table 2-50 (Continued)
Each Company's Quarterly Shipments of 4Mb ROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Vendor Total					
ROM	7,200	7,100	7,100	7,000	28,400
Total	7,200	7,100	7,100	7,000	28,400
Toshiba					
512Kx8					
ROM	1,400	1,210	1,060	940	4,610
Total	1,400	1,210	1,060	940	4,610
Vendor Total					
ROM	1,400	1,210	1,060	940	4,610
Total	1,400	1,210	1,060	940	4,610
UMC					
512Kx8					
ROM	2,500	2,550	2,580	2,600	10,230
Total	2,500	2,550	2,580	2,600	10,230
Vendor Total					
ROM	2,500	2,550	2,580	2,600	10,230
Total	2,500	2,550	2,580	2,600	10,230
Market Total					
512Kx8					
ROM	19,920	18,605	19,300	18,760	76,585
Total	19,920	18,605	19,300	18,760	76,585
256Kx16					
ROM	1,830	1,610	1,910	1,640	6,990
Total	1,830	1,610	1,910	1,640	6,990
All 4Mb					
ROM	21,750	20,215	21,210	20,400	83,575
Total	21,750	20,215	21,210	20,400	83,575
% Change from Previous Quarter	-31.2	-7.1	4.9	-3.8	-
Average Selling Price ($)	3.20	3.20	3.20	3.20	3.20
Revenue ($M)	69,600	64,688	67,872	65,280	267,440
Market Share (% of Units)					
Americas Companies	-	-	-	-	-
European Companies	-	-	-	-	-
Japanese Companies	61.5	62.5	60.1	62.8	61.7
Asia/Pacific Companies	38.5	37.5	39.9	37.2	38.3
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-51
Each Company's Quarterly Shipments of 8Mb ROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Fujitsu					
1Mbx8					
ROM	180	100	130	385	795
Total	180	100	130	385	795
Vendor Total					
ROM	180	100	130	385	795
Total	180	100	130	385	795
Hitachi					
1Mbx8					
ROM	2,800	1,500	2,100	3,500	9,900
Total	2,800	1,500	2,100	3,500	9,900
Vendor Total					
ROM	2,800	1,500	2,100	3,500	9,900
Total	2,800	1,500	2,100	3,500	9,900
LG Semicon					
1Mbx8					
ROM	1,300	1,000	1,100	1,400	4,800
Total	1,300	1,000	1,100	1,400	4,800
Vendor Total					
ROM	1,300	1,000	1,100	1,400	4,800
Total	1,300	1,000	1,100	1,400	4,800
Macronix					
1Mbx8					
ROM	1,400	1,100	1,300	1,400	5,200
Total	1,400	1,100	1,300	1,400	5,200
Vendor Total					
ROM	1,400	1,100	1,300	1,400	5,200
Total	1,400	1,100	1,300	1,400	5,200
Matsushita					
1Mbx8					
ROM	230	190	200	230	850
Total	230	190	200	230	850
Vendor Total					
ROM	230	190	200	230	850
Total	230	190	200	230	850
NEC					
1Mbx8					
ROM	2,700	2,400	2,500	2,900	10,500
Total	2,700	2,400	2,500	2,900	10,500

Table 2-51 (Continued)
Each Company's Quarterly Shipments of 8Mb ROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Vendor Total					
ROM	2,700	2,400	2,500	2,900	10,500
Total	2,700	2,400	2,500	2,900	10,500
Oki					
1Mbx8					
ROM	520	425	515	460	1,920
Total	520	425	515	460	1,920
512Kx16					
ROM	370	300	370	330	1,370
Total	370	300	370	330	1,370
Vendor Total					
ROM	890	725	885	790	3,290
Total	890	725	885	790	3,290
Ricoh					
1Mbx8					
ROM	60	30	15	5	110
Total	60	30	15	5	110
Vendor Total					
ROM	60	30	15	5	110
Total	60	30	15	5	110
Samsung					
1Mbx8					
ROM	770	680	780	750	2,980
Total	770	680	780	750	2,980
512Kx16					
ROM	2,310	2,050	2,350	2,260	8,970
Total	2,310	2,050	2,350	2,260	8,970
Vendor Total					
ROM	3,080	2,730	3,130	3,010	11,950
Total	3,080	2,730	3,130	3,010	11,950
Sharp					
1Mbx8					
ROM	3,665	3,065	3,305	3,690	13,725
Total	3,665	3,065	3,305	3,690	13,725
Vendor Total					
ROM	3,665	3,065	3,305	3,690	13,725
Total	3,665	3,065	3,305	3,690	13,725

Table 2-51 (Continued)
Each Company's Quarterly Shipments of 8Mb ROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Toshiba					
1Mbx8					
ROM	1,680	1,300	1,470	1,960	6,410
Total	1,680	1,300	1,470	1,960	6,410
Vendor Total					
ROM	1,680	1,300	1,470	1,960	6,410
Total	1,680	1,300	1,470	1,960	6,410
UMC					
1Mbx8					
ROM	1,000	385	670	1,440	3,495
Total	1,000	385	670	1,440	3,495
Vendor Total					
ROM	1,000	385	670	1,440	3,495
Total	1,000	385	670	1,440	3,495
Market Total					
1Mbx8					
ROM	16,305	12,175	14,085	18,120	60,685
Total	16,305	12,175	14,085	18,120	60,685
512Kx16					
ROM	2,680	2,350	2,720	2,590	10,340
Total	2,680	2,350	2,720	2,590	10,340
All 8Mb					
ROM	18,985	14,525	16,805	20,710	71,025
Total	18,985	14,525	16,805	20,710	71,025
% Change from Previous Quarter	-23.7	-23.5	15.7	23.2	-
Average Selling Price ($)	4.50	4.40	4.30	4.20	4.34
Revenue ($M)	85,433	63,910	72,262	86,982	308,586
Market Share (% of Units)					
Americas Companies	-	-	-	-	-
European Companies	-	-	-	-	-
Japanese Companies	64.3	64.1	63.1	65.0	64.2
Asia/Pacific Companies	35.7	35.9	36.9	35.0	35.8
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-52
Each Company's Quarterly Shipments of 16Mb ROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Fujitsu					
1Mbx16					
ROM	155	125	145	175	600
Total	155	125	145	175	600
Vendor Total					
ROM	155	125	145	175	600
Total	155	125	145	175	600
Hitachi					
2Mbx8					
ROM	1,600	1,200	1,300	1,900	6,000
Total	1,600	1,200	1,300	1,900	6,000
Vendor Total					
ROM	1,600	1,200	1,300	1,900	6,000
Total	1,600	1,200	1,300	1,900	6,000
LG Semicon					
2Mbx8					
ROM	900	500	900	1,300	3,600
Total	900	500	900	1,300	3,600
Vendor Total					
ROM	900	500	900	1,300	3,600
Total	900	500	900	1,300	3,600
Macronix					
2Mbx8					
ROM	4,300	3,100	3,700	5,900	17,000
Total	4,300	3,100	3,700	5,900	17,000
Vendor Total					
ROM	4,300	3,100	3,700	5,900	17,000
Total	4,300	3,100	3,700	5,900	17,000
Matsushita					
2Mbx8					
ROM	205	135	170	170	680
Total	205	135	170	170	680
Vendor Total					
ROM	205	135	170	170	680
Total	205	135	170	170	680
NEC					
2Mbx8					
ROM	1,500	1,300	1,400	2,200	6,400
Total	1,500	1,300	1,400	2,200	6,400

Table 2-52 (Continued)
Each Company's Quarterly Shipments of 16Mb ROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Vendor Total					
ROM	1,500	1,300	1,400	2,200	6,400
Total	1,500	1,300	1,400	2,200	6,400
Oki					
2Mbx8					
ROM	200	125	170	170	665
Total	200	125	170	170	665
1Mbx16					
ROM	775	510	640	640	2,565
Total	775	510	640	640	2,565
Vendor Total					
ROM	975	635	810	810	3,230
Total	975	635	810	810	3,230
Samsung					
1Mbx16					
ROM	2,190	2,010	2,020	2,210	8,430
Total	2,190	2,010	2,020	2,210	8,430
Vendor Total					
ROM	2,190	2,010	2,020	2,210	8,430
Total	2,190	2,010	2,020	2,210	8,430
Sharp					
2Mbx8					
ROM	5,300	2,000	3,800	6,800	17,900
Total	5,300	2,000	3,800	6,800	17,900
Vendor Total					
ROM	5,300	2,000	3,800	6,800	17,900
Total	5,300	2,000	3,800	6,800	17,900
Toshiba					
2Mbx8					
ROM	1,890	640	1,100	3,260	6,890
Total	1,890	640	1,100	3,260	6,890
Vendor Total					
ROM	1,890	640	1,100	3,260	6,890
Total	1,890	640	1,100	3,260	6,890

Table 2-52 (Continued)
Each Company's Quarterly Shipments of 16Mb ROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Market Total					
2Mbx8					
ROM	15,895	9,000	12,540	21,700	59,135
Total	15,895	9,000	12,540	21,700	59,135
1Mbx16					
ROM	3,120	2,645	2,805	3,025	11,595
Total	3,120	2,645	2,805	3,025	11,595
All 16Mb					
ROM	19,015	11,645	15,345	24,725	70,730
Total	19,015	11,645	15,345	24,725	70,730
% Change from Previous Quarter	-43.7	-38.8	31.8	61.1	-
Average Selling Price ($)	7.29	7.15	7.00	7.00	7.10
Revenue ($M)	138,619	83,262	107,415	173,075	502,371
Market Share (% of Units)					
Americas Companies	-	-	-	-	-
European Companies	-	-	-	-	-
Japanese Companies	61.1	51.8	56.9	61.9	59.0
Asia/Pacific Companies	38.9	48.2	43.1	38.1	41.0
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-53
Each Company's Quarterly Shipments of 32Mb ROM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
NEC					
4Mbx8					
ROM	1,400	1,200	1,600	4,000	8,200
Total	1,400	1,200	1,600	4,000	8,200
Vendor Total					
ROM	1,400	1,200	1,600	4,000	8,200
Total	1,400	1,200	1,600	4,000	8,200
Sharp					
4Mbx8					
ROM	4,600	2,150	3,200	5,400	15,350
Total	4,600	2,150	3,200	5,400	15,350
Vendor Total					
ROM	4,600	2,150	3,200	5,400	15,350
Total	4,600	2,150	3,200	5,400	15,350
Market Total					
4Mbx8					
ROM	6,000	3,350	4,800	9,400	23,550
Total	6,000	3,350	4,800	9,400	23,550
All 32Mb					
ROM	6,000	3,350	4,800	9,400	23,550
Total	6,000	3,350	4,800	9,400	23,550
% Change from Previous Quarter	-11.8	-44.2	43.3	95.8	-
Average Selling Price ($)	9.63	9.34	9.12	9.12	9.28
Revenue ($M)	57,750	31,285	43,754	85,686	218,475
Market Share (% of Units)					
Americas Companies	-	-	-	-	-
European Companies	-	-	-	-	-
Japanese Companies	100.0	100.0	100.0	100.0	100.0
Asia/Pacific Companies	-	-	-	-	-
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

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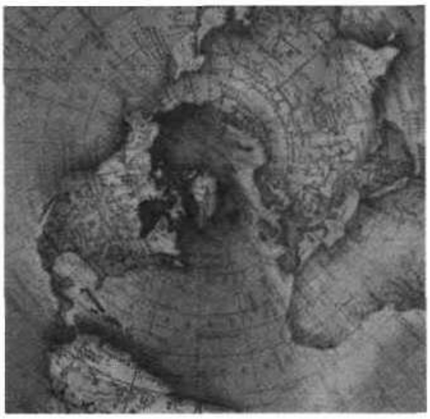

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Dataquest

1996 DRAM Unit Shipments

Market Statistics

Program: Memories Worldwide
Product Code: MMRY-WW-MS-9702
Publication Date: June 16, 1997
Filing: Market Statistics

1996 DRAM Unit Shipments

Market Statistics

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Chapter 1

Introduction

This document contains detailed statistics on the 1996 DRAM market. Analyses of companies' MOS memory shipments provide insight into high-technology markets and reinforce estimates of consumption, production, and company revenue.

Dataquest's Memories Worldwide program provides qualitative analysis of this data as part of a yearly subscription to its service. Clients of this program can find qualitative information in the Dataquest Memories Worldwide binder. Dataquest's client inquiry service can provide historical or more detailed information regarding the MOS memory market on request.

This introduction to the subsequent tables defines the market segments specific to this document. For a complete description of all market segments tracked by Dataquest, please refer to *Final Semiconductor Market Definitions* (SEMI-WW-GU-9701, February 5, 1997). A subscription to any Dataquest semiconductor service includes this guide.

Metric Definitions

Unit Shipments

Dataquest defines unit shipments as "for-revenue transfers of own-branded semiconductor products" from a device manufacturer (for example, Samsung) to an electronic equipment manufacturer (for example, Compaq Computer), subsystem assembler (for example, Kingston or SanDisk), or device reseller (for example, Arrow Electronics). This study counts the volume of devices sold (that is, units) rather than the dollar value of that volume (that is, not sales).

Inclusions for Unit Shipments

For shipments of devices on assembled subsystems (for example, modules), Dataquest counts the devices on the module rather than the module itself. Dataquest considers those devices shipped when the device manufacturer sells the module.

If a company sells any portion of a product category (for example, DRAM or EPROM) outside the company, then Dataquest includes all shipments of that category. For example, company ABC manufactures DRAM and EPROM. ABC's production of PCs consumes 99 percent of their DRAM and 100 percent of their EPROM. Dataquest will include 100 percent of ABC's DRAM shipments and 0 percent of ABC's EPROM shipments. Dataquest considers captive product shipped when the company transfers the product to the electronic equipment business unit or production facility.

Exclusions for Unit Shipments

Dataquest excludes logic devices with embedded memory even if the device manufacturer produces the device with a memory process. Dataquest counts these as microcomponents or ASIC or digital logic.

Dataquest excludes product categories that the company consumes 100 percent internally (totally captive production).

Dataquest excludes devices produced under contract for another device manufacturer to sell under that second manufacturer's brand name (contract manufacturing or foundry).

Dataquest excludes internal transfers from headquarters to sales subsidiaries but counts these parts when the subsidiary invoices them to an end user, to a third party, or to a value-added reseller.

Average Selling Price

At the bottom of each table, Dataquest includes an average selling price (ASP) for each density. Average selling price is the average billing price per unit paid for a product when it leaves the factory, taking into account discounts given to the distribution channel and multiple-purchase discounts. Dataquest averages prices over all companies, package types, lot sizes, speed mixes, and accounts (including military and commercial).

Revenue

Multiplying a product's shipment total by its ASP yields "dollarized units," which Dataquest defines as revenue for this report. These prices are industrywide approximations for each market segment. Dataquest intends use of these prices only as guidelines. Actual negotiated market prices may vary because of manufacturer-specific factors such as product quality, special features, service, delivery performance, volume discount, or other factors that may enhance or detract from the product's value. Therefore, multiplying a company's unit shipments by the industrywide ASP may not yield an accurate revenue figure. For company revenue by product type, please consult *Worldwide Memory Market Share* (MMRY-WW-MS-9701, May 19, 1997). A subscription to Dataquest's Memories Worldwide program includes this report.

Memory Definitions and Categories

Memory IC

A memory IC is an integrated circuit capable of and dedicated to storing retrievable electronic information in binary form. Dataquest limits the scope of this research to MOS (metal oxide semiconductor) DRAM, SRAM, EEPROM, EPROM, flash, and ROM only.

Volatile Memory

A memory IC that loses its contents with power interruption. Volatile memories include DRAM and SRAM. Dataquest includes DRAM unit shipments in this report and publishes SRAM unit shipments in a separate report titled *1996 SRAM Unit Shipments* (MMRY-WW-MS-9704, June 1997).

Nonvolatile Memory

A memory IC that retains its contents with power interruption. Nonvolatile memories include EEPROM, EPROM, and ROM. Dataquest publishes nonvolatile unit shipments in a separate report titled *1996 Nonvolatile Memory Unit Shipments* (MMRY-WW-MS-9703, June 1997).

Density

Dataquest classifies memory ICs by the number of bits the chip is able to store concurrently. Memory devices store bits in memory "cells" laid in rows and columns on the chip. The total number of cells is the density of the chip. Densities usually follow powers of two. For example, a 256-bit memory IC would contain 2^8 bits. Naming conventions have developed to append more dense chips with kilo- (K), mega- (or M), and giga- (G) to simplify references to that density. "Kilobits" (Kb) refers to 2^{10} bits. An 8Kb memory IC will contain 8×2^{10} bits (8,192 bits)—an "eight kilobit" chip. "Megabits" (Mb) refers to 2^{20} bits. A 4Mb memory IC will contain 4×2^{20} bits (4,194,304 bits)—a "four megabit" chip. "Gigabits" (Gb) refers to 2^{30} bits. A 1Gb memory IC will contain 1×2^{30} bits (1,073,741,824 bits)—a "one gigabit" chip. Dataquest limits the densities tracked according to device category. The tracked densities generally include all mainstream and high-volume densities.

This report includes DRAM densities from 256K through 64Mb.

Configuration

Along with density, Dataquest classifies memory ICs by their configuration (or organization) of the array of memory cells. The configuration is akin to the length and width of the array, with the product of these equaling the density. Memory IC manufacturers produce many different widths of the same density to accommodate each customer's system, data bus, and logic word width needs. Common configurations include x1 (1 bit wide), x4 (4 bits wide), x8 (8 bits wide), and x16 (16 bits wide).

Device Definitions

DRAM

DRAM stands for dynamic random access memory. DRAMs have single-transistor memory cells and require regular refreshes. They are volatile memories with multiplexed addressing. Dataquest subdivides the DRAM category into general-purpose architectures (standard) and display architectures (VRAM). Dataquest further subdivided these categories in 1996 to provide more detail. For densities under 4Mb, the "standard" and "VRAM" designations continue. For 4Mb densities and above, Dataquest has separated the general-purpose category into fast page mode (FPM), extended data out (EDO), synchronous (SDRAM), Rambus (RDRAM), enhanced (EDRAM), cache (CDRAM), and MoSys (MDRAM). Dataquest separated the display category into video (VRAM), Windows (WRAM), synchronous graphics (SGRAM), and multiport (M-DRAM).

Market Share Methodology

Dataquest uses primary and secondary sources to produce market statistics. The Memories Worldwide program surveys companies once a year to collect shipment data for each quarter of the previous year. Dataquest supplements this survey effort with additional primary and secondary research to verify market size, shipment totals, and pricing information. Dataquest's sources include the following:

- Device manufacturer surveys
- Information published by major industry participants
- Estimates made by knowledgeable and reliable industry spokespersons
- Industry or trade association data (including SIA-WSTS)
- Government data
- Published product literature and price lists
- Interviews with knowledgeable manufacturers, distributors, and users
- Relevant economic data
- Information and data from online or CD-ROM data banks
- Articles in both the general and trade press
- Reports from financial analysts
- End-user surveys

Despite the care taken in gathering, analyzing, and categorizing the data in a meaningful way, differences between Dataquest's data and other available data may exist. Various companies, government agencies, and trade associations may use different product or regional definitions or may include different companies in their summaries. Please keep these differences in mind when comparing data and numbers provided by Dataquest with those provided by other research companies.

Notes to Market Share Tables

To report market data in a more meaningful way, Dataquest sometimes consolidates or revises the numbers for a particular company, model, series, or industry. These notes explain any such changes contained in this document.

- In 1992, MOSel and Vitelic merged to form Mosel Vitelic, which Dataquest listed as an Asia/Pacific device manufacturer.
- In 1993, NMB Semiconductor changed its business name to Nittetsu Semiconductor.
- In 1993, Dataquest included MOS memory shipments from International Business Machines.
- In 1994, Dataquest changed Nittetsu Semiconductor to Nippon Steel Semiconductor.
- In 1994, Dataquest included MOS memory shipments from Alliance Semiconductor.

- In 1995, Dataquest included MOS memory shipments from G-Link.
- In 1995, Dataquest included MOS memory shipments from Integrated Silicon Solution Inc.
- In 1995, Dataquest changed Goldstar to LG Semicon.
- In 1995, Dataquest included MOS memory shipments from Vanguard International.
- In 1996, Dataquest included MOS memory shipments from Ramtron International.
- In 1996, Dataquest included MOS memory shipments from Silicon Storage Technology.
- In 1996, Dataquest included MOS memory shipments from Nan Ya Technology.

Chapter 2
Market Statistics Tables

Table 2-1
Each Company's Quarterly Shipments of DRAM by Configuration to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Alliance					
All 4Mb	-	-	300	3,500	3,800
Vendor Total	-	-	300	3,500	3,800
Fujitsu					
All 256K	340	200	130	100	770
All 1Mb	7,500	5,700	4,800	4,500	22,500
All 2Mb	70	93	36	40	239
All 4Mb	20,500	17,000	10,500	12,000	60,000
All 8Mb	10	50	900	1,200	2,160
All 16Mb	10,000	10,300	12,500	13,100	45,900
All 64Mb	-	-	1	70	72
Vendor Total	38,420	33,343	28,867	31,010	131,641
G-Link					
All 1Mb	-	-	200	2,300	2,500
All 4Mb	-	-	-	850	850
Vendor Total	-	-	200	3,150	3,350
Hitachi					
All 256K	1,110	950	785	625	3,470
All 1Mb	5	4	4	4	16
All 2Mb	550	540	530	520	2,140
All 4Mb	31,000	28,200	27,000	23,000	109,200
All 16Mb	20,700	24,600	31,200	45,000	121,500
All 64Mb	-	-	-	300	300
Vendor Total	53,365	54,294	59,519	69,449	236,626
Hyundai					
All 1Mb	5,300	3,750	3,000	2,150	14,200
All 4Mb	35,000	32,000	27,000	22,200	116,200
All 16Mb	19,050	23,150	27,550	31,875	101,625
All 64Mb	-	-	100	300	400
Vendor Total	59,350	58,900	57,650	56,525	232,425

Table 2-1 (Continued)
Each Company's Quarterly Shipments of DRAM by Configuration to the World, 1996
(Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
IBM Microelectronics					
All 4Mb	18,800	15,800	14,800	11,500	60,900
All 8Mb	-	-	-	2	2
All 16Mb	5,200	6,400	9,100	14,070	34,770
All 64Mb	21	60	150	170	401
Vendor Total	24,021	22,260	24,050	25,742	96,073
LG Semicon					
All 1Mb	2,775	2,200	1,700	1,275	7,950
All 4Mb	28,600	25,300	20,900	15,500	90,300
All 16Mb	12,900	18,500	24,300	30,600	86,300
All 64Mb	-	-	100	300	400
Vendor Total	44,275	46,000	47,000	47,675	184,950
Matsushita					
All 256K	310	270	240	240	1,060
All 1Mb	2,080	2,030	1,975	1,920	8,005
All 4Mb	8,700	7,400	6,100	4,800	27,000
All 16Mb	1,100	1,600	2,100	2,600	7,400
Vendor Total	12,190	11,300	10,415	9,560	43,465
Micron					
All 1Mb	350	150	50	-	550
All 4Mb	49,000	48,000	45,000	28,000	170,000
All 16Mb	2,500	4,200	9,500	18,450	34,650
Vendor Total	51,850	52,350	54,550	46,450	205,200
Mitsubishi					
All 256K	200	105	-	-	305
All 1Mb	9,000	8,000	8,000	8,000	33,000
All 4Mb	16,000	15,900	17,500	15,300	64,700
All 16Mb	11,700	14,000	16,800	20,200	62,700
All 64Mb	-	-	15	45	60
Vendor Total	36,900	38,005	42,315	43,545	160,765
Mosel Vitelic					
All 256K	40	50	90	25	205
All 1Mb	3,000	2,600	2,800	3,800	12,200
All 2Mb	4,475	5,365	5,100	6,100	21,040
All 4Mb	3,200	9,400	16,400	23,500	52,500
All 16Mb	255	215	235	5	710
Vendor Total	10,970	17,630	24,625	33,430	86,655

Table 2-1 (Continued)
Each Company's Quarterly Shipments of DRAM by Configuration to the World, 1996
(Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Motorola					
All 1Mb	278	67	-	-	345
All 4Mb	6,120	4,200	1,365	1,475	13,160
All 16Mb	2,200	2,400	2,800	3,500	10,900
All 64Mb	-	-	-	10	10
Vendor Total	8,598	6,667	4,165	4,985	24,415
Nan Ya Technology					
All 16Mb	-	3	1,200	1,203	2,406
Vendor Total	-	3	1,200	1,203	2,406
NEC					
All 256K	2,400	2,400	2,100	2,100	9,000
All 1Mb	1,800	1,700	1,600	1,500	6,600
All 2Mb	2,500	2,500	2,500	2,300	9,800
All 4Mb	30,880	23,815	19,455	17,300	91,450
All 8Mb	400	700	600	200	1,900
All 16Mb	24,900	25,160	31,300	37,300	118,660
All 64Mb	33	150	500	1,200	1,883
Vendor Total	62,913	56,425	58,055	61,900	239,293
Nippon Steel					
All 1Mb	3,550	2,500	4,050	4,270	14,370
All 4Mb	6,000	7,135	9,045	8,800	30,980
All 16Mb	40	40	60	115	255
Vendor Total	9,590	9,675	13,155	13,185	45,605
Oki					
All 256K	40	50	90	25	205
All 1Mb	5,550	5,440	5,325	5,215	21,530
All 2Mb	600	480	360	240	1,680
All 4Mb	6,000	6,500	9,500	7,000	29,000
All 16Mb	1,800	1,800	1,900	1,940	7,440
Vendor Total	13,990	14,270	17,175	14,420	59,855
Ramtron International					
All 4Mb	315	775	580	740	2,410
Vendor Total	315	775	580	740	2,410
Samsung					
All 1Mb	3,820	3,600	3,500	3,150	14,070
All 2Mb	1,640	1,600	1,430	1,570	6,240
All 4Mb	27,000	21,000	25,000	26,000	99,000
All 8Mb	3,800	3,900	4,350	4,950	17,000

Table 2-1 (Continued)
Each Company's Quarterly Shipments of DRAM by Configuration to the World, 1996
(Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
All 16Mb	39,000	26,800	45,000	60,000	170,800
All 64Mb	100	299	595	1,450	2,444
Vendor Total	75,360	57,199	79,875	97,120	309,554
Sanyo					
All 256K	750	900	700	650	3,000
All 1Mb	11,000	13,000	10,000	7,000	41,000
All 2Mb	1,000	1,400	1,000	600	4,000
All 4Mb	2	4	2	2	10
Vendor Total	12,752	15,304	11,702	8,252	48,010
Sharp					
All 256K	120	100	80	60	360
All 1Mb	1,660	1,675	1,685	1,695	6,715
All 4Mb	750	1,050	1,300	1,600	4,700
Vendor Total	2,530	2,825	3,065	3,355	11,775
Siemens					
All 1Mb	2,400	2,400	2,100	1,200	8,100
All 4Mb	10,500	16,500	17,500	13,000	57,500
All 16Mb	5,000	6,000	8,000	11,000	30,000
All 64Mb	-	30	80	250	360
Vendor Total	17,900	24,930	27,680	25,450	95,960
Texas Instruments					
All 256K	225	175	125	90	615
All 1Mb	1,740	1,950	2,170	2,385	8,245
All 4Mb	30,300	26,800	25,000	23,100	105,200
All 16Mb	12,200	19,000	24,000	30,000	85,200
All 64Mb	-	15	53	198	266
Vendor Total	44,465	47,940	51,348	55,773	199,526
Toshiba					
All 1Mb	11,675	10,100	8,510	6,920	37,205
All 2Mb	3,400	3,770	4,140	4,510	15,820
All 4Mb	22,000	19,500	16,800	14,000	72,300
All 16Mb	14,300	15,300	19,000	23,000	71,600
All 64Mb	-	-	30	100	130
Vendor Total	51,375	48,670	48,480	48,530	197,055
Vanguard					
All 4Mb	7,500	9,000	17,000	8,500	42,000
All 16Mb	-	-	-	3,500	3,500
Vendor Total	7,500	9,000	17,000	12,000	45,500

Table 2-1 (Continued)
Each Company's Quarterly Shipments of DRAM by Configuration to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Market Total					
All 256K	5,535	5,200	4,340	3,915	18,990
All 1Mb	73,483	66,866	61,469	57,284	259,101
All 2Mb	14,235	15,748	15,096	15,880	60,959
All 4Mb	358,167	335,279	328,047	281,667	1,303,160
All 8Mb	4,210	4,650	5,850	6,352	21,062
All 16Mb	182,845	199,468	266,545	347,458	996,316
All 64Mb	154	554	1,624	4,393	6,725
Total	638,628	627,764	682,971	716,949	2,666,312
Percentage Change from Previous Quarter		-5.1	-1.7	8.8	5.0
Average Selling Price ($)	16.22	9.84	7.80	7.72	10.27
Revenue ($M)	10,359,545	6,176,986	5,324,751	5,533,663	27,394,945
Market Share (% of Units)					
Americas Companies	20.2	20.7	19.8	19.6	20.1
European Companies	2.8	4.0	4.1	3.5	3.6
Japanese Companies	46.0	45.3	42.9	42.3	44.0
Asia/Pacific Companies	30.9	30.1	33.3	34.6	32.3
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-2
Each Company's Quarterly Shipments of 256K DRAM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Fujitsu					
64Kx4					
Video RAM	340	200	130	100	770
Total	340	200	130	100	770
Vendor Total					
Video RAM	340	200	130	100	770
Total	340	200	130	100	770
Hitachi					
256Kx1					
Standard	85	55	50	30	220
Total	85	55	50	30	220
64Kx4					
Standard	55	40	30	30	155
Video RAM	970	855	705	565	3,095
Total	1,025	895	735	595	3,250
Vendor Total					
Standard	140	95	80	60	375
Video RAM	970	855	705	565	3,095
Total	1,110	950	785	625	3,470
Matsushita					
256Kx1					
Standard	70	30	-	-	100
Total	70	30	-	-	100
64Kx4					
Standard	80	80	80	80	320
Video RAM	160	160	160	160	640
Total	240	240	240	240	960
Vendor Total					
Standard	150	110	80	80	420
Video RAM	160	160	160	160	640
Total	310	270	240	240	1,060
Mitsubishi					
64Kx4					
Video RAM	200	105	-	-	305
Total	200	105	-	-	305
Vendor Total					
Video RAM	200	105	-	-	305
Total	200	105	-	-	305

Table 2-2 (Continued)
Each Company's Quarterly Shipments of 256K DRAM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Mosel Vitelic					
64Kx4					
Standard	40	50	90	25	205
Total	40	50	90	25	205
Vendor Total					
Standard	40	50	90	25	205
Total	40	50	90	25	205
NEC					
256Kx1					
Standard	480	480	420	420	1,800
Total	480	480	420	420	1,800
64Kx4					
Standard	1,200	1,200	1,050	1,050	4,500
Video RAM	720	720	630	630	2,700
Total	1,920	1,920	1,680	1,680	7,200
Vendor Total					
Standard	1,680	1,680	1,470	1,470	6,300
Video RAM	720	720	630	630	2,700
Total	2,400	2,400	2,100	2,100	9,000
Oki					
64Kx4					
Standard	40	50	90	25	205
Total	40	50	90	25	205
Vendor Total					
Standard	40	50	90	25	205
Total	40	50	90	25	205
Sanyo					
256Kx1					
Standard	750	900	700	650	3,000
Total	750	900	700	650	3,000
Vendor Total					
Standard	750	900	700	650	3,000
Total	750	900	700	650	3,000
Sharp					
256Kx1					
Standard	10	10	10	5	35
Total	10	10	10	5	35
64Kx4					
Standard	110	90	70	55	325
Total	110	90	70	55	325

Table 2-2 (Continued)
Each Company's Quarterly Shipments of 256K DRAM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Vendor Total					
Standard	120	100	80	60	360
Total	120	100	80	60	360
Texas Instruments					
256Kx1					
Standard	125	95	70	50	340
Total	125	95	70	50	340
64Kx4					
Video RAM	100	80	55	40	275
Total	100	80	55	40	275
Vendor Total					
Standard	125	95	70	50	340
Video RAM	100	80	55	40	275
Total	225	175	125	90	615
Market Total					
256Kx1					
Standard	1,520	1,570	1,250	1,155	5,495
Total	1,520	1,570	1,250	1,155	5,495
64Kx4					
Standard	1,525	1,510	1,410	1,265	5,710
Video RAM	2,490	2,120	1,680	1,495	7,785
Total	4,015	3,630	3,090	2,760	13,495
All 256K					
Standard	3,045	3,080	2,660	2,420	11,205
Video RAM	2,490	2,120	1,680	1,495	7,785
Total	5,535	5,200	4,340	3,915	18,990
% Change from Previous Quarter	-6.4	-6.1	-16.5	-9.8	-
Average Selling Price ($)	2.09	1.88	1.69	1.52	1.82
Revenue ($M)	11,568	9,776	7,335	5,951	34,630
Market Share (% of Units)					
Americas Companies	4.1	3.4	2.9	2.3	3.2
European Companies	-	-	-	-	-
Japanese Companies	95.2	95.7	95.0	97.1	95.7
Asia/Pacific Companies	0.7	1.0	2.1	0.6	1.1
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-3
Each Company's Quarterly Shipments of 1Mb DRAM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Fujitsu					
1Mbx1					
Standard	4,000	2,700	1,800	1,500	10,000
Total	4,000	2,700	1,800	1,500	10,000
256Kx4					
Standard	3,500	3,000	3,000	3,000	12,500
Video RAM	-	-	-	-	-
Total	3,500	3,000	3,000	3,000	12,500
Vendor Total					
Standard	7,500	5,700	4,800	4,500	22,500
Video RAM	-	-	-	-	-
Total	7,500	5,700	4,800	4,500	22,500
G-Link					
128Kx8					
Standard	-	-	200	2,300	2,500
Total	-	-	200	2,300	2,500
Vendor Total					
Standard	-	-	200	2,300	2,500
Total	-	-	200	2,300	2,500
Hitachi					
1Mbx1					
Standard	3	3	3	3	12
Total	3	3	3	3	12
256Kx4					
Standard	2	1	1	1	5
Total	2	1	1	1	5
Vendor Total					
Standard	5	4	4	4	16
Total	5	4	4	4	16
Hyundai					
1Mbx1					
Standard	2,300	1,750	1,250	950	6,250
Total	2,300	1,750	1,250	950	6,250
256Kx4					
Standard	3,000	2,000	1,750	1,200	7,950
Total	3,000	2,000	1,750	1,200	7,950
Vendor Total					
Standard	5,300	3,750	3,000	2,150	14,200
Total	5,300	3,750	3,000	2,150	14,200

Table 2-3 (Continued)
Each Company's Quarterly Shipments of 1Mb DRAM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
LG Semicon					
1Mbx1					
Standard	1,025	825	675	525	3,050
Total	1,025	825	675	525	3,050
256Kx4					
Standard	1,750	1,375	1,025	750	4,900
Total	1,750	1,375	1,025	750	4,900
Vendor Total					
Standard	2,775	2,200	1,700	1,275	7,950
Total	2,775	2,200	1,700	1,275	7,950
Matsushita					
1Mbx1					
Standard	330	310	285	260	1,185
Total	330	310	285	260	1,185
256Kx4					
Standard	850	790	730	670	3,040
Video RAM	900	930	960	990	3,780
Total	1,750	1,720	1,690	1,660	6,820
Vendor Total					
Standard	1,180	1,100	1,015	930	4,225
Video RAM	900	930	960	990	3,780
Total	2,080	2,030	1,975	1,920	8,005
Micron					
1Mbx1					
Standard	160	50	-	-	210
Total	160	50	-	-	210
256Kx4					
Video RAM	190	100	50	-	340
Total	190	100	50	-	340
Vendor Total					
Standard	160	50	-	-	210
Video RAM	190	100	50	-	340
Total	350	150	50	-	550
Mitsubishi					
1Mbx1					
Standard	2,000	1,500	1,500	1,000	6,000
Total	2,000	1,500	1,500	1,000	6,000
256Kx4					
Standard	2,000	1,500	1,500	1,000	6,000
Total	2,000	1,500	1,500	1,000	6,000

Table 2-3 (Continued)
Each Company's Quarterly Shipments of 1Mb DRAM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
128Kx8					
Standard	1,000	1,000	1,000	1,000	4,000
Total	1,000	1,000	1,000	1,000	4,000
64Kx16					
Standard	4,000	4,000	4,000	5,000	17,000
Total	4,000	4,000	4,000	5,000	17,000
Vendor Total					
Standard	9,000	8,000	8,000	8,000	33,000
Total	9,000	8,000	8,000	8,000	33,000
Mosel Vitelic					
256Kx4					
Standard	500	300	300	300	1,400
Total	500	300	300	300	1,400
128Kx8					
Standard	2,000	2,000	2,000	2,000	8,000
Total	2,000	2,000	2,000	2,000	8,000
64Kx16					
Standard	500	300	500	1,500	2,800
Total	500	300	500	1,500	2,800
Vendor Total					
Standard	3,000	2,600	2,800	3,800	12,200
Total	3,000	2,600	2,800	3,800	12,200
Motorola					
1Mbx1					
Standard	278	67	-	-	345
Total	278	67	-	-	345
Vendor Total					
Standard	278	67	-	-	345
Total	278	67	-	-	345
NEC					
1Mbx1					
Standard	540	510	480	450	1,980
Total	540	510	480	450	1,980
256Kx4					
Standard	720	680	640	600	2,640
Video RAM	540	510	480	450	1,980
Total	1,260	1,190	1,120	1,050	4,620

Table 2-3 (Continued)
Each Company's Quarterly Shipments of 1Mb DRAM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Vendor Total					
Standard	1,260	1,190	1,120	1,050	4,620
Video RAM	540	510	480	450	1,980
Total	1,800	1,700	1,600	1,500	6,600
Nippon Steel					
1Mbx1					
Standard	970	850	800	980	3,600
Total	970	850	800	980	3,600
256Kx4					
Standard	2,580	1,650	2,970	2,580	9,780
Total	2,580	1,650	2,970	2,580	9,780
128Kx8					
Standard	-	-	-	100	100
Total	-	-	-	100	100
64Kx16					
Standard	-	-	280	610	890
Total	-	-	280	610	890
Vendor Total					
Standard	3,550	2,500	4,050	4,270	14,370
Total	3,550	2,500	4,050	4,270	14,370
Oki					
1Mbx1					
Standard	3,350	3,320	3,290	3,260	13,220
Total	3,350	3,320	3,290	3,260	13,220
256Kx4					
Standard	2,000	1,950	1,900	1,850	7,700
Video RAM	200	170	135	105	610
Total	2,200	2,120	2,035	1,955	8,310
Vendor Total					
Standard	5,350	5,270	5,190	5,110	20,920
Video RAM	200	170	135	105	610
Total	5,550	5,440	5,325	5,215	21,530
Samsung					
1Mbx1					
Standard	2,000	1,940	1,970	1,750	7,660
Total	2,000	1,940	1,970	1,750	7,660
256Kx4					
Standard	1,700	1,660	1,530	1,400	6,290
Video RAM	50	-	-	-	50
Total	1,750	1,660	1,530	1,400	6,340

Table 2-3 (Continued)
Each Company's Quarterly Shipments of 1Mb DRAM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
128Kx8					
Video RAM	70	-	-	-	70
Total	70	-	-	-	70
Vendor Total					
Standard	3,700	3,600	3,500	3,150	13,950
Video RAM	120	-	-	-	120
Total	3,820	3,600	3,500	3,150	14,070
Sanyo					
1Mbx1					
Standard	4,400	5,200	4,000	2,800	16,400
Total	4,400	5,200	4,000	2,800	16,400
256Kx4					
Video RAM	6,600	7,800	6,000	4,200	24,600
Total	6,600	7,800	6,000	4,200	24,600
Vendor Total					
Standard	4,400	5,200	4,000	2,800	16,400
Video RAM	6,600	7,800	6,000	4,200	24,600
Total	11,000	13,000	10,000	7,000	41,000
Sharp					
256Kx4					
Standard	1,660	1,675	1,685	1,695	6,715
Total	1,660	1,675	1,685	1,695	6,715
Vendor Total					
Standard	1,660	1,675	1,685	1,695	6,715
Total	1,660	1,675	1,685	1,695	6,715
Siemens					
256Kx4					
Standard	2,400	2,400	2,100	1,200	8,100
Total	2,400	2,400	2,100	1,200	8,100
Vendor Total					
Standard	2,400	2,400	2,100	1,200	8,100
Total	2,400	2,400	2,100	1,200	8,100
Texas Instruments					
256Kx4					
Video RAM	1,390	1,595	1,800	2,000	6,785
Total	1,390	1,595	1,800	2,000	6,785
128Kx8					
Standard	280	300	325	350	1,255
Total	280	300	325	350	1,255

Table 2-3 (Continued)
Each Company's Quarterly Shipments of 1Mb DRAM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
64Kx16					
Standard	70	55	45	35	205
Total	70	55	45	35	205
Vendor Total					
Standard	350	355	370	385	1,460
Video RAM	1,390	1,595	1,800	2,000	6,785
Total	1,740	1,950	2,170	2,385	8,245
Toshiba					
1Mbx1					
Standard	5,850	5,200	4,550	3,900	19,500
Total	5,850	5,200	4,550	3,900	19,500
256Kx4					
Standard	4,500	3,760	3,020	2,280	13,560
Video RAM	1,325	1,140	940	740	4,145
Total	5,825	4,900	3,960	3,020	17,705
Vendor Total					
Standard	10,350	8,960	7,570	6,180	33,060
Video RAM	1,325	1,140	940	740	4,145
Total	11,675	10,100	8,510	6,920	37,205
Market Total					
1Mbx1					
Standard	27,206	24,225	20,603	17,378	89,411
Total	27,206	24,225	20,603	17,378	89,411
256Kx4					
Standard	27,162	22,741	22,151	18,526	90,580
Video RAM	11,195	12,245	10,365	8,485	42,290
Total	38,357	34,986	32,516	27,011	132,870
128Kx8					
Standard	3,280	3,300	3,525	5,750	15,855
Video RAM	70	-	-	-	70
Total	3,350	3,300	3,525	5,750	15,925
64Kx16					
Standard	4,570	4,355	4,825	7,145	20,895
Total	4,570	4,355	4,825	7,145	20,895
All 1Mb					
Standard	62,218	54,621	51,104	48,799	216,741
Video RAM	11,265	12,245	10,365	8,485	42,360
Total	73,483	66,866	61,469	57,284	259,101

Table 2-3 (Continued)
Each Company's Quarterly Shipments of 1Mb DRAM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
% Change from Previous Quarter	-25.7	-9.0	-8.1	-6.8	-
Average Selling Price ($)	3.83	3.77	3.37	3.13	3.55
Revenue ($M)	281,666	252,183	207,150	179,387	920,385
Market Share (% of Units)					
Americas Companies	3.2	3.2	3.9	8.2	4.5
European Companies	3.3	3.6	3.4	2.1	3.1
Japanese Companies	73.2	75.0	74.8	71.6	73.7
Asia/Pacific Companies	20.3	18.2	17.9	18.1	18.7
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-4
Each Company's Quarterly Shipments of 2Mb DRAM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Fujitsu					
512Kx4					
Video RAM	70	93	36	40	239
Total	70	93	36	40	239
Vendor Total					
Video RAM	70	93	36	40	239
Total	70	93	36	40	239
Hitachi					
512Kx4					
Video RAM	550	540	530	520	2,140
Total	550	540	530	520	2,140
Vendor Total					
Video RAM	550	540	530	520	2,140
Total	550	540	530	520	2,140
Mosel Vitelic					
256Kx8					
Standard	4,165	5,000	4,545	4,200	17,910
Video RAM	100	25	10	-	135
Total	4,265	5,025	4,555	4,200	18,045
128Kx16					
Standard	210	340	545	1,900	2,995
Total	210	340	545	1,900	2,995
Vendor Total					
Standard	4,375	5,340	5,090	6,100	20,905
Video RAM	100	25	10	-	135
Total	4,475	5,365	5,100	6,100	21,040
NEC					
256Kx8					
Video RAM	2,500	2,500	2,500	2,300	9,800
Total	2,500	2,500	2,500	2,300	9,800
Vendor Total					
Video RAM	2,500	2,500	2,500	2,300	9,800
Total	2,500	2,500	2,500	2,300	9,800
Oki					
256Kx8					
Standard	600	480	360	240	1,680
Total	600	480	360	240	1,680
Vendor Total					
Standard	600	480	360	240	1,680
Total	600	480	360	240	1,680

Table 2-4 (Continued)
Each Company's Quarterly Shipments of 2Mb DRAM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Samsung					
256Kx8					
Video RAM	1,640	1,600	1,430	1,570	6,240
Total	1,640	1,600	1,430	1,570	6,240
Vendor Total					
Video RAM	1,640	1,600	1,430	1,570	6,240
Total	1,640	1,600	1,430	1,570	6,240
Sanyo					
512Kx4					
Video RAM	700	980	700	420	2,800
Total	700	980	700	420	2,800
256Kx8					
Video RAM	300	420	300	180	1,200
Total	300	420	300	180	1,200
Vendor Total					
Video RAM	1,000	1,400	1,000	600	4,000
Total	1,000	1,400	1,000	600	4,000
Toshiba					
256Kx8					
Video RAM	3,400	3,770	4,140	4,510	15,820
Total	3,400	3,770	4,140	4,510	15,820
Vendor Total					
Video RAM	3,400	3,770	4,140	4,510	15,820
Total	3,400	3,770	4,140	4,510	15,820
Market Total					
512Kx4					
Video RAM	1,320	1,613	1,266	980	5,179
Total	1,320	1,613	1,266	980	5,179
256Kx8					
Standard	4,765	5,480	4,905	4,440	19,590
Video RAM	7,940	8,315	8,380	8,560	33,195
Total	12,705	13,795	13,285	13,000	52,785
128Kx16					
Standard	210	340	545	1,900	2,995
Total	210	340	545	1,900	2,995
All 2Mb					
Standard	4,975	5,820	5,450	6,340	22,585
Video RAM	9,260	9,928	9,646	9,540	38,374
Total	14,235	15,748	15,096	15,880	60,959

Table 2-4 (Continued)
Each Company's Quarterly Shipments of 2Mb DRAM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
% Change from Previous Quarter	1.1	10.6	-4.1	5.2	-
Average Selling Price ($)	6.14	4.25	3.30	2.72	4.06
Revenue ($M)	87,403	66,929	49,817	43,194	247,342
Market Share (% of Units)					
Americas Companies	-	-	-	-	-
European Companies	-	-	-	-	-
Japanese Companies	57.0	55.8	56.7	51.7	55.2
Asia/Pacific Companies	43.0	44.2	43.3	48.3	44.8
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-5
Each Company's Quarterly Shipments of 4Mb DRAM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Alliance					
1Mbx4					
Fast Page Mode	-	-	300	3,500	3,800
Total	-	-	300	3,500	3,800
Vendor Total					
Fast Page Mode	-	-	300	3,500	3,800
Total	-	-	300	3,500	3,800
Fujitsu					
4Mbx1					
Fast Page Mode	870	690	405	250	2,215
Extended Data Out	150	160	115	175	600
Total	1,020	850	520	425	2,815
1Mbx4					
Fast Page Mode	10,455	7,850	3,960	1,980	24,245
Extended Data Out	1,845	1,840	1,190	4,640	9,515
Total	12,300	9,690	5,150	6,620	33,760
512Kx8					
Fast Page Mode	875	1,100	650	250	2,875
Extended Data Out	150	260	185	180	775
Total	1,025	1,360	835	430	3,650
256Kx16					
Fast Page Mode	5,230	4,130	3,070	2,475	14,905
Extended Data Out	925	970	925	2,050	4,870
Total	6,155	5,100	3,995	4,525	19,775
Vendor Total					
Fast Page Mode	17,430	13,770	8,085	4,955	44,240
Extended Data Out	3,070	3,230	2,415	7,045	15,760
Total	20,500	17,000	10,500	12,000	60,000
G-Link					
256Kx16					
Fast Page Mode	-	-	-	100	100
Extended Data Out	-	-	-	750	750
Total	-	-	-	850	850
Vendor Total					
Fast Page Mode	-	-	-	100	100
Extended Data Out	-	-	-	750	750
Total	-	-	-	850	850

Table 2-5 (Continued)
Each Company's Quarterly Shipments of 4Mb DRAM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Hitachi					
4Mbx1					
Fast Page Mode	2,500	2,300	2,000	1,650	8,450
Total	2,500	2,300	2,000	1,650	8,450
1Mbx4					
Fast Page Mode	11,500	9,200	7,360	5,225	33,285
Extended Data Out	2,700	3,800	4,785	5,125	16,410
Total	14,200	13,000	12,145	10,350	49,695
512Kx8					
Fast Page Mode	2,300	1,800	1,500	1,065	6,665
Extended Data Out	600	750	975	1,040	3,365
Total	2,900	2,550	2,475	2,105	10,030
512Kx9					
Fast Page Mode	300	250	230	200	980
Total	300	250	230	200	980
256Kx16					
Fast Page Mode	8,400	6,700	5,800	4,140	25,040
Extended Data Out	2,000	2,800	3,775	4,055	12,630
Total	10,400	9,500	9,575	8,195	37,670
256Kx18					
Fast Page Mode	700	600	575	500	2,375
Total	700	600	575	500	2,375
Vendor Total					
Fast Page Mode	25,700	20,850	17,465	12,780	76,795
Extended Data Out	5,300	7,350	9,535	10,220	32,405
Total	31,000	28,200	27,000	23,000	109,200
Hyundai					
4Mbx1					
Fast Page Mode	4,000	4,200	3,000	2,700	13,900
Total	4,000	4,200	3,000	2,700	13,900
1Mbx4					
Fast Page Mode	14,000	7,200	3,500	1,000	25,700
Extended Data Out	6,000	10,700	10,500	10,400	37,600
Total	20,000	17,900	14,000	11,400	63,300
256Kx16					
Fast Page Mode	9,000	4,600	3,000	800	17,400
Extended Data Out	2,000	5,300	7,000	7,300	21,600
Total	11,000	9,900	10,000	8,100	39,000

Table 2-5 (Continued)
Each Company's Quarterly Shipments of 4Mb DRAM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Vendor Total					
Fast Page Mode	27,000	16,000	9,500	4,500	57,000
Extended Data Out	8,000	16,000	17,500	17,700	59,200
Total	35,000	32,000	27,000	22,200	116,200
IBM Microelectronics					
1Mbx4					
Fast Page Mode	17,000	4,000	4,000	2,000	27,000
Extended Data Out	-	10,000	9,000	7,000	26,000
Total	17,000	14,000	13,000	9,000	53,000
256Kx16					
Video RAM	1,800	1,800	1,800	2,500	7,900
Total	1,800	1,800	1,800	2,500	7,900
Vendor Total					
Fast Page Mode	17,000	4,000	4,000	2,000	27,000
Extended Data Out	-	10,000	9,000	7,000	26,000
Video RAM	1,800	1,800	1,800	2,500	7,900
Total	18,800	15,800	14,800	11,500	60,900
LG Semicon					
4Mbx1					
Fast Page Mode	2,200	2,000	1,500	1,000	6,700
Total	2,200	2,000	1,500	1,000	6,700
1Mbx4					
Fast Page Mode	9,700	6,800	4,100	1,000	21,600
Extended Data Out	10,400	11,000	10,000	8,300	39,700
Total	20,100	17,800	14,100	9,300	61,300
512Kx8					
Fast Page Mode	1,000	900	700	650	3,250
Total	1,000	900	700	650	3,250
256Kx16					
Fast Page Mode	1,400	900	500	300	3,100
Extended Data Out	3,900	3,700	4,100	4,250	15,950
Total	5,300	4,600	4,600	4,550	19,050
Vendor Total					
Fast Page Mode	14,300	10,600	6,800	2,950	34,650
Extended Data Out	14,300	14,700	14,100	12,550	55,650
Total	28,600	25,300	20,900	15,500	90,300

Table 2-5 (Continued)
Each Company's Quarterly Shipments of 4Mb DRAM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Matsushita					
4Mbx1					
Fast Page Mode	700	700	600	500	2,500
Total	700	700	600	500	2,500
1Mbx4					
Fast Page Mode	4,400	4,000	2,000	700	11,100
Extended Data Out	-	-	1,000	1,500	2,500
Total	4,400	4,000	3,000	2,200	13,600
512Kx8					
Fast Page Mode	1,800	900	700	500	3,900
Total	1,800	900	700	500	3,900
256Kx16					
Fast Page Mode	1,800	1,800	1,400	1,000	6,000
Extended Data Out	-	-	400	600	1,000
Total	1,800	1,800	1,800	1,600	7,000
Vendor Total					
Fast Page Mode	8,700	7,400	4,700	2,700	23,500
Extended Data Out	-	-	1,400	2,100	3,500
Total	8,700	7,400	6,100	4,800	27,000
Micron					
4Mbx1					
Fast Page Mode	6,850	5,500	4,900	1,800	19,050
Total	6,850	5,500	4,900	1,800	19,050
1Mbx4					
Fast Page Mode	26,200	19,300	11,600	7,000	64,100
Extended Data Out	10,200	16,800	21,600	14,500	63,100
Total	36,400	36,100	33,200	21,500	127,200
256Kx16					
Fast Page Mode	4,150	3,400	2,400	1,200	11,150
Extended Data Out	1,600	3,000	4,500	3,500	12,600
Total	5,750	6,400	6,900	4,700	23,750
Vendor Total					
Fast Page Mode	37,200	28,200	18,900	10,000	94,300
Extended Data Out	11,800	19,800	26,100	18,000	75,700
Total	49,000	48,000	45,000	28,000	170,000

Table 2-5 (Continued)
Each Company's Quarterly Shipments of 4Mb DRAM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Mitsubishi					
4Mbx1					
Fast Page Mode	900	550	500	500	2,450
Extended Data Out	-	50	100	200	350
Total	900	600	600	700	2,800
1Mbx4					
Fast Page Mode	7,200	7,000	6,500	4,600	25,300
Extended Data Out	-	500	800	900	2,200
Total	7,200	7,500	7,300	5,500	27,500
512Kx8					
Fast Page Mode	900	600	600	800	2,900
Total	900	600	600	800	2,900
256Kx16					
Fast Page Mode	7,000	6,850	7,300	6,400	27,550
Extended Data Out	-	350	1,700	1,900	3,950
Total	7,000	7,200	9,000	8,300	31,500
Vendor Total					
Fast Page Mode	16,000	15,000	14,900	12,300	58,200
Extended Data Out	-	900	2,600	3,000	6,500
Total	16,000	15,900	17,500	15,300	64,700
Mosel Vitelic					
1Mbx4					
Fast Page Mode	200	2,400	3,500	3,500	9,600
Extended Data Out	-	2,000	4,000	7,000	13,000
Total	200	4,400	7,500	10,500	22,600
256Kx16					
Fast Page Mode	2,000	2,500	2,700	3,000	10,200
Extended Data Out	1,000	2,500	6,200	10,000	19,700
Total	3,000	5,000	8,900	13,000	29,900
Vendor Total					
Fast Page Mode	2,200	4,900	6,200	6,500	19,800
Extended Data Out	1,000	4,500	10,200	17,000	32,700
Total	3,200	9,400	16,400	23,500	52,500
Motorola					
4Mbx1					
Fast Page Mode	1,210	750	425	185	2,570
Extended Data Out	380	260	185	125	950
Total	1,590	1,010	610	310	3,520

Table 2-5 (Continued)
Each Company's Quarterly Shipments of 4Mb DRAM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
1Mbx4					
Fast Page Mode	3,440	2,375	145	700	6,660
Extended Data Out	1,090	815	610	465	2,980
Total	4,530	3,190	755	1,165	9,640
Vendor Total					
Fast Page Mode	4,650	3,125	570	885	9,230
Extended Data Out	1,470	1,075	795	590	3,930
Total	6,120	4,200	1,365	1,475	13,160
NEC					
4Mbx1					
Fast Page Mode	3,450	2,640	1,870	1,400	9,360
Total	3,450	2,640	1,870	1,400	9,360
1Mbx4					
Fast Page Mode	8,390	5,100	3,100	2,500	19,090
Extended Data Out	1,110	1,500	665	450	3,725
Total	9,500	6,600	3,765	2,950	22,815
512Kx8					
Fast Page Mode	5,550	3,710	2,970	2,250	14,480
Extended Data Out	800	1,140	925	700	3,565
Total	6,350	4,850	3,895	2,950	18,045
512Kx9					
Fast Page Mode	560	430	345	250	1,585
Total	560	430	345	250	1,585
256Kx16					
Fast Page Mode	7,665	5,620	5,985	6,550	25,820
Extended Data Out	935	1,580	1,710	1,600	5,825
Video RAM	2,090	1,820	1,595	1,325	6,830
Total	10,690	9,020	9,290	9,475	38,475
256Kx18					
Fast Page Mode	330	275	290	275	1,170
Total	330	275	290	275	1,170
Vendor Total					
Fast Page Mode	25,945	17,775	14,560	13,225	71,505
Extended Data Out	2,845	4,220	3,300	2,750	13,115
Video RAM	2,090	1,820	1,595	1,325	6,830
Total	30,880	23,815	19,455	17,300	91,450

Table 2-5 (Continued)
Each Company's Quarterly Shipments of 4Mb DRAM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Nippon Steel					
1Mbx4					
Fast Page Mode	3,400	3,270	2,815	1,700	11,185
Extended Data Out	1,600	2,220	3,880	4,000	11,700
Total	5,000	5,490	6,695	5,700	22,885
256Kx16					
Fast Page Mode	600	845	1,040	1,300	3,785
Extended Data Out	400	800	1,310	1,800	4,310
Total	1,000	1,645	2,350	3,100	8,095
Vendor Total					
Fast Page Mode	4,000	4,115	3,855	3,000	14,970
Extended Data Out	2,000	3,020	5,190	5,800	16,010
Total	6,000	7,135	9,045	8,800	30,980
Oki					
4Mbx1					
Fast Page Mode	850	650	950	700	3,150
Total	850	650	950	700	3,150
1Mbx4					
Fast Page Mode	3,900	3,800	3,650	900	12,250
Extended Data Out	-	425	1,550	1,500	3,475
Total	3,900	4,225	5,200	2,400	15,725
512Kx8					
Fast Page Mode	250	325	200	200	975
Total	250	325	200	200	975
256Kx16					
Fast Page Mode	1,000	1,175	2,200	2,200	6,575
Extended Data Out	-	125	950	1,500	2,575
Total	1,000	1,300	3,150	3,700	9,150
Vendor Total					
Fast Page Mode	6,000	5,950	7,000	4,000	22,950
Extended Data Out	-	550	2,500	3,000	6,050
Total	6,000	6,500	9,500	7,000	29,000
Ramtron International					
4Mbx1					
Enhanced DRAM	30	110	105	185	430
Total	30	110	105	185	430
1Mbx4					
Enhanced DRAM	225	525	380	420	1,550
Total	225	525	380	420	1,550

Table 2-5 (Continued)
Each Company's Quarterly Shipments of 4Mb DRAM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
512Kx8					
Enhanced DRAM	60	140	95	135	430
Total	60	140	95	135	430
Vendor Total					
Enhanced DRAM	315	775	580	740	2,410
Total	315	775	580	740	2,410
Samsung					
4Mbx1					
Fast Page Mode	2,400	2,100	2,300	2,500	9,300
Total	2,400	2,100	2,300	2,500	9,300
1Mbx4					
Fast Page Mode	8,500	4,000	400	600	13,500
Extended Data Out	1,000	3,400	8,400	8,550	21,350
Total	9,500	7,400	8,800	9,150	34,850
512Kx8					
Fast Page Mode	1,800	370	150	130	2,450
Extended Data Out	600	1,330	1,700	1,900	5,530
Total	2,400	1,700	1,850	2,030	7,980
512Kx9					
Fast Page Mode	200	200	250	220	870
Total	200	200	250	220	870
256Kx16					
Fast Page Mode	3,300	3,000	1,000	1,000	8,300
Extended Data Out	7,700	5,200	9,000	9,300	31,200
Video RAM	1,400	1,300	1,700	1,700	6,100
Total	12,400	9,500	11,700	12,000	45,600
256Kx18					
Fast Page Mode	100	100	100	100	400
Total	100	100	100	100	400
Vendor Total					
Fast Page Mode	16,300	9,770	4,200	4,550	34,820
Extended Data Out	9,300	9,930	19,100	19,750	58,080
Video RAM	1,400	1,300	1,700	1,700	6,100
Total	27,000	21,000	25,000	26,000	99,000

Table 2-5 (Continued)
Each Company's Quarterly Shipments of 4Mb DRAM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Sanyo					
4Mbx1					
Fast Page Mode	2	4	2	2	10
Total	2	4	2	2	10
Vendor Total					
Fast Page Mode	2	4	2	2	10
Total	2	4	2	2	10
Sharp					
1Mbx4					
Fast Page Mode	750	900	900	800	3,350
Extended Data Out	-	150	400	800	1,350
Total	750	1,050	1,300	1,600	4,700
Vendor Total					
Fast Page Mode	750	900	900	800	3,350
Extended Data Out	-	150	400	800	1,350
Total	750	1,050	1,300	1,600	4,700
Siemens					
4Mbx1					
Fast Page Mode	1,575	1,650	1,750	1,300	6,275
Total	1,575	1,650	1,750	1,300	6,275
1Mbx4					
Fast Page Mode	5,565	6,600	6,300	3,250	21,715
Extended Data Out	420	1,320	1,750	1,950	5,440
Total	5,985	7,920	8,050	5,200	27,155
256Kx16					
Fast Page Mode	2,730	6,270	6,650	5,200	20,850
Extended Data Out	210	660	1,050	1,300	3,220
Total	2,940	6,930	7,700	6,500	24,070
Vendor Total					
Fast Page Mode	9,870	14,520	14,700	9,750	48,840
Extended Data Out	630	1,980	2,800	3,250	8,660
Total	10,500	16,500	17,500	13,000	57,500
Texas Instruments					
4Mbx1					
Fast Page Mode	5,500	5,000	4,200	3,000	17,700
Total	5,500	5,000	4,200	3,000	17,700
1Mbx4					
Fast Page Mode	14,400	10,000	7,000	6,800	38,200
Extended Data Out	4,900	6,400	7,200	6,500	25,000
Total	19,300	16,400	14,200	13,300	63,200

Table 2-5 (Continued)
Each Company's Quarterly Shipments of 4Mb DRAM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
256Kx16					
Fast Page Mode	2,300	1,500	1,400	1,000	6,200
Extended Data Out	1,500	2,200	3,600	4,300	11,600
Video RAM	1,700	1,700	1,600	1,500	6,500
Total	5,500	5,400	6,600	6,800	24,300
Vendor Total					
Fast Page Mode	22,200	16,500	12,600	10,800	62,100
Extended Data Out	6,400	8,600	10,800	10,800	36,600
Video RAM	1,700	1,700	1,600	1,500	6,500
Total	30,300	26,800	25,000	23,100	105,200
Toshiba					
4Mbx1					
Fast Page Mode	1,540	1,120	840	540	4,040
Total	1,540	1,120	840	540	4,040
1Mbx4					
Fast Page Mode	6,650	4,095	2,410	1,750	14,905
Extended Data Out	5,450	6,400	4,500	3,400	19,750
Total	12,100	10,495	6,910	5,150	34,655
512Kx8					
Fast Page Mode	200	185	165	100	650
Extended Data Out	170	225	300	355	1,050
Total	370	410	465	455	1,700
512Kx9					
Fast Page Mode	65	70	80	80	295
Total	65	70	80	80	295
256Kx16					
Fast Page Mode	2,900	2,060	1,850	910	7,720
Extended Data Out	2,375	3,520	5,075	5,920	16,890
Video RAM	1,980	1,280	980	540	4,780
Total	7,255	6,860	7,905	7,370	29,390
256Kx18					
Fast Page Mode	670	545	600	405	2,220
Total	670	545	600	405	2,220
Vendor Total					
Fast Page Mode	12,025	8,075	5,945	3,785	29,830
Extended Data Out	7,995	10,145	9,875	9,675	37,690
Video RAM	1,980	1,280	980	540	4,780
Total	22,000	19,500	16,800	14,000	72,300

Table 2-5 (Continued)
Each Company's Quarterly Shipments of 4Mb DRAM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Vanguard					
1Mbx4					
Fast Page Mode	1,500	1,500	1,500	350	4,850
Extended Data Out	6,000	7,050	14,200	6,900	34,150
Total	7,500	8,550	15,700	7,250	39,000
256Kx16					
Fast Page Mode	-	150	100	50	300
Extended Data Out	-	300	1,200	1,200	2,700
Total	-	450	1,300	1,250	3,000
Vendor Total					
Fast Page Mode	1,500	1,650	1,600	400	5,150
Extended Data Out	6,000	7,350	15,400	8,100	36,850
Total	7,500	9,000	17,000	8,500	42,000
Market Total					
4Mbx1					
Fast Page Mode	34,547	29,854	25,242	18,027	107,670
Extended Data Out	530	470	400	500	1,900
Enhanced DRAM	30	110	105	185	430
Total	35,107	30,434	25,747	18,712	110,000
1Mbx4					
Fast Page Mode	157,150	109,390	75,040	49,855	391,435
Extended Data Out	52,715	86,320	106,030	93,880	338,945
Enhanced DRAM	225	525	380	420	1,550
Total	210,090	196,235	181,450	144,155	731,930
512Kx8					
Fast Page Mode	14,675	9,890	7,635	5,945	38,145
Extended Data Out	2,320	3,705	4,085	4,175	14,285
Enhanced DRAM	60	140	95	135	430
Total	17,055	13,735	11,815	10,255	52,860
512Kx9					
Fast Page Mode	1,125	950	905	750	3,730
Total	1,125	950	905	750	3,730
256Kx16					
Fast Page Mode	59,475	51,500	46,395	37,625	194,995
Extended Data Out	24,545	33,005	52,495	61,325	171,370
Video RAM	8,970	7,900	7,675	7,565	32,110
Total	92,990	92,405	106,565	106,515	398,475
256Kx18					
Fast Page Mode	1,800	1,520	1,565	1,280	6,165
Total	1,800	1,520	1,565	1,280	6,165

Table 2-5 (Continued)
Each Company's Quarterly Shipments of 4Mb DRAM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
All 4Mb					
Fast Page Mode	268,772	203,104	156,782	113,482	742,140
Extended Data Out	80,110	123,500	163,010	159,880	526,500
Enhanced DRAM	315	775	580	740	2,410
Video RAM	8,970	7,900	7,675	7,565	32,110
Total	358,167	335,279	328,047	281,667	1,303,160
% Change from Previous Quarter	-15.8	-6.4	-2.2	-14.1	-
Average Selling Price ($)	9.16	6.16	5.18	5.45	6.58
Revenue ($M)	3,279,577	2,064,763	1,699,118	1,533,915	8,577,373
Market Share (% of Units)					
Americas Companies	29.2	28.5	26.5	24.6	27.3
European Companies	2.9	4.9	5.3	4.6	4.4
Japanese Companies	39.6	37.7	35.7	36.9	37.6
Asia/Pacific Companies	28.3	28.8	32.4	34.0	30.7
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-6
Each Company's Quarterly Shipments of 8Mb DRAM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Fujitsu					
256Kx32					
Synchronous Graphics	10	50	900	1,200	2,160
Total	10	50	900	1,200	2,160
Vendor Total					
Synchronous Graphics	10	50	900	1,200	2,160
Total	10	50	900	1,200	2,160
IBM Microelectronics					
256Kx32					
Synchronous Graphics	-	-	-	2	2
Total	-	-	-	2	2
Vendor Total					
Synchronous Graphics	-	-	-	2	2
Total	-	-	-	2	2
NEC					
256Kx32					
Synchronous Graphics	400	700	600	200	1,900
Total	400	700	600	200	1,900
Vendor Total					
Synchronous Graphics	400	700	600	200	1,900
Total	400	700	600	200	1,900
Samsung					
256Kx32					
Synchronous Graphics	1,500	1,900	2,425	3,050	8,875
Windows RAM	2,300	2,000	1,925	1,900	8,125
Total	3,800	3,900	4,350	4,950	17,000
Vendor Total					
Synchronous Graphics	1,500	1,900	2,425	3,050	8,875
Windows RAM	2,300	2,000	1,925	1,900	8,125
Total	3,800	3,900	4,350	4,950	17,000
Market Total					
256Kx32					
Synchronous Graphics	1,910	2,650	3,925	4,452	12,937
Windows RAM	2,300	2,000	1,925	1,900	8,125
Total	4,210	4,650	5,850	6,352	21,062
All 8Mb					
Synchronous Graphics	1,910	2,650	3,925	4,452	12,937
Windows RAM	2,300	2,000	1,925	1,900	8,125
Total	4,210	4,650	5,850	6,352	21,062

Table 2-6 (Continued)
Each Company's Quarterly Shipments of 8Mb DRAM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
% Change from Previous Quarter	NA	10.5	25.8	8.6	-
Average Selling Price ($)	14.38	14.38	14.38	14.38	14.38
Revenue ($M)	60,540	66,867	84,123	91,342	302,872
Market Share (% of Units)					
Americas Companies	-	-	-	-	-
European Companies	-	-	-	-	-
Japanese Companies	9.7	16.1	25.6	22.0	19.3
Asia/Pacific Companies	90.3	83.9	74.4	77.9	80.7
Total	100.0	100.0	100.0	100.0	100.0

NA = Not available
Source: Dataquest (June 1997)

Table 2-7
Each Company's Quarterly Shipments of 16Mb DRAM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Fujitsu					
16Mbx1					
Fast Page Mode	100	105	130	-	335
Total	100	105	130	-	335
4Mbx4					
Fast Page Mode	2,695	2,315	2,145	1,480	8,635
Extended Data Out	1,960	2,575	3,310	4,085	11,930
Total	4,655	4,890	5,455	5,565	20,565
2Mbx8					
Fast Page Mode	1,375	1,180	1,835	990	5,380
Extended Data Out	1,000	1,210	2,300	2,725	7,235
Synchronous	495	520	835	1,125	2,975
Total	2,870	2,910	4,970	4,840	15,590
1Mbx16					
Fast Page Mode	1,375	1,180	865	825	4,245
Extended Data Out	1,000	1,215	1,080	1,870	5,165
Total	2,375	2,395	1,945	2,695	9,410
Vendor Total					
Fast Page Mode	5,545	4,780	4,975	3,295	18,595
Extended Data Out	3,960	5,000	6,690	8,680	24,330
Synchronous	495	520	835	1,125	2,975
Total	10,000	10,300	12,500	13,100	45,900
Hitachi					
16Mbx1					
Fast Page Mode	1,449	1,476	1,250	1,600	5,775
Total	1,449	1,476	1,250	1,600	5,775
4Mbx4					
Fast Page Mode	8,446	6,148	3,240	2,304	20,137
Extended Data Out	2,111	6,273	14,600	25,288	48,272
Total	10,557	12,421	17,840	27,592	68,410
2Mbx8					
Fast Page Mode	1,987	1,447	878	624	4,935
Extended Data Out	497	1,476	2,275	3,328	7,576
Synchronous	-	155	458	976	1,589
Total	2,484	3,078	3,610	4,928	14,100
1Mbx16					
Fast Page Mode	4,968	3,737	2,295	1,632	12,632
Extended Data Out	1,242	3,813	5,950	8,704	19,709
Synchronous	-	76	255	544	875
Total	6,210	7,626	8,500	10,880	33,216

Table 2-7 (Continued)
Each Company's Quarterly Shipments of 16Mb DRAM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Vendor Total					
Fast Page Mode	16,850	12,807	7,663	6,160	43,479
Extended Data Out	3,850	11,562	22,825	37,320	75,557
Synchronous	-	231	713	1,520	2,464
Total	20,700	24,600	31,200	45,000	121,500
Hyundai					
16Mbx1					
Fast Page Mode	50	50	50	75	225
Total	50	50	50	75	225
4Mbx4					
Fast Page Mode	4,500	2,500	2,600	2,000	11,600
Extended Data Out	4,500	6,500	8,000	10,000	29,000
Synchronous	-	-	-	800	800
Total	9,000	9,000	10,600	12,800	41,400
1Mbx16					
Fast Page Mode	5,500	5,500	5,300	3,000	19,300
Extended Data Out	4,500	8,600	11,600	16,000	40,700
Total	10,000	14,100	16,900	19,000	60,000
Vendor Total					
Fast Page Mode	10,050	8,050	7,950	5,075	31,125
Extended Data Out	9,000	15,100	19,600	26,000	69,700
Synchronous	-	-	-	800	800
Total	19,050	23,150	27,550	31,875	101,625
IBM Microelectronics					
4Mbx4					
Fast Page Mode	2,915	2,620	2,390	1,950	9,875
Extended Data Out	1,415	2,565	4,470	7,560	16,010
Synchronous	90	160	600	1,950	2,800
Total	4,420	5,345	7,460	11,460	28,685
2Mbx8					
Fast Page Mode	105	125	145	110	485
Extended Data Out	50	125	275	420	870
Synchronous	3	7	35	110	155
Total	158	257	455	640	1,510
1Mbx16					
Fast Page Mode	410	390	380	335	1,515
Extended Data Out	200	385	710	1,300	2,595
Synchronous	12	23	95	335	465
Total	622	798	1,185	1,970	4,575

Table 2-7 (Continued)
Each Company's Quarterly Shipments of 16Mb DRAM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Vendor Total					
Fast Page Mode	3,430	3,135	2,915	2,395	11,875
Extended Data Out	1,665	3,075	5,455	9,280	19,475
Synchronous	105	190	730	2,395	3,420
Total	5,200	6,400	9,100	14,070	34,770
LG Semicon					
16Mbx1					
Fast Page Mode	200	165	100	100	565
Total	200	165	100	100	565
4Mbx4					
Fast Page Mode	1,525	1,060	700	300	3,585
Extended Data Out	3,375	5,825	7,700	9,900	26,800
Total	4,900	6,885	8,400	10,200	30,385
2Mbx8					
Fast Page Mode	100	-	-	-	100
Total	100	-	-	-	100
1Mbx16					
Fast Page Mode	4,250	5,800	4,500	4,800	19,350
Extended Data Out	3,450	5,650	11,300	15,500	35,900
Total	7,700	11,450	15,800	20,300	55,250
Vendor Total					
Fast Page Mode	6,075	7,025	5,300	5,200	23,600
Extended Data Out	6,825	11,475	19,000	25,400	62,700
Total	12,900	18,500	24,300	30,600	86,300
Matsushita					
16Mbx1					
Fast Page Mode	500	500	400	400	1,800
Total	500	500	400	400	1,800
4Mbx4					
Fast Page Mode	300	500	250	300	1,350
Extended Data Out	-	-	150	300	450
Total	300	500	400	600	1,800
2Mbx8					
Fast Page Mode	100	250	200	125	675
Extended Data Out	-	-	50	75	125
Total	100	250	250	200	800
1Mbx16					
Fast Page Mode	200	350	800	700	2,050
Extended Data Out	-	-	250	700	950
Total	200	350	1,050	1,400	3,000

Table 2-7 (Continued)
Each Company's Quarterly Shipments of 16Mb DRAM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Vendor Total					
Fast Page Mode	1,100	1,600	1,650	1,525	5,875
Extended Data Out	-	-	450	1,075	1,525
Total	1,100	1,600	2,100	2,600	7,400
Micron					
4Mbx4					
Fast Page Mode	700	1,050	1,270	2,200	5,220
Extended Data Out	970	1,750	5,100	10,100	17,920
Total	1,670	2,800	6,370	12,300	23,140
2Mbx8					
Fast Page Mode	20	60	50	100	230
Extended Data Out	10	40	230	450	730
Total	30	100	280	550	960
1Mbx16					
Fast Page Mode	335	490	550	1,000	2,375
Extended Data Out	465	810	2,300	4,600	8,175
Total	800	1,300	2,850	5,600	10,550
Vendor Total					
Fast Page Mode	1,055	1,600	1,870	3,300	7,825
Extended Data Out	1,445	2,600	7,630	15,150	26,825
Total	2,500	4,200	9,500	18,450	34,650
Mitsubishi					
16Mbx1					
Fast Page Mode	700	750	700	700	2,850
Total	700	750	700	700	2,850
4Mbx4					
Fast Page Mode	4,680	4,000	3,000	2,500	14,180
Extended Data Out	1,170	4,000	6,000	7,000	18,170
Synchronous	-	150	200	500	850
Total	5,850	8,150	9,200	10,000	33,200
2Mbx8					
Fast Page Mode	2,250	1,300	1,000	700	5,250
Extended Data Out	560	700	1,000	1,200	3,460
Synchronous	-	100	200	500	800
Total	2,810	2,100	2,200	2,400	9,510
1Mbx16					
Fast Page Mode	1,870	1,500	1,800	2,000	7,170
Extended Data Out	470	1,300	2,600	4,500	8,870
Synchronous	-	200	300	600	1,100
Total	2,340	3,000	4,700	7,100	17,140

Table 2-7 (Continued)
Each Company's Quarterly Shipments of 16Mb DRAM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Vendor Total					
Fast Page Mode	9,500	7,550	6,500	5,900	29,450
Extended Data Out	2,200	6,000	9,600	12,700	30,500
Synchronous	-	450	700	1,600	2,750
Total	11,700	14,000	16,800	20,200	62,700
Mosel Vitelic					
1Mbx16					
Extended Data Out	255	215	235	5	710
Total	255	215	235	5	710
Vendor Total					
Extended Data Out	255	215	235	5	710
Total	255	215	235	5	710
Motorola					
4Mbx4					
Extended Data Out	2,160	2,350	2,730	3,400	10,640
Total	2,160	2,350	2,730	3,400	10,640
1Mbx16					
Extended Data Out	40	50	70	100	260
Total	40	50	70	100	260
Vendor Total					
Extended Data Out	2,200	2,400	2,800	3,500	10,900
Total	2,200	2,400	2,800	3,500	10,900
Nan Ya Technology					
4Mbx4					
Extended Data Out	-	3	1,200	1,203	2,406
Total	-	3	1,200	1,203	2,406
Vendor Total					
Extended Data Out	-	3	1,200	1,203	2,406
Total	-	3	1,200	1,203	2,406
NEC					
16Mbx1					
Fast Page Mode	1,020	780	640	720	3,160
Total	1,020	780	640	720	3,160
4Mbx4					
Fast Page Mode	2,430	865	1,050	1,100	5,445
Extended Data Out	3,285	4,900	9,500	11,100	28,785
Synchronous	500	520	150	2,440	3,610
Total	6,215	6,285	10,700	14,640	37,840

Table 2-7 (Continued)
Each Company's Quarterly Shipments of 16Mb DRAM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
2Mbx8					
Fast Page Mode	2,840	880	710	720	5,150
Extended Data Out	3,840	4,975	6,605	6,980	22,400
Synchronous	600	550	1,030	1,600	3,780
Total	7,280	6,405	8,345	9,300	31,330
2Mbx9					
Synchronous	160	130	160	200	650
Total	160	130	160	200	650
1Mbx16					
Fast Page Mode	3,800	1,520	1,025	1,020	7,365
Extended Data Out	5,140	8,620	8,340	8,440	30,540
Synchronous	1,285	1,420	2,090	2,980	7,775
Total	10,225	11,560	11,455	12,440	45,680
Vendor Total					
Fast Page Mode	10,090	4,045	3,425	3,560	21,120
Extended Data Out	12,265	18,495	24,445	26,520	81,725
Synchronous	2,545	2,620	3,430	7,220	15,815
Total	24,900	25,160	31,300	37,300	118,660
Nippon Steel					
2Mbx8					
Fast Page Mode	6	6	8	10	30
Extended Data Out	4	4	8	15	31
Total	10	10	15	25	60
1Mbx16					
Fast Page Mode	28	28	23	40	119
Extended Data Out	2	2	23	50	77
Total	30	30	45	90	195
Vendor Total					
Fast Page Mode	34	34	30	50	148
Extended Data Out	6	6	30	65	107
Total	40	40	60	115	255
Oki					
16Mbx1					
Fast Page Mode	150	150	100	100	500
Total	150	150	100	100	500
4Mbx4					
Fast Page Mode	1,250	1,350	500	300	3,400
Extended Data Out	-	-	600	800	1,400
Total	1,250	1,350	1,100	1,100	4,800

Table 2-7 (Continued)
Each Company's Quarterly Shipments of 16Mb DRAM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
2Mbx8					
Fast Page Mode	-	-	250	250	500
Extended Data Out	-	-	50	70	120
Total	-	-	300	320	620
1Mbx16					
Fast Page Mode	400	300	320	300	1,320
Extended Data Out	-	-	80	120	200
Total	400	300	400	420	1,520
Vendor Total					
Fast Page Mode	1,800	1,800	1,170	950	5,720
Extended Data Out	-	-	730	990	1,720
Total	1,800	1,800	1,900	1,940	7,440
Samsung					
4Mbx4					
Fast Page Mode	10,500	4,420	1,960	2,550	19,430
Extended Data Out	6,825	13,800	16,660	19,050	56,335
Synchronous	175	180	980	3,800	5,135
Total	17,500	18,400	19,600	25,400	80,900
2Mbx8					
Fast Page Mode	3,600	1,585	690	870	6,745
Extended Data Out	2,340	4,950	5,865	6,530	19,685
Synchronous	60	65	345	1,300	1,770
Total	6,000	6,600	6,900	8,700	28,200
1Mbx16					
Fast Page Mode	9,300	430	1,850	2,600	14,180
Extended Data Out	6,050	1,350	15,725	19,500	42,625
Synchronous	150	20	925	3,800	4,895
Total	15,500	1,800	18,500	25,900	61,700
Vendor Total					
Fast Page Mode	23,400	6,435	4,500	6,020	40,355
Extended Data Out	15,215	20,100	38,250	45,080	118,645
Synchronous	385	265	2,250	8,900	11,800
Total	39,000	26,800	45,000	60,000	170,800
Siemens					
4Mbx4					
Fast Page Mode	3,250	3,240	3,520	2,860	12,870
Extended Data Out	650	960	1,440	3,850	6,900
Total	3,900	4,200	4,960	6,710	19,770

Table 2-7 (Continued)
Each Company's Quarterly Shipments of 16Mb DRAM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
2Mbx8					
Fast Page Mode	450	360	240	330	1,380
Extended Data Out	100	180	160	330	770
Total	550	540	400	660	2,150
1Mbx16					
Fast Page Mode	450	900	1,440	1,320	4,110
Extended Data Out	100	360	1,040	1,980	3,480
Synchronous	-	-	160	330	490
Total	550	1,260	2,640	3,630	8,080
Vendor Total					
Fast Page Mode	4,150	4,500	5,200	4,510	18,360
Extended Data Out	850	1,500	2,640	6,160	11,150
Synchronous	-	-	160	330	490
Total	5,000	6,000	8,000	11,000	30,000
Texas Instruments					
16Mbx1					
Fast Page Mode	1,700	2,000	3,500	3,850	11,050
Extended Data Out	800	900	1,500	1,850	5,050
Total	2,500	2,900	5,000	5,700	16,100
4Mbx4					
Fast Page Mode	2,200	2,600	3,500	5,000	13,300
Extended Data Out	1,500	3,800	5,000	7,350	17,650
Synchronous	200	250	300	900	1,650
Total	3,900	6,650	8,800	13,250	32,600
2Mbx8					
Fast Page Mode	1,000	1,100	1,800	2,100	6,000
Extended Data Out	1,100	1,600	2,100	3,000	7,800
Synchronous	100	150	250	500	1,000
Total	2,200	2,850	4,150	5,600	14,800
1Mbx16					
Fast Page Mode	2,600	4,300	3,000	800	10,700
Extended Data Out	1,000	2,300	3,000	4,250	10,550
Synchronous	-	-	50	400	450
Total	3,600	6,600	6,050	5,450	21,700
Vendor Total					
Fast Page Mode	7,500	10,000	11,800	11,750	41,050
Extended Data Out	4,400	8,600	11,600	16,450	41,050
Synchronous	300	400	600	1,800	3,100
Total	12,200	19,000	24,000	30,000	85,200

Table 2-7 (Continued)
Each Company's Quarterly Shipments of 16Mb DRAM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Toshiba					
16Mbx1					
Fast Page Mode	430	305	190	230	1,155
Total	430	305	190	230	1,155
4Mbx4					
Fast Page Mode	975	755	990	460	3,180
Extended Data Out	1,460	1,820	6,080	7,360	16,720
Synchronous	-	25	530	1,380	1,935
Total	2,435	2,600	7,600	9,200	21,835
2Mbx8					
Fast Page Mode	340	265	150	70	825
Extended Data Out	515	645	910	1,105	3,175
Synchronous	-	10	80	205	295
Total	855	920	1,140	1,380	4,295
1Mbx16					
Fast Page Mode	4,230	3,330	1,310	610	9,480
Extended Data Out	6,350	8,030	8,055	9,750	32,185
Synchronous	-	115	705	1,830	2,650
Total	10,580	11,475	10,070	12,190	44,315
Vendor Total					
Fast Page Mode	5,975	4,655	2,640	1,370	14,640
Extended Data Out	8,325	10,495	15,045	18,215	52,080
Synchronous	-	150	1,315	3,415	4,880
Total	14,300	15,300	19,000	23,000	71,600
Vanguard					
1Mbx16					
Fast Page Mode	-	-	-	200	200
Extended Data Out	-	-	-	3,300	3,300
Total	-	-	-	3,500	3,500
Vendor Total					
Fast Page Mode	-	-	-	200	200
Extended Data Out	-	-	-	3,300	3,300
Total	-	-	-	3,500	3,500
Market Total					
16Mbx1					
Fast Page Mode	6,299	6,281	7,060	7,775	27,415
Extended Data Out	800	900	1,500	1,850	5,050
Total	7,099	7,181	8,560	9,625	32,465

Table 2-7 (Continued)
Each Company's Quarterly Shipments of 16Mb DRAM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
4Mbx4					
Fast Page Mode	46,366	33,423	27,115	25,304	132,207
Extended Data Out	31,381	57,121	92,540	128,346	309,388
Synchronous	965	1,285	2,760	11,770	16,780
Total	78,712	91,829	122,415	165,420	458,376
2Mbx8					
Fast Page Mode	14,173	8,558	7,955	6,999	37,685
Extended Data Out	10,016	15,905	21,828	26,228	73,976
Synchronous	1,258	1,557	3,233	6,316	12,364
Total	25,447	26,020	33,015	39,543	124,025
2Mbx9					
Synchronous	160	130	160	200	650
Total	160	130	160	200	650
1Mbx16					
Fast Page Mode	39,716	29,755	25,458	21,182	116,110
Extended Data Out	30,264	42,700	72,358	100,669	245,991
Synchronous	1,447	1,854	4,580	10,819	18,700
Total	71,427	74,309	102,395	132,670	380,801
All 16Mb					
Fast Page Mode	106,554	78,016	67,588	61,260	313,417
Extended Data Out	72,461	116,626	188,225	257,093	634,405
Synchronous	3,830	4,826	10,733	29,105	48,494
Total	182,845	199,468	266,545	347,458	996,316
% Change from Previous Quarter	42.2	9.1	33.6	30.4	-
Average Selling Price ($)	36.19	18.29	11.64	9.42	16.71
Revenue ($M)	6,617,492	3,649,082	3,103,679	3,273,523	16,643,776
Market Share (% of Units)					
Americas Companies	12.1	16.0	17.0	19.0	16.6
European Companies	2.7	3.0	3.0	3.2	3.0
Japanese Companies	46.2	46.5	43.1	41.2	43.7
Asia/Pacific Companies	38.9	34.4	36.9	36.6	36.7
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

Table 2-8
Each Company's Quarterly Shipments of 64Mb DRAM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Fujitsu					
16Mbx4					
Synchronous	-	-	1	40	41
Total	-	-	1	40	41
4Mbx16					
Synchronous	-	-	-	30	30
Total	-	-	-	30	30
Vendor Total					
Synchronous	-	-	1	70	72
Total	-	-	1	70	72
Hitachi					
16Mbx4					
Extended Data Out	-	-	-	250	250
Total	-	-	-	250	250
8Mbx8					
Extended Data Out	-	-	-	50	50
Total	-	-	-	50	50
Vendor Total					
Extended Data Out	-	-	-	300	300
Total	-	-	-	300	300
Hyundai					
16Mbx4					
Extended Data Out	-	-	80	240	320
Total	-	-	80	240	320
8Mbx8					
Extended Data Out	-	-	20	60	80
Total	-	-	20	60	80
Vendor Total					
Extended Data Out	-	-	100	300	400
Total	-	-	100	300	400
IBM Microelectronics					
16Mbx4					
Fast Page Mode	14	30	48	29	120
Extended Data Out	4	17	55	73	148
Total	17	47	103	102	268
8Mbx8					
Extended Data Out	-	1	4	5	10
Total	-	1	4	5	10

Table 2-8 (Continued)
Each Company's Quarterly Shipments of 64Mb DRAM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
4Mbx16					
Extended Data Out	3	13	44	63	123
Total	3	13	44	63	123
Vendor Total					
Fast Page Mode	14	30	48	29	120
Extended Data Out	7	31	102	141	280
Total	21	60	150	170	401
LG Semicon					
16Mbx4					
Extended Data Out	-	-	80	240	320
Total	-	-	80	240	320
8Mbx8					
Extended Data Out	-	-	20	60	80
Total	-	-	20	60	80
Vendor Total					
Extended Data Out	-	-	100	300	400
Total	-	-	100	300	400
Mitsubishi					
16Mbx4					
Extended Data Out	-	-	12	30	42
Total	-	-	12	30	42
8Mbx8					
Extended Data Out	-	-	3	15	18
Total	-	-	3	15	18
Vendor Total					
Extended Data Out	-	-	15	45	60
Total	-	-	15	45	60
Motorola					
16Mbx4					
Extended Data Out	-	-	-	6	6
Total	-	-	-	6	6
8Mbx8					
Extended Data Out	-	-	-	4	4
Total	-	-	-	4	4
Vendor Total					
Extended Data Out	-	-	-	10	10
Total	-	-	-	10	10

Table 2-8 (Continued)
Each Company's Quarterly Shipments of 64Mb DRAM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
NEC					
16Mbx4					
Extended Data Out	20	90	263	452	824
Synchronous	7	30	88	94	218
Total	26	120	350	546	1,042
8Mbx8					
Extended Data Out	5	23	75	390	493
Synchronous	2	8	25	120	154
Total	7	30	100	510	647
4Mbx16					
Extended Data Out	-	-	38	108	146
Synchronous	-	-	13	36	49
Total	-	-	50	144	194
Vendor Total					
Extended Data Out	25	113	375	950	1,462
Synchronous	8	38	125	250	421
Total	33	150	500	1,200	1,883
Samsung					
16Mbx4					
Fast Page Mode	8	23	20	50	101
Extended Data Out	68	180	353	750	1,351
Synchronous	4	23	40	200	267
Total	80	225	413	1,000	1,718
8Mbx8					
Fast Page Mode	2	6	5	13	26
Extended Data Out	17	48	98	188	350
Synchronous	1	6	12	50	69
Total	20	60	115	250	445
4Mbx16					
Extended Data Out	-	2	4	13	18
Synchronous	-	12	64	188	263
Total	-	14	68	200	281
Vendor Total					
Fast Page Mode	10	29	26	63	127
Extended Data Out	85	230	454	950	1,719
Synchronous	5	41	115	438	598
Total	100	299	595	1,450	2,444

Table 2-8 (Continued)
Each Company's Quarterly Shipments of 64Mb DRAM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
Siemens					
16Mbx4					
Extended Data Out	-	30	80	250	360
Total	-	30	80	250	360
Vendor Total					
Extended Data Out	-	30	80	250	360
Total	-	30	80	250	360
Texas Instruments					
16Mbx4					
Fast Page Mode	-	3	6	9	17
Extended Data Out	-	4	12	38	54
Synchronous	-	-	1	3	4
Total	-	6	19	50	75
8Mbx8					
Fast Page Mode	-	4	10	27	41
Extended Data Out	-	5	22	113	140
Synchronous	-	-	2	9	11
Total	-	9	34	149	191
Vendor Total					
Fast Page Mode	-	6	16	36	58
Extended Data Out	-	9	34	151	194
Synchronous	-	-	3	12	15
Total	-	15	53	198	266
Toshiba					
16Mbx4					
Extended Data Out	-	-	24	80	104
Total	-	-	24	80	104
8Mbx8					
Extended Data Out	-	-	6	20	26
Total	-	-	6	20	26
Vendor Total					
Extended Data Out	-	-	30	100	130
Total	-	-	30	100	130
Market Total					
16Mbx4					
Fast Page Mode	22	55	74	88	238
Extended Data Out	92	321	958	2,408	3,779
Synchronous	11	53	130	337	530
Total	124	428	1,162	2,833	4,547

Table 2-8 (Continued)
Each Company's Quarterly Shipments of 64Mb DRAM to the World, 1996 (Thousands of Units Shipped)

	Q1/96	Q2/96	Q3/96	Q4/96	1996
8Mbx8					
Fast Page Mode	2	10	15	39	66
Extended Data Out	22	77	247	905	1,251
Synchronous	3	14	38	179	233
Total	27	100	301	1,123	1,550
4Mbx16					
Extended Data Out	3	14	85	184	286
Synchronous	-	12	76	254	342
Total	3	26	162	437	628
All 64Mb					
Fast Page Mode	24	64	89	127	304
Extended Data Out	117	411	1,291	3,497	5,315
Synchronous	13	78	244	769	1,105
Total	154	554	1,624	4,393	6,725
% Change from Previous Quarter	2,460.0	260.5	193.3	170.5	-
Average Selling Price ($)	138.67	121.68	106.84	92.50	99.42
Revenue ($M)	21,300	67,386	173,530	406,353	668,568
Market Share (% of Units)					
Americas Companies	13.3	13.6	12.5	8.6	10.1
European Companies	-	5.4	4.9	5.7	5.4
Japanese Companies	21.5	27.1	33.6	39.0	36.4
Asia/Pacific Companies	65.1	53.9	48.9	46.7	48.2
Total	100.0	100.0	100.0	100.0	100.0

Source: Dataquest (June 1997)

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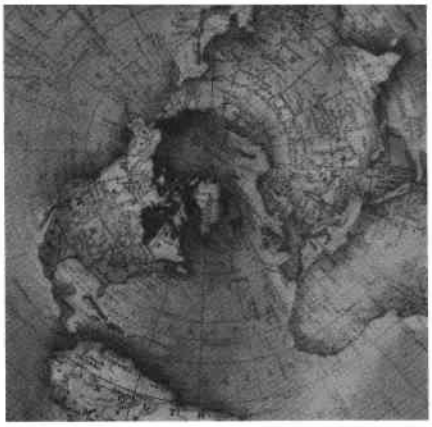

Dataquest

Worldwide Memory Market Share, 1994 to 1996

Market Statistics

Program: Memories Worldwide
Product Code: MMRY-WW-MS-9701
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Worldwide Memory Market Share, 1994 to 1996

Introduction

This document contains detailed information on Dataquest's view of the MOS and bipolar memory IC markets. Included in this document are the 1994-1996 market share estimates.

Analyses of the MOS and bipolar memory markets by company provide insight into high-technology markets and reinforce estimates of consumption, production, and company revenue.

Worldwide market share estimates combine data from many countries, each of which has different and fluctuating exchange rates. Estimates of non-U.S. market consumption or revenue are based upon the average exchange rate for the given year. Refer to the section titled "Exchange Rates" for more information regarding these average rates. As a rule, our estimates are calculated in local currencies, and then converted to U.S. dollars.

More detailed data on this market may be requested through our client inquiry service. Dataquest's qualitative analysis of this data can be found in other Dataquest documents 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 semiconductor market segments tracked by Dataquest, please refer to the *Semiconductor Market Definitions* document.

Dataquest segments the MOS memory market into the following categories: DRAM, SRAM, EPROM, mask ROM, EEPROM, flash memory, and other MOS memory. MOS memory is defined as a MOS IC in which binary data is stored and electronically retrieved. Dataquest does not subdivide the bipolar memory category. Bipolar memory is defined as a bipolar IC in which binary data is stored and electronically retrieved.

Merchant versus Captive Consumption: Dataquest includes all revenue, both merchant and captive, for semiconductor suppliers selling to the merchant market. The data completely excludes captive suppliers in which devices are manufactured solely for the company's own use. A product that is used internally is valued at market price rather than at transfer or factory price.

Definitions

This section lists the definitions that are used by Dataquest to present the data in this document. Complete definitions for all Dataquest semiconductor terms can be found in the *Semiconductor Market Definitions* document.

Product Definitions

DRAM: Includes 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. 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 (P-SRAM). SRAMs have memory cells consisting of a minimum of four transistors (P-SRAMs 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 P-SRAM).

EPROM: Includes erasable programmable read-only memory. This product classification includes ultraviolet EPROM (UV EPROM) and one-time programmable read-only memory (OTPROM). 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.

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. This category includes MOS digital content addressable memory (CAM), MOS digital cache-tag RAM, MOS digital first-in/first-out (FIFO) memory, MOS digital last-in/first-out (LIFO) memory, and ferroelectric memory.

Regional Definitions

Americas

North America: Includes Canada, Mexico, and the United States (50 states).

South America

Central America

Japan

Japan is the only single-country region.

Europe, Africa, and the Middle East

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 (Belarus, Russian Federation, Ukraine, Georgia, Moldavia, Armenia, Azerbaijan, Kazakhstan, Uzbekistan, Tadjikistan, Kyrgyzstan, and Turkmenistan).

Asia/Pacific

Includes Hong Kong, Singapore, South Korea, Taiwan, Australia, Bangladesh, Cambodia, China, India, Indonesia, Laos, Malaysia, Maldives, Myanmar, Nepal, New Zealand, Pakistan, the Philippines, Sri Lanka, Thailand, and Vietnam.

Line Item Definitions

Factory revenue is defined as the money value received by a semiconductor manufacturer for its products. Revenue from the sale of semiconductors sold either as finished goods, die, or wafers to another semiconductor vendor for resale is attributed to the semiconductor vendor that sells the product to a distributor or equipment manufacturer.

Market Share Methodology

Dataquest utilizes both primary and secondary sources to produce market statistics data. In the fourth quarter of each year, Dataquest surveys all major participants within each industry. Selected companies are resurveyed during the first quarter of the following year to verify final annual results. This primary research is supplemented with additional primary research and secondary research to verify market size, shipment totals, and pricing information. Sources of data utilized by Dataquest include the following:

- Information published by major industry participants

- Estimates made by knowledgeable and reliable industry spokespersons
- Government data or trade association data (such as WSTS, MITI, and U.S. DOC)
- Published product literature and price lists
- Interviews with knowledgeable manufacturers, distributors, and users
- Relevant economic data
- Information and data from online and CD-ROM data banks
- Articles in both the general and trade press
- Reports from financial analysts
- End-user surveys

Dataquest believes that the estimates presented in this document are the most accurate and meaningful statistics available.

Despite the care taken in gathering, analyzing, and categorizing the data in a meaningful way, careful attention must be paid to the definitions and assumptions used herein when interpreting the estimates presented in this document. Various companies, government agencies, and trade associations may use slightly different definitions of product categories and regional groupings, or they may include different companies in their summaries. These differences should be kept in mind when making comparisons between data and numbers provided by Dataquest and those provided by other sources.

Notes on Market Share

In the process of conducting data collection and preparing market statistics information, Dataquest will sometimes consolidate or revise a particular company, model, series, or industry's numbers. In this section, we explain any such changes contained within this document for your reference.

Notes to Market Share Tables

1. Appian Technology product lines were acquired by Cirrus Logic in 1994.

2. Dialog, Eurosil, Matra, Telefunken, and Siliconix are now known as TEMIC.

3. LG Semicon was formerly known as Goldstar.

4. IMP was formerly known as International Microelectronic Products.

5. Inmos revenue is included in SGS-Thomson revenue.

6. Linfinity was formerly known as Silicon General.

7. NCR was acquired by Hyundai in 1994 and is operated as Symbios Logic Inc.

8. Nippon Steel Semiconductor was formerly known as NMB Semiconductor.

9. Philips revenue includes Signetics revenue.

10. Thomson Semiconductors Specific (TCS) was formed through the merger of Thomson Composants Microndes (TCM) and Thomson Composants Militaires et Spatiaux (TMS).

11. The following companies were added to worldwide market share tables starting in 1996 and may result in higher 1996 market growth rates in certain product areas:

- C-Cube
- Chip Express
- Digital Semiconductor
- Orbit Semiconductor
- Sun Microsystems
- Vanguard
- VIA Technologies

12. Part of IBM's 1994 and 1995 logic revenue has been reclassified and restated.

13. Rockwell's 1994 revenue has been restated.

14. National Semiconductor's 1994 revenue has been restated.

15. Motorola's 1995 revenue has been restated.

16. Comlinear revenue is included in National Semiconductor's revenue.

17. Silicon Storage Technology has been added to worldwide market share starting in 1995.

18. ABB IXYS is now IXYS and has been placed in Americas companies.

19. Texas Instruments purchased Silicon Systems in 1996.

20. Rockwell purchased Brooktree in 1996.

21. NEC's 1995 revenue has been restated.

Exchange Rates

Dataquest uses an average annual exchange rate in converting revenue to U.S. dollar amounts. Table 1 outlines these rates for 1993 through 1995.

Table 1
Exchange Rates

	1994	1995	1996
Japan (Yen/U.S.$)	101.81	93.90	108.81
France (Franc/U.S.$)	5.54	4.97	5.12
Germany (Deutsche Mark/U.S.$)	1.62	1.43	1.50
United Kingdom (U.S.$/Pound Sterling)	1.53	1.59	1.56

Source: Dataquest (April 1997)

Section 1: Shipments Worldwide

Table 1-1
Each Company's Factory Revenue from Shipments of MOS Memory Worldwide (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Total Market	33,505	55,287	37,807	100.0	100.0	100.0
Americas Companies	8,430	13,641	9,399	25.2	24.7	24.9
Advanced Micro Devices	442	719	711	1.3	1.3	1.9
Alliance Semiconductor	90	210	66	0.3	0.4	0.2
Lucent Technologies	3	3	0	0	0	0
Atmel	331	478	793	1.0	0.9	2.1
Catalyst	49	48	54	0.1	0	0.1
Cypress Semiconductor	285	424	382	0.9	0.8	1.0
Dallas Semiconductor	30	56	0	0	0.1	0
Electronic Designs	26	43	51	0	0	0.1
G-Link USA	0	14	15	0	0	0
Gould AMI	44	0	0	0.1	0	0
Harris	12	18	9	0	0	0
IBM	1,520	2,100	996	4.5	3.8	2.6
Integrated Device Technology	252	444	378	0.8	0.8	1.0
Integrated Silicon Solution Inc.	60	158	111	0.2	0.3	0.3
Intel	458	766	950	1.4	1.4	2.5
IMP	1	0	0	0	0	0
ITT	10	0	0	0	0	0
Logic Devices	2	5	2	0	0	0
Microchip Technology	82	102	117	0.2	0.2	0.3
Micron Technology	1,492	2,601	1,558	4.5	4.7	4.1
Motorola	948	1,237	827	2.8	2.2	2.2
National Semiconductor	179	188	127	0.5	0.3	0.3
Paradigm	36	55	23	0.1	0	0
Performance Semiconductor	5	7	0	0	0	0
Quality Semiconductor	7	14	1	0	0	0
Ramtron	15	25	14	0	0	0
Seeq Technology	5	6	0	0	0	0
Silicon Storage Technology	0	35	91	0	0	0.2
Texas Instruments	1,931	3,754	1,984	5.8	6.8	5.2
WaferScale Integration	15	17	16	0	0	0
Xicor	100	114	123	0.3	0.2	0.3

Table 1-1 (Continued)
Each Company's Factory Revenue from Shipments of MOS Memory Worldwide
(Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Japanese Companies	15,519	24,062	15,708	46.3	43.5	41.5
Fujitsu	1,692	2,589	1,656	5.0	4.7	4.4
Hitachi	3,232	5,132	3,514	9.6	9.3	9.3
Matsushita	396	492	300	1.2	0.9	0.8
Mitsubishi	1,652	2,547	1,614	4.9	4.6	4.3
NEC	3,096	5,353	3,913	9.2	9.7	10.3
Nippon Steel Semiconductor	160	549	198	0.5	1.0	0.5
Oki	697	1,228	541	2.1	2.2	1.4
Ricoh	19	6	3	0	0	0
Rohm	56	61	51	0.2	0.1	0.1
Sanyo	183	257	302	0.5	0.5	0.8
Seiko Epson	42	41	19	0.1	0	0
Sharp	867	1,030	727	2.6	1.9	1.9
Sony	387	489	330	1.2	0.9	0.9
Toshiba	3,018	4,264	2,513	9.0	7.7	6.6
Yamaha	1	1	1	0	0	0
Other Japanese	21	23	26	0	0	0
European Companies	1,484	2,023	1,669	4.4	3.7	4.4
Philips	14	0	0	0	0	0
SGS-Thomson	589	646	738	1.8	1.2	2.0
Siemens	858	1,353	911	2.6	2.4	2.4
TEMIC	23	24	20	0	0	0
Asia/Pacific Companies	8,072	15,561	11,031	24.1	28.1	29.2
LG Semicon	1,525	2,635	2,021	4.6	4.8	5.3
Hualon Microelectronics Corp.	46	54	23	0.1	0	0
Holtek	0	0	2	0	0	0
Hyundai	1,515	4,116	2,236	4.5	7.4	5.9
Macronix	200	236	288	0.6	0.4	0.8
Mosel Vitelic	259	502	398	0.8	0.9	1.1
Samsung	4,194	7,498	5,501	12.5	13.6	14.6
United Microelectronics Corp.	191	203	177	0.6	0.4	0.5
Vanguard	0	0	225	0	0	0.6
Winbond Electronics	142	317	160	0.4	0.6	0.4

Source: Dataquest (May 1997)

Table 1-2
Each Company's Factory Revenue from Shipments of Dynamic RAM Worldwide (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Total Market	23,266	42,249	25,927	100.0	100.0	100.0
Americas Companies	5,144	8,605	4,511	22.1	20.4	17.4
Alliance Semiconductor	0	2	10	0	0	0
IBM	1,520	2,000	938	6.5	4.7	3.6
Micron Technology	1,360	2,434	1,511	5.8	5.8	5.8
Motorola	610	715	295	2.6	1.7	1.1
Ramtron	15	25	14	0	0	0
Texas Instruments	1,639	3,429	1,734	7.0	8.1	6.7
G-Link USA	0	0	9	0	0	0
Japanese Companies	10,895	18,849	11,250	46.8	44.6	43.4
Fujitsu	1,173	2,051	1,194	5.0	4.9	4.6
Hitachi	2,434	4,239	2,767	10.5	10.0	10.7
Matsushita	328	474	281	1.4	1.1	1.1
Mitsubishi	1,372	2,201	1,283	5.9	5.2	4.9
NEC	2,407	4,592	3,108	10.3	10.9	12.0
Nippon Steel Semiconductor	160	549	198	0.7	1.3	0.8
Oki	605	1,001	349	2.6	2.4	1.3
Sanyo	86	164	193	0.4	0.4	0.7
Sharp	71	115	56	0.3	0.3	0.2
Sony	4	5	3	0	0	0
Toshiba	2,255	3,458	1,818	9.7	8.2	7.0
European Companies	786	1,300	845	3.4	3.1	3.3
Siemens	786	1,300	845	3.4	3.1	3.3
Asia/Pacific Companies	6,441	13,495	9,321	27.7	31.9	36.0
LG Semicon	1,391	2,500	1,891	6.0	5.9	7.3
Hyundai	1,360	3,950	2,147	5.8	9.3	8.3
Mosel Vitelic	231	453	386	1.0	1.1	1.5
Samsung	3,459	6,592	4,672	14.9	15.6	18.0
Vanguard	0	0	225	0	0	0.9

Source: Dataquest (May 1997)

Table 1-3
Each Company's Factory Revenue from Shipments of Static RAM Worldwide (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Total Market	4,514	6,265	4,848	100.0	100.0	100.0
Americas Companies	1,074	1,944	1,305	23.8	31.0	26.9
Advanced Micro Devices	4	4	3	0	0	0
Alliance Semiconductor	90	208	56	2.0	3.3	1.2
Cypress Semiconductor	194	303	257	4.3	4.8	5.3
Dallas Semiconductor	30	56	0	0.7	0.9	0
Electronic Designs	26	43	49	0.6	0.7	1.0
G-Link USA	0	14	6	0	0.2	0.1
Harris	8	11	5	0.2	0.2	0.1
IBM	0	100	58	0	1.6	1.2
Integrated Device Technology	139	285	185	3.1	4.5	3.8
Integrated Silicon Solution Inc.	48	145	88	1.1	2.3	1.8
Logic Devices	2	5	2	0	0	0
Micron Technology	132	167	46	2.9	2.7	0.9
Motorola	329	519	518	7.3	8.3	10.7
National Semiconductor	10	4	2	0.2	0	0
Paradigm	36	55	23	0.8	0.9	0.5
Performance Semiconductor	5	7	0	0.1	0.1	0
Quality Semiconductor	4	0	0	0	0	0
Texas Instruments	17	18	7	0.4	0.3	0.1
Japanese Companies	2,505	2,844	2,433	55.5	45.4	50.2
Fujitsu	322	233	59	7.1	3.7	1.2
Hitachi	557	662	605	12.3	10.6	12.5
Matsushita	26	13	9	0.6	0.2	0.2
Mitsubishi	212	304	293	4.7	4.9	6.0
NEC	353	421	423	7.8	6.7	8.7
Oki	19	16	9	0.4	0.3	0.2
Ricoh	9	0	0	0.2	0	0
Rohm	22	28	21	0.5	0.4	0.4
Sanyo	79	75	49	1.8	1.2	1.0
Seiko Epson	41	40	19	0.9	0.6	0.4
Sharp	140	190	144	3.1	3.0	3.0
Sony	349	445	327	7.7	7.1	6.7
Toshiba	376	417	475	8.3	6.7	9.8
European Companies	24	51	34	0.5	0.8	0.7
SGS-Thomson	4	27	14	0	0.4	0.3
TEMIC	20	24	20	0.4	0.4	0.4

Table 1-3 (Continued)
Each Company's Factory Revenue from Shipments of Static RAM Worldwide (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Asia/Pacific Companies	911	1,426	1,076	20.2	22.8	22.2
LG Semicon	69	72	78	1.5	1.1	1.6
Hualon Microelectronics Corp.	7	12	7	0.2	0.2	0.1
Hyundai	129	166	89	2.9	2.6	1.8
Mosel Vitelic	28	22	12	0.6	0.4	0.2
Samsung	419	672	605	9.3	10.7	12.5
United Microelectronics Corp.	118	173	138	2.6	2.8	2.8
Winbond Electronics	141	309	147	3.1	4.9	3.0

Source: Dataquest (May 1997)

Table 1-4
Each Company's Factory Revenue from Shipments of Nonvolatile Memory Worldwide (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Total Market	5,407	6,239	6,455	100.0	100.0	100.0
Americas Companies	1,990	2,775	3,292	36.8	44.5	51.0
Advanced Micro Devices	425	702	708	7.9	11.3	11.0
Atmel	331	478	793	6.1	7.7	12.3
Catalyst	49	48	54	0.9	0.8	0.8
Cypress Semiconductor	48	95	51	0.9	1.5	0.8
Electronic Designs	0	0	2	0	0	0
Gould AMI	44	0	0	0.8	0	0
Harris	4	7	4	0	0.1	0
Integrated Silicon Solution Inc.	12	13	23	0.2	0.2	0.4
Intel	458	766	950	8.5	12.3	14.7
IMP	1	0	0	0	0	0
ITT	10	0	0	0.2	0	0
Microchip Technology	82	102	117	1.5	1.6	1.8
Micron Technology	0	0	1	0	0	0
Motorola	9	0	5	0.2	0	0
National Semiconductor	169	160	125	3.1	2.6	1.9
Seeq Technology	5	6	0	0	0	0
Silicon Storage Technology	0	35	91	0	0.6	1.4
Texas Instruments	240	245	243	4.4	3.9	3.8
WaferScale Integration	15	17	16	0.3	0.3	0.2
Xicor	88	101	109	1.6	1.6	1.7
Japanese Companies	2,089	2,211	1,774	38.6	35.4	27.5
Fujitsu	197	305	403	3.6	4.9	6.2
Hitachi	241	231	142	4.5	3.7	2.2
Matsushita	42	5	10	0.8	0	0.2
Mitsubishi	68	38	34	1.3	0.6	0.5
NEC	336	340	287	6.2	5.4	4.4
Oki	73	87	65	1.4	1.4	1.0
Ricoh	10	6	1	0.2	0	0
Rohm	34	33	30	0.6	0.5	0.5
Sanyo	10	12	55	0.2	0.2	0.9
Seiko Epson	1	1	0	0	0	0
Sharp	655	724	526	12.1	11.6	8.1
Sony	34	39	0	0.6	0.6	0
Toshiba	387	389	220	7.2	6.2	3.4
Yamaha	1	1	1	0	0	0

Table 1-4 (Continued)
Each Company's Factory Revenue from Shipments of Nonvolatile Memory Worldwide (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
European Companies	635	640	755	11.7	10.3	11.7
Philips	14	0	0	0.3	0	0
SGS-Thomson	546	587	689	10.1	9.4	10.7
Siemens	72	53	66	1.3	0.8	1.0
TEMIC	3	0	0	0	0	0
Asia/Pacific Companies	693	613	634	12.8	9.8	9.8
LG Semicon	65	63	52	1.2	1.0	0.8
Hualon Microelectronics Corp.	39	42	16	0.7	0.7	0.2
Holtek	0	0	2	0	0	0
Macronix	200	236	288	3.7	3.8	4.5
Samsung	315	234	224	5.8	3.8	3.5
United Microelectronics Corp.	73	30	39	1.4	0.5	0.6
Winbond Electronics	1	8	13	0	0.1	0.2

Source: Dataquest (May 1997)

Table 1-5
Each Company's Factory Revenue from Shipments of EPROM Worldwide
(Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	**1995**	**1996**	**1994**	**1995**	**1996**
Total Market	1,561	1,437	1,249	100.0	100.0	100.0
Americas Companies	781	773	649	50.0	53.8	52.0
Advanced Micro Devices	215	175	166	13.8	12.2	13.3
Atmel	128	148	227	8.2	10.3	18.2
Cypress Semiconductor	48	95	51	3.1	6.6	4.1
Integrated Silicon Solution Inc.	12	9	10	0.8	0.6	0.8
Intel	8	0	0	0.5	0	0
Microchip Technology	27	20	13	1.7	1.4	1.0
National Semiconductor	119	98	51	7.6	6.8	4.1
Texas Instruments	209	211	115	13.4	14.7	9.2
WaferScale Integration	15	17	16	1.0	1.2	1.3
Japanese Companies	308	256	179	19.7	17.8	14.3
Fujitsu	79	60	19	5.1	4.2	1.5
Hitachi	69	64	48	4.4	4.5	3.8
Mitsubishi	41	26	14	2.6	1.8	1.1
NEC	43	36	38	2.8	2.5	3.0
Oki	9	17	14	0.6	1.2	1.1
Sanyo	4	4	1	0.3	0.3	0
Sharp	3	3	3	0.2	0.2	0.2
Toshiba	60	46	42	3.8	3.2	3.4
European Companies	395	336	337	25.3	23.4	27.0
SGS-Thomson	395	336	337	25.3	23.4	27.0
Asia/Pacific Companies	77	72	84	4.9	5.0	6.7
Macronix	77	72	84	4.9	5.0	6.7

Source: Dataquest (May 1997)

Table 1-6
Each Company's Factory Revenue from Shipments of EEPROM Worldwide (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Total Market	746	793	1,050	100.0	100.0	100.0
Americas Companies	407	460	644	54.6	58.0	61.3
Atmel	138	152	236	18.5	19.2	22.5
Catalyst	39	42	46	5.2	5.3	4.4
Integrated Silicon Solution Inc.	0	4	5	0	0.5	0.5
Microchip Technology	55	82	104	7.4	10.3	9.9
Motorola	9	0	0	1.2	0	0
National Semiconductor	50	62	74	6.7	7.8	7.0
Seeq Technology	5	6	0	0.7	0.8	0
Texas Instruments	23	11	70	3.1	1.4	6.7
Xicor	88	101	109	11.8	12.7	10.4
Japanese Companies	115	108	84	15.4	13.6	8.0
Fujitsu	12	11	5	1.6	1.4	0.5
Hitachi	7	8	7	0.9	1.0	0.7
Mitsubishi	7	8	2	0.9	1.0	0.2
NEC	39	39	35	5.2	4.9	3.3
Oki	15	6	5	2.0	0.8	0.5
Rohm	32	33	30	4.3	4.2	2.9
Sanyo	3	3	0	0.4	0.4	0
European Companies	204	222	322	27.3	28.0	30.7
Philips	14	0	0	1.9	0	0
SGS-Thomson	115	169	256	15.4	21.3	24.4
Siemens	72	53	66	9.7	6.7	6.3
TEMIC	3	0	0	0.4	0	0
Asia/Pacific Companies	20	3	0	2.7	0.4	0
Samsung	20	3	0	2.7	0.4	0

Source: Dataquest (May 1997)

Table 1-7
Each Company's Factory Revenue from Shipments of Flash Memory Worldwide (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Total Market	884	1,942	2,866	100.0	100.0	100.0
Americas Companies	742	1,535	1,993	83.9	79.0	69.5
Advanced Micro Devices	210	527	542	23.8	27.1	18.9
Atmel	65	178	330	7.4	9.2	11.5
Catalyst	10	6	8	1.1	0.3	0.3
Electronic Designs	0	0	2	0	0	0
Integrated Silicon Solution Inc.	0	0	8	0	0	0.3
Intel	450	766	950	50.9	39.4	33.1
Micron Technology	0	0	1	0	0	0
Motorola	0	0	5	0	0	0.2
Silicon Storage Technology	0	35	91	0	1.8	3.2
Texas Instruments	7	23	56	0.8	1.2	2.0
Japanese Companies	100	311	707	11.3	16.0	24.7
Fujitsu	14	178	369	1.6	9.2	12.9
Hitachi	3	0	2	0.3	0	0
Matsushita	0	0	10	0	0	0.3
Mitsubishi	10	4	18	1.1	0.2	0.6
NEC	6	18	30	0.7	0.9	1.0
Oki	4	0	0	0.5	0	0
Rohm	2	0	0	0.2	0	0
Sanyo	0	0	50	0	0	1.7
Sharp	11	45	149	1.2	2.3	5.2
Toshiba	50	66	79	5.7	3.4	2.8
European Companies	36	82	96	4.1	4.2	3.3
SGS-Thomson	36	82	96	4.1	4.2	3.3
Asia/Pacific Companies	6	14	70	0.7	0.7	2.4
Macronix	3	14	39	0.3	0.7	1.4
Samsung	3	0	31	0.3	0	1.1

Source: Dataquest (May 1997)

Table 1-8
Each Company's Factory Revenue from Shipments of Mask ROM Worldwide (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Total Market	2,216	2,067	1,290	100.0	100.0	100.0
Americas Companies	60	7	6	2.7	0.3	0.5
Gould AMI	44	0	0	2.0	0	0
Harris	4	7	4	0.2	0.3	0.3
IMP	1	0	0	0	0	0
ITT	10	0	0	0.5	0	0
Texas Instruments	1	0	2	0	0	0.2
Japanese Companies	1,566	1,536	804	70.7	74.3	62.3
Fujitsu	92	56	10	4.2	2.7	0.8
Hitachi	162	159	85	7.3	7.7	6.6
Matsushita	42	5	0	1.9	0.2	0
Mitsubishi	10	0	0	0.5	0	0
NEC	248	247	184	11.2	11.9	14.3
Oki	45	64	46	2.0	3.1	3.6
Ricoh	10	6	1	0.5	0.3	0
Sanyo	3	5	4	0.1	0.2	0.3
Seiko Epson	1	1	0	0	0	0
Sharp	641	676	374	28.9	32.7	29.0
Sony	34	39	0	1.5	1.9	0
Toshiba	277	277	99	12.5	13.4	7.7
Yamaha	1	1	1	0	0	0
Asia/Pacific Companies	590	524	480	26.6	25.4	37.2
LG Semicon	65	63	52	2.9	3.0	4.0
Hualon Microelectronics Corp.	39	42	16	1.8	2.0	1.2
Holtek	0	0	2	0	0	0.2
Macronix	120	150	165	5.4	7.3	12.8
Samsung	292	231	193	13.2	11.2	15.0
United Microelectronics Corp.	73	30	39	3.3	1.5	3.0
Winbond Electronics	1	8	13	0	0.4	1.0

Source: Dataquest (May 1997)

Table 1-9
Each Company's Factory Revenue from Shipments of Other MOS Memory Worldwide (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Total Market	318	534	577	100.0	100.0	100.0
Americas Companies	222	317	291	69.8	59.4	50.4
Advanced Micro Devices	13	13	0	4.1	2.4	0
Lucent Technologies	3	3	0	0.9	0.6	0
Cypress Semiconductor	43	26	74	13.5	4.9	12.8
Integrated Device Technology	113	159	193	35.5	29.8	33.4
Motorola	0	3	9	0	0.6	1.6
National Semiconductor	0	24	0	0	4.5	0
Quality Semiconductor	3	14	1	0.9	2.6	0.2
Texas Instruments	35	62	0	11.0	11.6	0
Xicor	12	13	14	3.8	2.4	2.4
Japanese Companies	30	158	251	9.4	29.6	43.5
Mitsubishi	0	4	4	0	0.7	0.7
NEC	0	0	95	0	0	16.5
Oki	0	124	118	0	23.2	20.5
Ricoh	0	0	2	0	0	0.3
Sanyo	8	6	5	2.5	1.1	0.9
Sharp	1	1	1	0.3	0.2	0.2
Other Japanese	21	23	26	6.6	4.3	4.5
European Companies	39	32	35	12.3	6.0	6.1
SGS-Thomson	39	32	35	12.3	6.0	6.1
Asia/Pacific Companies	27	27	0	8.5	5.1	0
Hyundai	26	0	0	8.2	0	0
Mosel Vitelic	0	27	0	0	5.1	0
Samsung	1	0	0	0.3	0	0

Source: Dataquest (May 1997)

Table 1-10
Top 40 Worldwide Companies' Factory Revenue from Shipments of MOS Memory Worldwide (Millions of U.S. Dollars)

1995 Rank	1996 Rank		Revenue 1995	Revenue 1996	Percentage Change	1996 Market Share (%)
1	1	Samsung	7,498	5,501	-26.6	14.6
2	2	NEC	5,353	3,913	-26.9	10.3
3	3	Hitachi	5,132	3,514	-31.5	9.3
4	4	Toshiba	4,264	2,513	-41.1	6.6
5	5	Hyundai	4,116	2,236	-45.7	5.9
7	6	LG Semicon	2,635	2,021	-23.3	5.3
6	7	Texas Instruments	3,754	1,984	-47.1	5.2
9	8	Fujitsu	2,589	1,656	-36.0	4.4
10	9	Mitsubishi	2,547	1,614	-36.6	4.3
8	10	Micron Technology	2,601	1,558	-40.1	4.1
11	11	IBM	2,100	996	-52.6	2.6
16	12	Intel	766	950	24.0	2.5
12	13	Siemens	1,353	911	-32.7	2.4
13	14	Motorola	1,237	827	-33.1	2.2
23	15	Atmel	478	793	65.9	2.1
18	16	SGS-Thomson	646	738	14.2	2.0
15	17	Sharp	1,030	727	-29.4	1.9
17	18	Advanced Micro Devices	719	711	-1.1	1.9
14	19	Oki	1,228	541	-55.9	1.4
20	20	Mosel Vitelic	502	398	-20.7	1.1
25	21	Cypress Semiconductor	424	382	-9.9	1.0
24	22	Integrated Device Technology	444	378	-14.9	1.0
22	23	Sony	489	330	-32.5	0.9
27	24	Sanyo	257	302	17.5	0.8
21	25	Matsushita	492	300	-39.0	0.8
28	26	Macronix	236	288	22.0	0.8
253	27	Vanguard	0	225	NA	0.6
19	28	Nippon Steel Semiconductor	549	198	-63.9	0.5
30	29	United Microelectronics Corp.	203	177	-12.8	0.5
26	30	Winbond Electronics	317	160	-49.5	0.4
31	31	National Semiconductor	188	127	-32.4	0.3
33	32	Xicor	114	123	7.9	0.3
34	33	Microchip Technology	102	117	14.7	0.3
32	34	Integrated Silicon Solution Inc.	158	111	-29.7	0.3
42	35	Silicon Storage Technology	35	91	160.0	0.2
29	36	Alliance Semiconductor	210	66	-68.6	0.2
39	37	Catalyst	48	54	12.5	0.1
35	38	Rohm	61	51	-16.4	0.1

Table 1-10 (Continued)
Top 40 Worldwide Companies' Factory Revenue from Shipments of MOS Memory Worldwide (Millions of U.S. Dollars)

1995 Rank	1996 Rank		Revenue 1995	Revenue 1996	Percentage Change	1996 Market Share (%)
40	39	Electronic Designs	43	51	18.6	0.1
37	40	Paradigm	55	23	-58.2	0
		All Others	314	151	-51.9	0.4
		Americas Companies	13,641	9,399	-31.1	24.9
		Japanese Companies	24,062	15,708	-34.7	41.5
		European Companies	2,023	1,669	-17.5	4.4
		Asia/Pacific Companies	15,561	11,031	-29.1	29.2
		Total Market	55,287	37,807	-31.6	100.0

NA = Not available
Source: Dataquest (May 1997)

Table 1-11
Top 10 Worldwide Companies' Factory Revenue from Shipments of Dynamic RAM Worldwide (Millions of U.S. Dollars)

1995 Rank	1996 Rank		Revenue 1995	Revenue 1996	Percentage Change	1996 Market Share (%)
1	1	Samsung	6,592	4,672	-29.1	18.0
2	2	NEC	4,592	3,108	-32.3	12.0
3	3	Hitachi	4,239	2,767	-34.7	10.7
4	4	Hyundai	3,950	2,147	-45.6	8.3
7	5	LG Semicon	2,500	1,891	-24.4	7.3
5	6	Toshiba	3,458	1,818	-47.4	7.0
6	7	Texas Instruments	3,429	1,734	-49.4	6.7
8	8	Micron Technology	2,434	1,511	-37.9	5.8
9	9	Mitsubishi	2,201	1,283	-41.7	4.9
10	10	Fujitsu	2,051	1,194	-41.8	4.6
		All Others	6,803	3,802	-44.1	14.7
		Americas Companies	8,605	4,511	-47.6	17.4
		Japanese Companies	18,849	11,250	-40.3	43.4
		European Companies	1,300	845	-35.0	3.3
		Asia/Pacific Companies	13,495	9,321	-30.9	36.0
		Total Market	42,249	25,927	-38.6	100.0

Source: Dataquest (May 1997)

Table 1-12
Top 10 Worldwide Companies' Factory Revenue from Shipments of Static RAM Worldwide (Millions of U.S. Dollars)

1995 Rank	1996 Rank		Revenue 1995	Revenue 1996	Percentage Change	1996 Market Share (%)
1	1	Samsung	672	605	-10.0	12.5
2	2	Hitachi	662	605	-8.6	12.5
3	3	Motorola	519	518	-0.2	10.7
6	4	Toshiba	417	475	13.9	9.8
5	5	NEC	421	423	0.5	8.7
4	6	Sony	445	327	-26.5	6.7
8	7	Mitsubishi	304	293	-3.6	6.0
9	8	Cypress Semiconductor	303	257	-15.2	5.3
10	9	Integrated Device Technology	285	185	-35.1	3.8
7	10	Winbond Electronics	309	147	-52.4	3.0
		All Others	1,928	1,013	-47.5	20.9
		Americas Companies	1,944	1,305	-32.9	26.9
		Japanese Companies	2,844	2,433	-14.5	50.2
		European Companies	51	34	-33.3	0.7
		Asia/Pacific Companies	1,426	1,076	-24.5	22.2
		Total Market	6,265	4,848	-22.6	100.0

Source: Dataquest (May 1997)

Table 1-13
Top 10 Worldwide Companies' Factory Revenue from Shipments of Nonvolatile Memory Worldwide (Millions of U.S. Dollars)

1995 Rank	1996 Rank		Revenue 1995	Revenue 1996	Percentage Change	1996 Market Share (%)
1	1	Intel	766	950	24.0	14.7
5	2	Atmel	478	793	65.9	12.3
3	3	Advanced Micro Devices	702	708	0.9	11.0
4	4	SGS-Thomson	587	689	17.4	10.7
2	5	Sharp	724	526	-27.3	8.1
8	6	Fujitsu	305	403	32.1	6.2
10	7	Macronix	236	288	22.0	4.5
7	8	NEC	340	287	-15.6	4.4
9	9	Texas Instruments	245	243	-0.8	3.8
11	10	Samsung	234	224	-4.3	3.5
		All Others	1,622	1,344	-17.1	20.8
		Americas Companies	2,775	3,292	18.6	51.0
		Japanese Companies	2,211	1,774	-19.8	27.5
		European Companies	640	755	18.0	11.7
		Asia/Pacific Companies	613	634	3.4	9.8
		Total Market	6,239	6,455	3.5	100.0

Source: Dataquest (May 1997)

Table 1-14
Top 10 Worldwide Companies' Factory Revenue from Shipments of EPROM Worldwide (Millions of U.S. Dollars)

1995 Rank	1996 Rank		Revenue 1995	Revenue 1996	Percentage Change	1996 Market Share (%)
1	1	SGS-Thomson	336	337	0.3	27.0
4	2	Atmel	148	227	53.4	18.2
3	3	Advanced Micro Devices	175	166	-5.1	13.3
2	4	Texas Instruments	211	115	-45.5	9.2
7	5	Macronix	72	84	16.7	6.7
5	6	National Semiconductor	98	51	-48.0	4.1
6	7	Cypress Semiconductor	95	51	-46.3	4.1
8	8	Hitachi	64	48	-25.0	3.8
10	9	Toshiba	46	42	-8.7	3.4
11	10	NEC	36	38	5.6	3.0
		All Others	156	90	-42.3	7.2
		Americas Companies	773	649	-16.0	52.0
		Japanese Companies	256	179	-30.1	14.3
		European Companies	336	337	0.3	27.0
		Asia/Pacific Companies	72	84	16.7	6.7
		Total Market	1,437	1,249	-13.1	100.0

Source: Dataquest (May 1997)

Table 1-15
Top 10 Worldwide Companies' Factory Revenue from Shipments of EEPROM Worldwide (Millions of U.S. Dollars)

1995 Rank	1996 Rank		Revenue 1995	Revenue 1996	Percentage Change	1996 Market Share (%)
1	1	SGS-Thomson	169	256	51.5	24.4
2	2	Atmel	152	236	55.3	22.5
3	3	Xicor	101	109	7.9	10.4
4	4	Microchip Technology	82	104	26.8	9.9
5	5	National Semiconductor	62	74	19.4	7.0
10	6	Texas Instruments	11	70	536.4	6.7
6	7	Siemens	53	66	24.5	6.3
7	8	Catalyst	42	46	9.5	4.4
8	9	NEC	39	35	-10.3	3.3
9	10	Rohm	33	30	-9.1	2.9
		All Others	49	24	-51.0	2.3
		Americas Companies	460	644	40.0	61.3
		Japanese Companies	108	84	-22.2	8.0
		European Companies	222	322	45.0	30.7
		Asia/Pacific Companies	3	-	-100.0	0
		Total Market	793	1,050	32.4	100.0

Source: Dataquest (May 1997)

Table 1-16
Top 10 Worldwide Companies' Factory Revenue from Shipments of Flash Memory Worldwide (Millions of U.S. Dollars)

1995 Rank	1996 Rank		Revenue 1995	Revenue 1996	Percentage Change	1996 Market Share (%)
1	1	Intel	766	950	24.0	33.1
2	2	Advanced Micro Devices	527	542	2.8	18.9
4	3	Fujitsu	178	369	107.3	12.9
3	4	Atmel	178	330	85.4	11.5
7	5	Sharp	45	149	231.1	5.2
5	6	SGS-Thomson	82	96	17.1	3.3
8	7	Silicon Storage Technology	35	91	160.0	3.2
6	8	Toshiba	66	79	19.7	2.8
9	9	Texas Instruments	23	56	143.5	2.0
23	10	Sanyo	0	50	NA	1.7
		All Others	42	154	266.7	5.4
		Americas Companies	1,535	1,993	29.8	69.5
		Japanese Companies	311	707	127.3	24.7
		European Companies	82	96	17.1	3.3
		Asia/Pacific Companies	14	70	400.0	2.4
		Total Market	1,942	2,866	47.6	100.0

NA = Not available
Source: Dataquest (May 1997)

Table 1-17
Top 10 Worldwide Companies' Factory Revenue from Shipments of Mask ROM Worldwide (Millions of U.S. Dollars)

1995 Rank	1996 Rank		Revenue 1995	Revenue 1996	Percentage Change	1996 Market Share (%)
1	1	Sharp	676	374	-44.7	29.0
4	2	Samsung	231	193	-16.5	15.0
3	3	NEC	247	184	-25.5	14.3
6	4	Macronix	150	165	10.0	12.8
2	5	Toshiba	277	99	-64.3	7.7
5	6	Hitachi	159	85	-46.5	6.6
8	7	LG Semicon	63	52	-17.5	4.0
7	8	Oki	64	46	-28.1	3.6
12	9	United Microelectronics Corp.	30	39	30.0	3.0
10	10	Hualon Microelectronics Corp.	42	16	-61.9	1.2
		All Others	128	37	-71.1	2.9
		Americas Companies	7	6	-14.3	0.5
		Japanese Companies	1,536	804	-47.7	62.3
		European Companies	0	-	NA	0
		Asia/Pacific Companies	524	480	-8.4	37.2
		Total Market	2,067	1,290	-37.6	100.0

NA = Not available
Source: Dataquest (May 1997)

Table 1-18
Top 10 Worldwide Companies' Factory Revenue from Shipments of Other MOS Memory Worldwide (Millions of U.S. Dollars)

1995 Rank	1996 Rank		Revenue 1995	Revenue 1996	Percentage Change	1996 Market Share (%)
1	1	Integrated Device Technology	159	193	21.4	33.4
2	2	Oki	124	118	-4.8	20.5
17	3	NEC	0	95	NA	16.5
6	4	Cypress Semiconductor	26	74	184.6	12.8
4	5	SGS-Thomson	32	35	9.4	6.1
10	6	Xicor	13	14	7.7	2.4
13	7	Motorola	3	9	200.0	1.6
11	8	Sanyo	6	5	-16.7	0.9
12	9	Mitsubishi	4	4	0	0.7
28	10	Ricoh	0	2	NA	0.3
		All Others	167	28	-83.2	4.9
		Americas Companies	317	291	-8.2	50.4
		Japanese Companies	158	251	58.9	43.5
		European Companies	32	35	9.4	6.1
		Asia/Pacific Companies	27	-	-100.0	0
		Total Market	534	577	8.1	100.0

NA = Not available
Source: Dataquest (May 1997)

Section 2: Shipments to Americas

Table 2-1
Each Company's Factory Revenue from Shipments of MOS Memory to Americas (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Total Market	12,469	20,480	14,112	100.0	100.0	100.0
Americas Companies	4,187	6,579	4,605	33.6	32.1	32.6
Advanced Micro Devices	224	336	360	1.8	1.6	2.6
Alliance Semiconductor	50	124	25	0.4	0.6	0.2
Atmel	166	222	265	1.3	1.1	1.9
Catalyst	19	22	24	0.2	0.1	0.2
Cypress Semiconductor	199	302	277	1.6	1.5	2.0
Dallas Semiconductor	12	20	0	0	0	0
Electronic Designs	20	32	37	0.2	0.2	0.3
G-Link USA	0	8	7	0	0	0
Gould AMI	23	0	0	0.2	0	0
Harris	8	14	6	0	0	0
IBM	708	892	420	5.7	4.4	3.0
Integrated Device Technology	164	269	221	1.3	1.3	1.6
Integrated Silicon Solution Inc.	30	62	58	0.2	0.3	0.4
Intel	288	402	415	2.3	2.0	2.9
IMP	1	0	0	0	0	0
Logic Devices	2	5	2	0	0	0
Lucent Technologies	3	3	0	0	0	0
Microchip Technology	31	29	28	0.2	0.1	0.2
Micron Technology	1,050	1,874	1,144	8.4	9.2	8.1
Motorola	483	614	529	3.9	3.0	3.7
National Semiconductor	72	85	38	0.6	0.4	0.3
Paradigm	32	39	20	0.3	0.2	0.1
Performance Semiconductor	3	4	0	0	0	0
Quality Semiconductor	5	14	1	0	0	0
Ramtron	3	5	14	0	0	0
Seeq Technology	5	6	0	0	0	0
Silicon Storage Technology	0	10	21	0	0	0.1
Texas Instruments	532	1,122	621	4.3	5.5	4.4
WaferScale Integration	6	4	4	0	0	0
Xicor	48	60	68	0.4	0.3	0.5

Table 2-1 (Continued)
Each Company's Factory Revenue from Shipments of MOS Memory to Americas (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Japanese Companies	5,261	8,393	5,233	42.2	41.0	37.1
Fujitsu	376	553	253	3.0	2.7	1.8
Hitachi	1,298	2,067	1,338	10.4	10.1	9.5
Matsushita	96	159	96	0.8	0.8	0.7
Mitsubishi	637	806	521	5.1	3.9	3.7
NEC	1,140	2,235	1,546	9.1	10.9	11.0
Nippon Steel Semiconductor	56	141	69	0.4	0.7	0.5
Oki	300	542	235	2.4	2.6	1.7
Rohm	16	14	13	0.1	0	0
Sanyo	1	11	58	0	0	0.4
Seiko Epson	12	10	4	0	0	0
Sharp	89	127	63	0.7	0.6	0.4
Sony	115	144	106	0.9	0.7	0.8
Toshiba	1,116	1,572	920	9.0	7.7	6.5
Other Japanese	9	12	11	0	0	0
European Companies	274	346	264	2.2	1.7	1.9
Philips	1	0	0	0	0	0
SGS-Thomson	147	181	144	1.2	0.9	1.0
Siemens	123	160	114	1.0	0.8	0.8
TEMIC	3	5	6	0	0	0
Asia/Pacific Companies	2,747	5,162	4,010	22.0	25.2	28.4
LG Semicon	519	511	429	4.2	2.5	3.0
Hualon Microelectronics Corp.	0	0	1	0	0	0
Hyundai	518	1,390	842	4.2	6.8	6.0
Macronix	40	49	58	0.3	0.2	0.4
Mosel Vitelic	146	175	104	1.2	0.9	0.7
Samsung	1,503	2,983	2,549	12.1	14.6	18.1
Vanguard	0	0	4	0	0	0
Winbond Electronics	21	54	23	0.2	0.3	0.2

Source: Dataquest (May 1997)

Table 2-2
Each Company's Factory Revenue from Shipments of Dynamic RAM to Americas (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Total Market	9,030	15,739	10,107	100.0	100.0	100.0
Americas Companies	2,392	3,909	2,231	26.5	24.8	22.1
G-Link USA	0	0	4	0	0	0
IBM	708	836	391	7.8	5.3	3.9
Micron Technology	953	1,762	1,103	10.6	11.2	10.9
Motorola	273	294	189	3.0	1.9	1.9
Ramtron	3	5	14	0	0	0.1
Texas Instruments	455	1,012	530	5.0	6.4	5.2
Japanese Companies	4,144	7,078	4,192	45.9	45.0	41.5
Fujitsu	260	446	250	2.9	2.8	2.5
Hitachi	1,050	1,773	1,096	11.6	11.3	10.8
Matsushita	83	158	91	0.9	1.0	0.9
Mitsubishi	574	744	454	6.4	4.7	4.5
NEC	1,040	2,096	1,380	11.5	13.3	13.7
Nippon Steel Semiconductor	56	141	69	0.6	0.9	0.7
Oki	281	454	154	3.1	2.9	1.5
Sanyo	1	6	30	0	0	0.3
Sharp	18	29	16	0.2	0.2	0.2
Toshiba	781	1,231	652	8.6	7.8	6.5
European Companies	123	160	114	1.4	1.0	1.1
Siemens	123	160	114	1.4	1.0	1.1
Asia/Pacific Companies	2,371	4,592	3,570	26.3	29.2	35.3
LG Semicon	500	500	417	5.5	3.2	4.1
Hyundai	466	1,350	819	5.2	8.6	8.1
Mosel Vitelic	127	149	101	1.4	0.9	1.0
Samsung	1,278	2,593	2,229	14.2	16.5	22.1
Vanguard	0	0	4	0	0	0

Source: Dataquest (May 1997)

Table 2-3
Each Company's Factory Revenue from Shipments of Static RAM to Americas (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Total Market	1,630	2,509	1,882	100.0	100.0	100.0
Americas Companies	697	1,212	844	42.8	48.3	44.8
Advanced Micro Devices	0	2	2	0	0	0.1
Alliance Semiconductor	50	124	25	3.1	4.9	1.3
Cypress Semiconductor	136	210	182	8.3	8.4	9.7
Dallas Semiconductor	12	20	0	0.7	0.8	0
Electronic Designs	20	32	35	1.2	1.3	1.9
G-Link USA	0	8	3	0	0.3	0.2
Harris	6	9	4	0.4	0.4	0.2
IBM	0	56	29	0	2.2	1.5
Integrated Device Technology	89	203	117	5.5	8.1	6.2
Integrated Silicon Solution Inc.	23	56	50	1.4	2.2	2.7
Logic Devices	2	5	2	0.1	0.2	0.1
Micron Technology	97	112	40	6.0	4.5	2.1
Motorola	210	319	332	12.9	12.7	17.6
National Semiconductor	9	4	2	0.6	0.2	0.1
Paradigm	32	39	20	2.0	1.6	1.1
Performance Semiconductor	3	4	0	0.2	0.2	0
Quality Semiconductor	2	0	0	0.1	0	0
Texas Instruments	6	9	1	0.4	0.4	0
Japanese Companies	707	851	729	43.4	33.9	38.7
Fujitsu	83	64	2	5.1	2.6	0.1
Hitachi	181	233	210	11.1	9.3	11.2
Matsushita	0	0	2	0	0	0.1
Mitsubishi	48	59	66	2.9	2.4	3.5
NEC	81	121	109	5.0	4.8	5.8
Oki	3	2	1	0.2	0	0
Rohm	4	5	5	0.2	0.2	0.3
Sanyo	0	3	3	0	0.1	0.2
Seiko Epson	12	10	4	0.7	0.4	0.2
Sharp	23	35	27	1.4	1.4	1.4
Sony	115	144	106	7.1	5.7	5.6
Toshiba	157	175	194	9.6	7.0	10.3
European Companies	6	20	11	0.4	0.8	0.6
SGS-Thomson	3	15	5	0.2	0.6	0.3
TEMIC	3	5	6	0.2	0.2	0.3

Table 2-3 (Continued)
Each Company's Factory Revenue from Shipments of Static RAM to Americas (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Asia/Pacific Companies	220	426	298	13.5	17.0	15.8
LG Semicon	8	11	12	0.5	0.4	0.6
Hyundai	28	40	23	1.7	1.6	1.2
Mosel Vitelic	19	17	3	1.2	0.7	0.2
Samsung	144	306	239	8.8	12.2	12.7
Winbond Electronics	21	52	21	1.3	2.1	1.1

Source: Dataquest (May 1997)

Table 2-4
Each Company's Factory Revenue from Shipments of Nonvolatile Memory to Americas (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Total Market	1,634	1,951	1,820	100.0	100.0	100.0
Americas Companies	966	1,285	1,361	59.1	65.9	74.8
Advanced Micro Devices	214	326	358	13.1	16.7	19.7
Atmel	166	222	265	10.2	11.4	14.6
Catalyst	19	22	24	1.2	1.1	1.3
Cypress Semiconductor	33	73	40	2.0	3.7	2.2
Electronic Designs	0	0	2	0	0	0.1
Gould AMI	23	0	0	1.4	0	0
Harris	2	5	2	0.1	0.3	0.1
Integrated Silicon Solution Inc.	7	6	8	0.4	0.3	0.4
Intel	288	402	415	17.6	20.6	22.8
IMP	1	0	0	0	0	0
Microchip Technology	31	29	28	1.9	1.5	1.5
Micron Technology	0	0	1	0	0	0
Motorola	0	0	3	0	0	0.2
National Semiconductor	63	57	36	3.9	2.9	2.0
Seeq Technology	5	6	0	0.3	0.3	0
Silicon Storage Technology	0	10	21	0	0.5	1.2
Texas Instruments	64	67	90	3.9	3.4	4.9
WaferScale Integration	6	4	4	0.4	0.2	0.2
Xicor	44	56	64	2.7	2.9	3.5
Japanese Companies	400	375	189	24.5	19.2	10.4
Fujitsu	33	43	1	2.0	2.2	0
Hitachi	67	61	32	4.1	3.1	1.8
Matsushita	13	1	3	0.8	0	0.2
Mitsubishi	15	3	1	0.9	0.2	0
NEC	19	18	19	1.2	0.9	1.0
Oki	16	11	8	1.0	0.6	0.4
Rohm	12	9	8	0.7	0.5	0.4
Sanyo	0	1	24	0	0	1.3
Sharp	47	62	19	2.9	3.2	1.0
Toshiba	178	166	74	10.9	8.5	4.1
European Companies	136	156	128	8.3	8.0	7.0
Philips	1	0	0	0	0	0
SGS-Thomson	135	156	128	8.3	8.0	7.0

Table 2-4 (Continued)
Each Company's Factory Revenue from Shipments of Nonvolatile Memory to Americas (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Asia/Pacific Companies	132	135	142	8.1	6.9	7.8
LG Semicon	11	0	0	0.7	0	0
Hualon Microelectronics Corp.	0	0	1	0	0	0
Macronix	40	49	58	2.4	2.5	3.2
Samsung	81	84	81	5.0	4.3	4.5
Winbond Electronics	0	2	2	0	0.1	0.1

Source: Dataquest (May 1997)

Table 2-5
Each Company's Factory Revenue from Shipments of EPROM to Americas (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Total Market	527	419	388	100.0	100.0	100.0
Americas Companies	322	280	259	61.1	66.8	66.8
Advanced Micro Devices	105	63	71	19.9	15.0	18.3
Atmel	53	49	95	10.1	11.7	24.5
Cypress Semiconductor	33	73	40	6.3	17.4	10.3
Integrated Silicon Solution Inc.	7	5	2	1.3	1.2	0.5
Intel	3	0	0	0.6	0	0
Microchip Technology	10	8	7	1.9	1.9	1.8
National Semiconductor	44	24	11	8.3	5.7	2.8
Texas Instruments	61	54	29	11.6	12.9	7.5
WaferScale Integration	6	4	4	1.1	1.0	1.0
Japanese Companies	74	43	26	14.0	10.3	6.7
Fujitsu	17	12	0	3.2	2.9	0
Hitachi	17	13	9	3.2	3.1	2.3
Mitsubishi	7	0	0	1.3	0	0
NEC	5	2	2	0.9	0.5	0.5
Oki	1	0	0	0.2	0	0
Toshiba	27	16	15	5.1	3.8	3.9
European Companies	107	77	81	20.3	18.4	20.9
SGS-Thomson	107	77	81	20.3	18.4	20.9
Asia/Pacific Companies	24	19	22	4.6	4.5	5.7
Macronix	24	19	22	4.6	4.5	5.7

Source: Dataquest (May 1997)

Table 2-6
Each Company's Factory Revenue from Shipments of EEPROM to Americas (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Total Market	233	290	282	100.0	100.0	100.0
Americas Companies	183	226	251	78.5	77.9	89.0
Atmel	79	90	100	33.9	31.0	35.5
Catalyst	15	19	20	6.4	6.6	7.1
Integrated Silicon Solution Inc.	0	1	2	0	0.3	0.7
Microchip Technology	21	21	21	9.0	7.2	7.4
National Semiconductor	19	33	25	8.2	11.4	8.9
Seeq Technology	5	6	0	2.1	2.1	0
Texas Instruments	0	0	19	0	0	6.7
Xicor	44	56	64	18.9	19.3	22.7
Japanese Companies	24	18	13	10.3	6.2	4.6
Fujitsu	1	1	0	0.4	0.3	0
Mitsubishi	5	3	0	2.1	1.0	0
NEC	5	5	5	2.1	1.7	1.8
Oki	3	0	0	1.3	0	0
Rohm	10	9	8	4.3	3.1	2.8
European Companies	17	46	18	7.3	15.9	6.4
Philips	1	0	0	0.4	0	0
SGS-Thomson	16	46	18	6.9	15.9	6.4
Asia/Pacific Companies	9	0	0	3.9	0	0
Samsung	9	0	0	3.9	0	0

Source: Dataquest (May 1997)

Table 2-7
Each Company's Factory Revenue from Shipments of Flash Memory to Americas (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Total Market	474	852	950	100.0	100.0	100.0
Americas Companies	434	774	848	91.6	90.8	89.3
Advanced Micro Devices	109	263	287	23.0	30.9	30.2
Atmel	34	83	70	7.2	9.7	7.4
Catalyst	4	3	4	0.8	0.4	0.4
Electronic Designs	0	0	2	0	0	0.2
Integrated Silicon Solution Inc.	0	0	4	0	0	0.4
Intel	285	402	415	60.1	47.2	43.7
Micron Technology	0	0	1	0	0	0.1
Motorola	0	0	3	0	0	0.3
Silicon Storage Technology	0	10	21	0	1.2	2.2
Texas Instruments	2	13	41	0.4	1.5	4.3
Japanese Companies	27	44	53	5.7	5.2	5.6
Fujitsu	5	25	1	1.1	2.9	0.1
Hitachi	2	0	0	0.4	0	0
Matsushita	0	0	3	0	0	0.3
Mitsubishi	2	0	1	0.4	0	0.1
NEC	3	5	7	0.6	0.6	0.7
Rohm	2	0	0	0.4	0	0
Sanyo	0	0	23	0	0	2.4
Sharp	2	0	0	0.4	0	0
Toshiba	11	14	18	2.3	1.6	1.9
European Companies	12	33	29	2.5	3.9	3.1
SGS-Thomson	12	33	29	2.5	3.9	3.1
Asia/Pacific Companies	1	1	20	0.2	0.1	2.1
Macronix	0	1	12	0	0.1	1.3
Samsung	1	0	8	0.2	0	0.8

Source: Dataquest (May 1997)

Table 2-8
Each Company's Factory Revenue from Shipments of Mask ROM to Americas (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Total Market	400	390	200	100.0	100.0	100.0
Americas Companies	27	5	3	6.8	1.3	1.5
Gould AMI	23	0	0	5.8	0	0
Harris	2	5	2	0.5	1.3	1.0
IMP	1	0	0	0.3	0	0
Texas Instruments	1	0	1	0.3	0	0.5
Japanese Companies	275	270	97	68.8	69.2	48.5
Fujitsu	10	5	0	2.5	1.3	0
Hitachi	48	48	23	12.0	12.3	11.5
Matsushita	13	1	0	3.3	0.3	0
Mitsubishi	1	0	0	0.3	0	0
NEC	6	6	5	1.5	1.5	2.5
Oki	12	11	8	3.0	2.8	4.0
Sanyo	0	1	1	0	0.3	0.5
Sharp	45	62	19	11.3	15.9	9.5
Toshiba	140	136	41	35.0	34.9	20.5
Asia/Pacific Companies	98	115	100	24.5	29.5	50.0
LG Semicon	11	0	0	2.8	0	0
Hualon Microelectronics Corp.	0	0	1	0	0	0.5
Macronix	16	29	24	4.0	7.4	12.0
Samsung	71	84	73	17.8	21.5	36.5
Winbond Electronics	0	2	2	0	0.5	1.0

Source: Dataquest (May 1997)

Table 2-9
Each Company's Factory Revenue from Shipments of Other MOS Memory to Americas (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Total Market	175	281	303	100.0	100.0	100.0
Americas Companies	132	173	169	75.4	61.6	55.8
Advanced Micro Devices	10	8	0	5.7	2.8	0
Cypress Semiconductor	30	19	55	17.1	6.8	18.2
Integrated Device Technology	75	66	104	42.9	23.5	34.3
Lucent Technologies	3	3	0	1.7	1.1	0
Motorola	0	1	5	0	0.4	1.7
National Semiconductor	0	24	0	0	8.5	0
Quality Semiconductor	3	14	1	1.7	5.0	0.3
Texas Instruments	7	34	0	4.0	12.1	0
Xicor	4	4	4	2.3	1.4	1.3
Japanese Companies	10	89	123	5.7	31.7	40.6
NEC	0	0	38	0	0	12.5
Oki	0	75	72	0	26.7	23.8
Sanyo	0	1	1	0	0.4	0.3
Sharp	1	1	1	0.6	0.4	0.3
Other Japanese	9	12	11	5.1	4.3	3.6
European Companies	9	10	11	5.1	3.6	3.6
SGS-Thomson	9	10	11	5.1	3.6	3.6
Asia/Pacific Companies	24	9	0	13.7	3.2	0
Hyundai	24	0	0	13.7	0	0
Mosel Vitelic	0	9	0	0	3.2	0

Source: Dataquest (May 1997)

Section 3: Shipments to Japan

Table 3-1
Each Company's Factory Revenue from Shipments of MOS Memory to Japan (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Total Market	7,246	12,168	8,602	100.0	100.0	100.0
Americas Companies	958	1,907	1,265	13.2	15.7	14.7
Advanced Micro Devices	46	50	56	0.6	0.4	0.7
Alliance Semiconductor	0	6	2	0	0	0
Atmel	39	87	207	0.5	0.7	2.4
Catalyst	10	7	7	0.1	0	0
Cypress Semiconductor	22	25	22	0.3	0.2	0.3
Dallas Semiconductor	3	3	0	0	0	0
IBM	100	428	210	1.4	3.5	2.4
Integrated Device Technology	23	41	52	0.3	0.3	0.6
Integrated Silicon Solution Inc.	0	6	4	0	0	0
Intel	16	68	122	0.2	0.6	1.4
Microchip Technology	15	28	27	0.2	0.2	0.3
Micron Technology	18	56	32	0.2	0.5	0.4
Motorola	109	142	65	1.5	1.2	0.8
National Semiconductor	27	35	22	0.4	0.3	0.3
Paradigm	1	0	0	0	0	0
Ramtron	2	4	0	0	0	0
Silicon Storage Technology	0	0	18	0	0	0.2
Texas Instruments	504	893	388	7.0	7.3	4.5
WaferScale Integration	2	5	9	0	0	0.1
Xicor	21	23	22	0.3	0.2	0.3
Japanese Companies	5,234	7,933	5,748	72.2	65.2	66.8
Fujitsu	687	967	659	9.5	7.9	7.7
Hitachi	955	1,702	1,239	13.2	14.0	14.4
Matsushita	222	245	149	3.1	2.0	1.7
Mitsubishi	355	701	471	4.9	5.8	5.5
NEC	886	1,392	1,286	12.2	11.4	15.0
Nippon Steel Semiconductor	46	206	36	0.6	1.7	0.4
Oki	134	248	185	1.8	2.0	2.2
Ricoh	16	6	3	0.2	0	0
Rohm	26	30	24	0.4	0.2	0.3
Sanyo	88	143	180	1.2	1.2	2.1
Seiko Epson	21	20	10	0.3	0.2	0.1
Sharp	608	697	531	8.4	5.7	6.2

Table 3-1 (Continued)
Each Company's Factory Revenue from Shipments of MOS Memory to Japan (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Sony	187	192	121	2.6	1.6	1.4
Toshiba	1,000	1,381	849	13.8	11.3	9.9
Yamaha	1	1	1	0	0	0
Other Japanese	2	2	4	0	0	0
European Companies	94	102	101	1.3	0.8	1.2
Philips	1	0	0	0	0	0
SGS-Thomson	88	93	96	1.2	0.8	1.1
Siemens	5	9	5	0	0	0
Asia/Pacific Companies	960	2,226	1,488	13.2	18.3	17.3
LG Semicon	106	389	237	1.5	3.2	2.8
Hualon Microelectronics Corp.	0	0	1	0	0	0
Hyundai	124	345	244	1.7	2.8	2.8
Macronix	77	110	141	1.1	0.9	1.6
Mosel Vitelic	8	112	41	0.1	0.9	0.5
Samsung	619	1,242	788	8.5	10.2	9.2
United Microelectronics Corp.	25	26	24	0.3	0.2	0.3
Vanguard	0	0	7	0	0	0
Winbond Electronics	1	2	5	0	0	0

Source: Dataquest (May 1997)

Table 3-2
Each Company's Factory Revenue from Shipments of Dynamic RAM to Japan (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Total Market	4,012	8,490	5,166	100.0	100.0	100.0
Americas Companies	620	1,380	584	15.5	16.3	11.3
IBM	100	420	200	2.5	4.9	3.9
Micron Technology	16	55	30	0.4	0.6	0.6
Motorola	72	90	23	1.8	1.1	0.4
Ramtron	2	4	0	0	0	0
Texas Instruments	430	811	331	10.7	9.6	6.4
Japanese Companies	2,717	5,193	3,420	67.7	61.2	66.2
Fujitsu	391	644	396	9.7	7.6	7.7
Hitachi	562	1,278	888	14.0	15.1	17.2
Matsushita	179	230	140	4.5	2.7	2.7
Mitsubishi	243	562	352	6.1	6.6	6.8
NEC	434	904	766	10.8	10.6	14.8
Nippon Steel Semiconductor	46	206	36	1.1	2.4	0.7
Oki	76	128	89	1.9	1.5	1.7
Sanyo	27	91	123	0.7	1.1	2.4
Sharp	42	65	29	1.0	0.8	0.6
Sony	4	5	3	0	0	0
Toshiba	713	1,080	598	17.8	12.7	11.6
European Companies	5	9	5	0.1	0.1	0
Siemens	5	9	5	0.1	0.1	0
Asia/Pacific Companies	670	1,908	1,157	16.7	22.5	22.4
LG Semicon	93	383	230	2.3	4.5	4.5
Hyundai	92	310	229	2.3	3.7	4.4
Mosel Vitelic	8	106	40	0.2	1.2	0.8
Samsung	477	1,109	651	11.9	13.1	12.6
Vanguard	0	0	7	0	0	0.1

Source: Dataquest (May 1997)

Table 3-3
Each Company's Factory Revenue from Shipments of Static RAM to Japan (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Total Market	1,397	1,446	1,239	100.0	100.0	100.0
Americas Companies	77	105	86	5.5	7.3	6.9
Advanced Micro Devices	2	0	1	0.1	0	0
Alliance Semiconductor	0	6	2	0	0.4	0.2
Cypress Semiconductor	15	18	14	1.1	1.2	1.1
Dallas Semiconductor	3	3	0	0.2	0.2	0
IBM	0	8	10	0	0.6	0.8
Integrated Device Technology	13	11	9	0.9	0.8	0.7
Integrated Silicon Solution Inc.	0	6	2	0	0.4	0.2
Micron Technology	2	1	2	0.1	0	0.2
Motorola	37	52	41	2.6	3.6	3.3
Paradigm	1	0	0	0	0	0
Texas Instruments	4	0	5	0.3	0	0.4
Japanese Companies	1,227	1,222	1,057	87.8	84.5	85.3
Fujitsu	181	111	53	13.0	7.7	4.3
Hitachi	271	290	272	19.4	20.1	22.0
Matsushita	23	11	4	1.6	0.8	0.3
Mitsubishi	68	105	98	4.9	7.3	7.9
NEC	186	200	239	13.3	13.8	19.3
Oki	9	7	4	0.6	0.5	0.3
Ricoh	8	0	0	0.6	0	0
Rohm	14	17	12	1.0	1.2	1.0
Sanyo	44	37	26	3.1	2.6	2.1
Seiko Epson	20	19	10	1.4	1.3	0.8
Sharp	102	111	83	7.3	7.7	6.7
Sony	162	165	118	11.6	11.4	9.5
Toshiba	139	149	138	9.9	10.3	11.1
European Companies	0	3	3	0	0.2	0.2
SGS-Thomson	0	3	3	0	0.2	0.2
Asia/Pacific Companies	93	116	93	6.7	8.0	7.5
LG Semicon	12	6	7	0.9	0.4	0.6
Hyundai	31	35	15	2.2	2.4	1.2
Mosel Vitelic	0	0	1	0	0	0
Samsung	34	73	66	2.4	5.0	5.3
United Microelectronics Corp.	15	0	0	1.1	0	0
Winbond Electronics	1	2	4	0	0.1	0.3

Source: Dataquest (May 1997)

Table 3-4
Each Company's Factory Revenue from Shipments of Nonvolatile Memory to Japan (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Total Market	1,785	2,116	2,044	100.0	100.0	100.0
Americas Companies	226	368	546	12.7	17.4	26.7
Advanced Micro Devices	43	48	55	2.4	2.3	2.7
Atmel	39	87	207	2.2	4.1	10.1
Catalyst	10	7	7	0.6	0.3	0.3
Cypress Semiconductor	4	6	4	0.2	0.3	0.2
Integrated Silicon Solution Inc.	0	0	2	0	0	0
Intel	16	68	122	0.9	3.2	6.0
Microchip Technology	15	28	27	0.8	1.3	1.3
National Semiconductor	27	35	22	1.5	1.7	1.1
Silicon Storage Technology	0	0	18	0	0	0.9
Texas Instruments	50	62	52	2.8	2.9	2.5
WaferScale Integration	2	5	9	0.1	0.2	0.4
Xicor	20	22	21	1.1	1.0	1.0
Japanese Companies	1,280	1,465	1,169	71.7	69.2	57.2
Fujitsu	115	212	210	6.4	10.0	10.3
Hitachi	122	134	79	6.8	6.3	3.9
Matsushita	20	4	5	1.1	0.2	0.2
Mitsubishi	44	31	18	2.5	1.5	0.9
NEC	266	288	232	14.9	13.6	11.4
Oki	49	70	52	2.7	3.3	2.5
Ricoh	8	6	1	0.4	0.3	0
Rohm	12	13	12	0.7	0.6	0.6
Sanyo	9	10	27	0.5	0.5	1.3
Seiko Epson	1	1	0	0	0	0
Sharp	464	521	419	26.0	24.6	20.5
Sony	21	22	0	1.2	1.0	0
Toshiba	148	152	113	8.3	7.2	5.5
Yamaha	1	1	1	0	0	0
European Companies	83	87	91	4.6	4.1	4.5
Philips	1	0	0	0	0	0
SGS-Thomson	82	87	91	4.6	4.1	4.5
Asia/Pacific Companies	196	196	238	11.0	9.3	11.6
LG Semicon	1	0	0	0	0	0
Hualon Microelectronics Corp.	0	0	1	0	0	0
Macronix	77	110	141	4.3	5.2	6.9
Samsung	108	60	71	6.1	2.8	3.5
United Microelectronics Corp.	10	26	24	0.6	1.2	1.2
Winbond Electronics	0	0	1	0	0	0

Source: Dataquest (May 1997)

Table 3-5
Each Company's Factory Revenue from Shipments of EPROM to Japan (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Total Market	396	439	348	100.0	100.0	100.0
Americas Companies	123	160	113	31.1	36.4	32.5
Advanced Micro Devices	28	27	27	7.1	6.2	7.8
Atmel	11	25	30	2.8	5.7	8.6
Cypress Semiconductor	4	6	4	1.0	1.4	1.1
Integrated Silicon Solution Inc.	0	0	1	0	0	0.3
Intel	2	0	0	0.5	0	0
Microchip Technology	5	7	1	1.3	1.6	0.3
National Semiconductor	23	30	10	5.8	6.8	2.9
Texas Instruments	48	60	31	12.1	13.7	8.9
WaferScale Integration	2	5	9	0.5	1.1	2.6
Japanese Companies	191	184	127	48.2	41.9	36.5
Fujitsu	59	47	19	14.9	10.7	5.5
Hitachi	35	35	26	8.8	8.0	7.5
Mitsubishi	29	24	12	7.3	5.5	3.4
NEC	27	26	27	6.8	5.9	7.8
Oki	8	17	14	2.0	3.9	4.0
Sanyo	4	4	1	1.0	0.9	0.3
Sharp	3	3	3	0.8	0.7	0.9
Toshiba	26	28	25	6.6	6.4	7.2
European Companies	69	72	73	17.4	16.4	21.0
SGS-Thomson	69	72	73	17.4	16.4	21.0
Asia/Pacific Companies	13	23	35	3.3	5.2	10.1
Macronix	13	23	35	3.3	5.2	10.1

Source: Dataquest (May 1997)

Table 3-6
Each Company's Factory Revenue from Shipments of EEPROM to Japan (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Total Market	122	143	167	100.0	100.0	100.0
Americas Companies	52	68	108	42.6	47.6	64.7
Atmel	12	14	28	9.8	9.8	16.8
Catalyst	6	6	6	4.9	4.2	3.6
Microchip Technology	10	21	26	8.2	14.7	15.6
National Semiconductor	4	5	12	3.3	3.5	7.2
Texas Instruments	0	0	15	0	0	9.0
Xicor	20	22	21	16.4	15.4	12.6
Japanese Companies	59	66	49	48.4	46.2	29.3
Fujitsu	11	10	5	9.0	7.0	3.0
Hitachi	1	3	2	0.8	2.1	1.2
Mitsubishi	1	4	1	0.8	2.8	0.6
NEC	27	28	25	22.1	19.6	15.0
Oki	4	5	4	3.3	3.5	2.4
Rohm	12	13	12	9.8	9.1	7.2
Sanyo	3	3	0	2.5	2.1	0
European Companies	10	9	10	8.2	6.3	6.0
Philips	1	0	0	0.8	0	0
SGS-Thomson	9	9	10	7.4	6.3	6.0
Asia/Pacific Companies	1	0	0	0.8	0	0
Samsung	1	0	0	0.8	0	0

Source: Dataquest (May 1997)

Table 3-7
Each Company's Factory Revenue from Shipments of Flash Memory to Japan (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Total Market	120	361	786	100.0	100.0	100.0
Americas Companies	51	140	325	42.5	38.8	41.3
Advanced Micro Devices	15	21	28	12.5	5.8	3.6
Atmel	16	48	149	13.3	13.3	19.0
Catalyst	4	1	1	3.3	0.3	0.1
Integrated Silicon Solution Inc.	0	0	1	0	0	0.1
Intel	14	68	122	11.7	18.8	15.5
Silicon Storage Technology	0	0	18	0	0	2.3
Texas Instruments	2	2	6	1.7	0.6	0.8
Japanese Companies	64	215	433	53.3	59.6	55.1
Fujitsu	5	110	176	4.2	30.5	22.4
Hitachi	1	0	2	0.8	0	0.3
Matsushita	0	0	5	0	0	0.6
Mitsubishi	6	3	5	5.0	0.8	0.6
NEC	3	12	21	2.5	3.3	2.7
Oki	4	0	0	3.3	0	0
Sanyo	0	0	24	0	0	3.1
Sharp	6	43	145	5.0	11.9	18.4
Toshiba	39	47	55	32.5	13.0	7.0
European Companies	4	6	8	3.3	1.7	1.0
SGS-Thomson	4	6	8	3.3	1.7	1.0
Asia/Pacific Companies	1	0	20	0.8	0	2.5
Macronix	0	0	5	0	0	0.6
Samsung	1	0	15	0.8	0	1.9

Source: Dataquest (May 1997)

Table 3-8
Each Company's Factory Revenue from Shipments of Mask ROM to Japan (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Total Market	1,147	1,173	743	100.0	100.0	100.0
Japanese Companies	966	1,000	560	84.2	85.3	75.4
Fujitsu	40	45	10	3.5	3.8	1.3
Hitachi	85	96	49	7.4	8.2	6.6
Matsushita	20	4	0	1.7	0.3	0
Mitsubishi	8	0	0	0.7	0	0
NEC	209	222	159	18.2	18.9	21.4
Oki	33	48	34	2.9	4.1	4.6
Ricoh	8	6	1	0.7	0.5	0.1
Sanyo	2	3	2	0.2	0.3	0.3
Seiko Epson	1	1	0	0	0	0
Sharp	455	475	271	39.7	40.5	36.5
Sony	21	22	0	1.8	1.9	0
Toshiba	83	77	33	7.2	6.6	4.4
Yamaha	1	1	1	0	0	0.1
Asia/Pacific Companies	181	173	183	15.8	14.7	24.6
LG Semicon	1	0	0	0	0	0
Hualon Microelectronics Corp.	0	0	1	0	0	0.1
Macronix	64	87	101	5.6	7.4	13.6
Samsung	106	60	56	9.2	5.1	7.5
United Microelectronics Corp.	10	26	24	0.9	2.2	3.2
Winbond Electronics	0	0	1	0	0	0.1

Source: Dataquest (May 1997)

Table 3-9
Each Company's Factory Revenue from Shipments of Other MOS Memory to Japan (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Total Market	52	116	153	100.0	100.0	100.0
Americas Companies	35	54	49	67.3	46.6	32.0
Advanced Micro Devices	1	2	0	1.9	1.7	0
Cypress Semiconductor	3	1	4	5.8	0.9	2.6
Integrated Device Technology	10	30	43	19.2	25.9	28.1
Motorola	0	0	1	0	0	0.7
Texas Instruments	20	20	0	38.5	17.2	0
Xicor	1	1	1	1.9	0.9	0.7
Japanese Companies	10	53	102	19.2	45.7	66.7
Mitsubishi	0	3	3	0	2.6	2.0
NEC	0	0	49	0	0	32.0
Oki	0	43	40	0	37.1	26.1
Ricoh	0	0	2	0	0	1.3
Sanyo	8	5	4	15.4	4.3	2.6
Other Japanese	2	2	4	3.8	1.7	2.6
European Companies	6	3	2	11.5	2.6	1.3
SGS-Thomson	6	3	2	11.5	2.6	1.3
Asia/Pacific Companies	1	6	0	1.9	5.2	0
Hyundai	1	0	0	1.9	0	0
Mosel Vitelic	0	6	0	0	5.2	0

Source: Dataquest (May 1997)

Section 4: Shipments to Europe, Middle East, and Africa

Table 4-1
Each Company's Factory Revenue from Shipments of MOS Memory to Europe, Middle East, and Africa (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Total Market	6,574	10,074	7,058	100.0	100.0	100.0
Americas Companies	1,917	2,768	2,006	29.2	27.5	28.4
Advanced Micro Devices	123	253	225	1.9	2.5	3.2
Alliance Semiconductor	5	21	9	0	0.2	0.1
Atmel	70	101	142	1.1	1.0	2.0
Catalyst	10	10	11	0.2	0	0.2
Cypress Semiconductor	46	66	56	0.7	0.7	0.8
Dallas Semiconductor	6	12	0	0	0.1	0
Electronic Designs	6	11	11	0	0.1	0.2
G-Link USA	0	0	1	0	0	0
Gould AMI	4	0	0	0	0	0
Harris	4	3	3	0	0	0
IBM	632	652	314	9.6	6.5	4.4
Integrated Device Technology	52	87	79	0.8	0.9	1.1
Integrated Silicon Solution Inc.	4	16	10	0	0.2	0.1
Intel	109	195	250	1.7	1.9	3.5
Microchip Technology	18	22	25	0.3	0.2	0.4
Micron Technology	170	336	259	2.6	3.3	3.7
Motorola	193	258	138	2.9	2.6	2.0
National Semiconductor	41	36	28	0.6	0.4	0.4
Paradigm	1	6	1	0	0	0
Performance Semiconductor	1	1	0	0	0	0
Ramtron	1	2	0	0	0	0
Silicon Storage Technology	0	0	4	0	0	0
Texas Instruments	389	646	409	5.9	6.4	5.8
WaferScale Integration	5	6	2	0	0	0
Xicor	27	28	29	0.4	0.3	0.4
Japanese Companies	2,163	3,472	2,249	32.9	34.5	31.9
Fujitsu	319	643	433	4.9	6.4	6.1
Hitachi	450	618	469	6.8	6.1	6.6
Matsushita	15	26	18	0.2	0.3	0.3
Mitsubishi	256	436	278	3.9	4.3	3.9
NEC	522	849	540	7.9	8.4	7.7
Nippon Steel Semiconductor	0	0	1	0	0	0
Oki	117	189	61	1.8	1.9	0.9

Table 4-1 (Continued)
Each Company's Factory Revenue from Shipments of MOS Memory to Europe, Middle East, and Africa (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Rohm	5	5	3	0	0	0
Sanyo	4	8	7	0	0	0
Seiko Epson	5	5	2	0	0	0
Sharp	36	35	25	0.5	0.3	0.4
Sony	38	79	70	0.6	0.8	1.0
Toshiba	396	579	342	6.0	5.7	4.8
European Companies	783	1,084	899	11.9	10.8	12.7
Philips	7	0	0	0.1	0	0
SGS-Thomson	266	275	391	4.0	2.7	5.5
Siemens	492	790	494	7.5	7.8	7.0
TEMIC	18	19	14	0.3	0.2	0.2
Asia/Pacific Companies	1,711	2,750	1,904	26.0	27.3	27.0
LG Semicon	379	452	376	5.8	4.5	5.3
Hyundai	337	781	395	5.1	7.8	5.6
Macronix	3	15	13	0	0.1	0.2
Mosel Vitelic	3	18	12	0	0.2	0.2
Samsung	978	1,470	1,090	14.9	14.6	15.4
United Microelectronics Corp.	10	10	12	0.2	0	0.2
Vanguard	0	0	5	0	0	0
Winbond Electronics	1	4	1	0	0	0

Source: Dataquest (May 1997)

Table 4-2
Each Company's Factory Revenue from Shipments of Dynamic RAM to Europe, Middle East, and Africa (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Total Market	4,927	7,887	4,759	100.0	100.0	100.0
Americas Companies	1,236	1,701	949	25.1	21.6	19.9
IBM	632	626	305	12.8	7.9	6.4
Micron Technology	146	317	257	3.0	4.0	5.4
Motorola	140	172	49	2.8	2.2	1.0
Ramtron	1	2	0	0	0	0
Texas Instruments	317	584	337	6.4	7.4	7.1
G-Link USA	0	0	1	0	0	0
Japanese Companies	1,711	2,912	1,677	34.7	36.9	35.2
Fujitsu	281	585	340	5.7	7.4	7.1
Hitachi	370	534	392	7.5	6.8	8.2
Matsushita	15	26	16	0.3	0.3	0.3
Mitsubishi	198	352	186	4.0	4.5	3.9
NEC	431	756	458	8.7	9.6	9.6
Nippon Steel Semiconductor	0	0	1	0	0	0
Oki	110	176	50	2.2	2.2	1.1
Sanyo	0	7	6	0	0	0.1
Sharp	3	6	3	0	0	0
Toshiba	303	470	225	6.1	6.0	4.7
European Companies	420	737	428	8.5	9.3	9.0
Siemens	420	737	428	8.5	9.3	9.0
Asia/Pacific Companies	1,560	2,537	1,705	31.7	32.2	35.8
LG Semicon	375	440	361	7.6	5.6	7.6
Hyundai	325	760	387	6.6	9.6	8.1
Mosel Vitelic	2	16	12	0	0.2	0.3
Samsung	858	1,321	940	17.4	16.7	19.8
Vanguard	0	0	5	0	0	0.1

Source: Dataquest (May 1997)

Table 4-3
Each Company's Factory Revenue from Shipments of Static RAM to Europe, Middle East, and Africa (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Total Market	620	921	800	100.0	100.0	100.0
Americas Companies	165	289	213	26.6	31.4	26.6
Advanced Micro Devices	2	2	0	0.3	0.2	0
Alliance Semiconductor	5	21	9	0.8	2.3	1.1
Cypress Semiconductor	31	49	41	5.0	5.3	5.1
Dallas Semiconductor	6	12	0	1.0	1.3	0
Electronic Designs	6	11	11	1.0	1.2	1.4
Harris	2	1	1	0.3	0.1	0.1
IBM	0	26	9	0	2.8	1.1
Integrated Device Technology	30	40	43	4.8	4.3	5.4
Integrated Silicon Solution Inc.	3	15	9	0.5	1.6	1.1
Micron Technology	24	19	2	3.9	2.1	0.3
Motorola	52	85	86	8.4	9.2	10.8
National Semiconductor	1	0	0	0.2	0	0
Paradigm	1	6	1	0.2	0.7	0.1
Performance Semiconductor	1	1	0	0.2	0.1	0
Texas Instruments	1	1	1	0.2	0.1	0.1
Japanese Companies	317	425	399	51.1	46.1	49.9
Fujitsu	22	30	0	3.5	3.3	0
Hitachi	60	70	66	9.7	7.6	8.3
Matsushita	0	0	1	0	0	0.1
Mitsubishi	52	82	90	8.4	8.9	11.3
NEC	66	72	55	10.6	7.8	6.9
Oki	2	2	1	0.3	0.2	0.1
Rohm	1	1	0	0.2	0.1	0
Sanyo	4	1	1	0.6	0.1	0.1
Seiko Epson	5	5	2	0.8	0.5	0.3
Sharp	12	19	16	1.9	2.1	2.0
Sony	38	79	70	6.1	8.6	8.8
Toshiba	55	64	97	8.9	6.9	12.1
European Companies	15	27	19	2.4	2.9	2.4
SGS-Thomson	0	8	5	0	0.9	0.6
TEMIC	15	19	14	2.4	2.1	1.8
Asia/Pacific Companies	123	180	169	19.8	19.5	21.1
LG Semicon	4	8	10	0.6	0.9	1.3
Hyundai	12	21	8	1.9	2.3	1.0
Mosel Vitelic	1	1	0	0.2	0.1	0
Samsung	100	136	138	16.1	14.8	17.3
United Microelectronics Corp.	5	10	12	0.8	1.1	1.5
Winbond Electronics	1	4	1	0.2	0.4	0.1

Source: Dataquest (May 1997)

Table 4-4
Each Company's Factory Revenue from Shipments of Nonvolatile Memory to Europe, Middle East, and Africa (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Total Market	966	1,180	1,414	100.0	100.0	100.0
Americas Companies	476	714	787	49.3	60.5	55.7
Advanced Micro Devices	119	249	225	12.3	21.1	15.9
Atmel	70	101	142	7.2	8.6	10.0
Catalyst	10	10	11	1.0	0.8	0.8
Cypress Semiconductor	8	13	5	0.8	1.1	0.4
Gould AMI	4	0	0	0.4	0	0
Harris	2	2	2	0.2	0.2	0.1
Integrated Silicon Solution Inc.	1	1	1	0.1	0	0
Intel	109	195	250	11.3	16.5	17.7
Microchip Technology	18	22	25	1.9	1.9	1.8
Motorola	1	0	1	0.1	0	0
National Semiconductor	40	36	28	4.1	3.1	2.0
Silicon Storage Technology	0	0	4	0	0	0.3
Texas Instruments	69	59	71	7.1	5.0	5.0
WaferScale Integration	5	6	2	0.5	0.5	0.1
Xicor	20	20	20	2.1	1.7	1.4
Japanese Companies	135	130	163	14.0	11.0	11.5
Fujitsu	16	28	93	1.7	2.4	6.6
Hitachi	20	14	11	2.1	1.2	0.8
Matsushita	0	0	1	0	0	0
Mitsubishi	6	2	2	0.6	0.2	0.1
NEC	25	21	22	2.6	1.8	1.6
Oki	5	6	5	0.5	0.5	0.4
Rohm	4	4	3	0.4	0.3	0.2
Sharp	21	10	6	2.2	0.8	0.4
Toshiba	38	45	20	3.9	3.8	1.4
European Companies	327	304	434	33.9	25.8	30.7
Philips	7	0	0	0.7	0	0
SGS-Thomson	245	251	368	25.4	21.3	26.0
Siemens	72	53	66	7.5	4.5	4.7
TEMIC	3	0	0	0.3	0	0
Asia/Pacific Companies	28	32	30	2.9	2.7	2.1
LG Semicon	0	4	5	0	0.3	0.4
Macronix	3	15	13	0.3	1.3	0.9
Samsung	20	13	12	2.1	1.1	0.8
United Microelectronics Corp.	5	0	0	0.5	0	0

Source: Dataquest (May 1997)

Table 4-5
Each Company's Factory Revenue from Shipments of EPROM to Europe, Middle East, and Africa (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Total Market	350	333	282	100.0	100.0	100.0
Americas Companies	176	183	134	50.3	55.0	47.5
Advanced Micro Devices	58	62	48	16.6	18.6	17.0
Atmel	24	30	33	6.9	9.0	11.7
Cypress Semiconductor	8	13	5	2.3	3.9	1.8
Integrated Silicon Solution Inc.	1	1	1	0.3	0.3	0.4
Intel	3	0	0	0.9	0	0
Microchip Technology	6	3	3	1.7	0.9	1.1
National Semiconductor	26	21	11	7.4	6.3	3.9
Texas Instruments	45	47	31	12.9	14.1	11.0
WaferScale Integration	5	6	2	1.4	1.8	0.7
Japanese Companies	24	13	13	6.9	3.9	4.6
Fujitsu	1	0	0	0.3	0	0
Hitachi	6	6	5	1.7	1.8	1.8
Mitsubishi	4	1	1	1.1	0.3	0.4
NEC	7	4	5	2.0	1.2	1.8
Toshiba	6	2	2	1.7	0.6	0.7
European Companies	147	122	128	42.0	36.6	45.4
SGS-Thomson	147	122	128	42.0	36.6	45.4
Asia/Pacific Companies	3	15	7	0.9	4.5	2.5
Macronix	3	15	7	0.9	4.5	2.5

Source: Dataquest (May 1997)

Table 4-6
Each Company's Factory Revenue from Shipments of EEPROM to Europe, Middle East, and Africa (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Total Market	300	274	431	100.0	100.0	100.0
Americas Companies	113	108	156	37.7	39.4	36.2
Atmel	34	34	52	11.3	12.4	12.1
Catalyst	9	9	10	3.0	3.3	2.3
Microchip Technology	12	19	22	4.0	6.9	5.1
Motorola	1	0	0	0.3	0	0
National Semiconductor	14	15	17	4.7	5.5	3.9
Texas Instruments	23	11	35	7.7	4.0	8.1
Xicor	20	20	20	6.7	7.3	4.6
Japanese Companies	18	11	10	6.0	4.0	2.3
Hitachi	4	3	3	1.3	1.1	0.7
Mitsubishi	1	1	1	0.3	0.4	0.2
NEC	4	2	2	1.3	0.7	0.5
Oki	5	1	1	1.7	0.4	0.2
Rohm	4	4	3	1.3	1.5	0.7
European Companies	162	154	265	54.0	56.2	61.5
Philips	7	0	0	2.3	0	0
SGS-Thomson	80	101	199	26.7	36.9	46.2
Siemens	72	53	66	24.0	19.3	15.3
TEMIC	3	0	0	1.0	0	0
Asia/Pacific Companies	7	1	0	2.3	0.4	0
Samsung	7	1	0	2.3	0.4	0

Source: Dataquest (May 1997)

Table 4-7
Each Company's Factory Revenue from Shipments of Flash Memory to Europe, Middle East, and Africa (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Total Market	206	483	641	100.0	100.0	100.0
Americas Companies	181	421	495	87.9	87.2	77.2
Advanced Micro Devices	61	187	177	29.6	38.7	27.6
Atmel	12	37	57	5.8	7.7	8.9
Catalyst	1	1	1	0.5	0.2	0.2
Intel	106	195	250	51.5	40.4	39.0
Motorola	0	0	1	0	0	0.2
Silicon Storage Technology	0	0	4	0	0	0.6
Texas Instruments	1	1	5	0.5	0.2	0.8
Japanese Companies	6	34	101	2.9	7.0	15.8
Fujitsu	3	28	93	1.5	5.8	14.5
Matsushita	0	0	1	0	0	0.2
Mitsubishi	1	0	0	0.5	0	0
NEC	0	1	1	0	0.2	0.2
Sharp	2	0	0	1.0	0	0
Toshiba	0	5	6	0	1.0	0.9
European Companies	18	28	41	8.7	5.8	6.4
SGS-Thomson	18	28	41	8.7	5.8	6.4
Asia/Pacific Companies	1	0	4	0.5	0	0.6
Macronix	0	0	3	0	0	0.5
Samsung	1	0	1	0.5	0	0.2

Source: Dataquest (May 1997)

Table 4-8
Each Company's Factory Revenue from Shipments of Mask ROM to Europe, Middle East, and Africa (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Total Market	110	90	60	100.0	100.0	100.0
Americas Companies	6	2	2	5.5	2.2	3.3
Gould AMI	4	0	0	3.6	0	0
Harris	2	2	2	1.8	2.2	3.3
Japanese Companies	87	72	39	79.1	80.0	65.0
Fujitsu	12	0	0	10.9	0	0
Hitachi	10	5	3	9.1	5.6	5.0
NEC	14	14	14	12.7	15.6	23.3
Oki	0	5	4	0	5.6	6.7
Sharp	19	10	6	17.3	11.1	10.0
Toshiba	32	38	12	29.1	42.2	20.0
Asia/Pacific Companies	17	16	19	15.5	17.8	31.7
LG Semicon	0	4	5	0	4.4	8.3
Macronix	0	0	3	0	0	5.0
Samsung	12	12	11	10.9	13.3	18.3
United Microelectronics Corp.	5	0	0	4.5	0	0

Source: Dataquest (May 1997)

Table 4-9
Each Company's Factory Revenue from Shipments of Other MOS Memory to Europe, Middle East, and Africa (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Total Market	61	86	85	100.0	100.0	100.0
Americas Companies	40	64	57	65.6	74.4	67.1
Advanced Micro Devices	2	2	0	3.3	2.3	0
Cypress Semiconductor	7	4	10	11.5	4.7	11.8
Integrated Device Technology	22	47	36	36.1	54.7	42.4
Motorola	0	1	2	0	1.2	2.4
Texas Instruments	2	2	0	3.3	2.3	0
Xicor	7	8	9	11.5	9.3	10.6
Japanese Companies	0	5	10	0	5.8	11.8
NEC	0	0	5	0	0	5.9
Oki	0	5	5	0	5.8	5.9
European Companies	21	16	18	34.4	18.6	21.2
SGS-Thomson	21	16	18	34.4	18.6	21.2
Asia/Pacific Companies	0	1	0	0	1.2	0
Mosel Vitelic	0	1	0	0	1.2	0

Source: Dataquest (May 1997)

Section 5: Shipments to Asia/Pacific

Table 5-1
Each Company's Factory Revenue from Shipments of MOS Memory to Asia/Pacific (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Total Market	7,216	12,565	8,035	100.0	100.0	100.0
Americas Companies	1,368	2,387	1,523	19.0	19.0	19.0
Advanced Micro Devices	49	80	70	0.7	0.6	0.9
Alliance Semiconductor	35	59	30	0.5	0.5	0.4
Atmel	56	68	179	0.8	0.5	2.2
Catalyst	10	9	12	0.1	0	0.1
Cypress Semiconductor	18	31	27	0.2	0.2	0.3
Dallas Semiconductor	9	21	0	0.1	0.2	0
Electronic Designs	0	0	3	0	0	0
G-Link USA	0	6	7	0	0	0
Gould AMI	17	0	0	0.2	0	0
Harris	0	1	0	0	0	0
IBM	80	128	52	1.1	1.0	0.6
Integrated Device Technology	13	47	26	0.2	0.4	0.3
Integrated Silicon Solution Inc.	26	74	39	0.4	0.6	0.5
Intel	45	101	163	0.6	0.8	2.0
ITT	10	0	0	0.1	0	0
Microchip Technology	18	23	37	0.2	0.2	0.5
Micron Technology	254	335	123	3.5	2.7	1.5
Motorola	163	223	95	2.3	1.8	1.2
National Semiconductor	39	32	39	0.5	0.3	0.5
Paradigm	2	10	2	0	0	0
Performance Semiconductor	1	2	0	0	0	0
Quality Semiconductor	2	0	0	0	0	0
Ramtron	9	14	0	0.1	0.1	0
Silicon Storage Technology	0	25	48	0	0.2	0.6
Texas Instruments	506	1,093	566	7.0	8.7	7.0
WaferScale Integration	2	2	1	0	0	0
Xicor	4	3	4	0	0	0
Japanese Companies	2,861	4,264	2,478	39.6	33.9	30.8
Fujitsu	310	426	311	4.3	3.4	3.9
Hitachi	529	745	468	7.3	5.9	5.8
Matsushita	63	62	37	0.9	0.5	0.5
Mitsubishi	404	604	344	5.6	4.8	4.3
NEC	548	877	541	7.6	7.0	6.7

Table 5-1 (Continued)
Each Company's Factory Revenue from Shipments of MOS Memory to Asia/Pacific (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Nippon Steel Semiconductor	58	202	92	0.8	1.6	1.1
Oki	146	249	60	2.0	2.0	0.7
Ricoh	3	0	0	0	0	0
Rohm	9	12	11	0.1	0	0.1
Sanyo	90	95	57	1.2	0.8	0.7
Seiko Epson	4	6	3	0	0	0
Sharp	134	171	108	1.9	1.4	1.3
Sony	47	74	33	0.7	0.6	0.4
Toshiba	506	732	402	7.0	5.8	5.0
Other Japanese	10	9	11	0.1	0	0.1
European Companies	333	491	405	4.6	3.9	5.0
Philips	5	0	0	0	0	0
SGS-Thomson	88	97	107	1.2	0.8	1.3
Siemens	238	394	298	3.3	3.1	3.7
TEMIC	2	0	0	0	0	0
Asia/Pacific Companies	2,654	5,423	3,629	36.8	43.2	45.2
LG Semicon	521	1,283	979	7.2	10.2	12.2
Hualon Microelectronics Corp.	46	54	21	0.6	0.4	0.3
Holtek	0	0	2	0	0	0
Hyundai	536	1,600	755	7.4	12.7	9.4
Macronix	80	62	76	1.1	0.5	0.9
Mosel Vitelic	102	197	241	1.4	1.6	3.0
Samsung	1,094	1,803	1,074	15.2	14.3	13.4
United Microelectronics Corp.	156	167	141	2.2	1.3	1.8
Vanguard	0	0	209	0	0	2.6
Winbond Electronics	119	257	131	1.6	2.0	1.6

Source: Dataquest (May 1997)

Table 5-2
Each Company's Factory Revenue from Shipments of Dynamic RAM to Asia/Pacific (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Total Market	5,297	10,133	5,895	100.0	100.0	100.0
Americas Companies	896	1,615	747	16.9	15.9	12.7
Alliance Semiconductor	0	2	10	0	0	0.2
IBM	80	118	42	1.5	1.2	0.7
Micron Technology	245	300	121	4.6	3.0	2.1
Motorola	125	159	34	2.4	1.6	0.6
Ramtron	9	14	0	0.2	0.1	0
Texas Instruments	437	1,022	536	8.2	10.1	9.1
G-Link USA	0	0	4	0	0	0
Japanese Companies	2,323	3,666	1,961	43.9	36.2	33.3
Fujitsu	241	376	208	4.5	3.7	3.5
Hitachi	452	654	391	8.5	6.5	6.6
Matsushita	51	60	34	1.0	0.6	0.6
Mitsubishi	357	543	291	6.7	5.4	4.9
NEC	502	836	504	9.5	8.3	8.5
Nippon Steel Semiconductor	58	202	92	1.1	2.0	1.6
Oki	138	243	56	2.6	2.4	0.9
Sanyo	58	60	34	1.1	0.6	0.6
Sharp	8	15	8	0.2	0.1	0.1
Toshiba	458	677	343	8.6	6.7	5.8
European Companies	238	394	298	4.5	3.9	5.1
Siemens	238	394	298	4.5	3.9	5.1
Asia/Pacific Companies	1,840	4,458	2,889	34.7	44.0	49.0
LG Semicon	423	1,177	883	8.0	11.6	15.0
Hyundai	477	1,530	712	9.0	15.1	12.1
Mosel Vitelic	94	182	233	1.8	1.8	4.0
Samsung	846	1,569	852	16.0	15.5	14.5
Vanguard	0	0	209	0	0	3.5

Source: Dataquest (May 1997)

Table 5-3
Each Company's Factory Revenue from Shipments of Static RAM to Asia/Pacific (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Total Market	867	1,389	927	100.0	100.0	100.0
Americas Companies	135	338	162	15.6	24.3	17.5
Alliance Semiconductor	35	57	20	4.0	4.1	2.2
Cypress Semiconductor	12	26	20	1.4	1.9	2.2
Dallas Semiconductor	9	21	0	1.0	1.5	0
Electronic Designs	0	0	3	0	0	0.3
G-Link USA	0	6	3	0	0.4	0.3
Harris	0	1	0	0	0	0
IBM	0	10	10	0	0.7	1.1
Integrated Device Technology	7	31	16	0.8	2.2	1.7
Integrated Silicon Solution Inc.	22	68	27	2.5	4.9	2.9
Micron Technology	9	35	2	1.0	2.5	0.2
Motorola	30	63	59	3.5	4.5	6.4
Paradigm	2	10	2	0.2	0.7	0.2
Performance Semiconductor	1	2	0	0.1	0.1	0
Quality Semiconductor	2	0	0	0.2	0	0
Texas Instruments	6	8	0	0.7	0.6	0
Japanese Companies	254	346	248	29.3	24.9	26.8
Fujitsu	36	28	4	4.2	2.0	0.4
Hitachi	45	69	57	5.2	5.0	6.1
Matsushita	3	2	2	0.3	0.1	0.2
Mitsubishi	44	58	39	5.1	4.2	4.2
NEC	20	28	20	2.3	2.0	2.2
Oki	5	5	3	0.6	0.4	0.3
Ricoh	1	0	0	0.1	0	0
Rohm	3	5	4	0.3	0.4	0.4
Sanyo	31	34	19	3.6	2.4	2.0
Seiko Epson	4	6	3	0.5	0.4	0.3
Sharp	3	25	18	0.3	1.8	1.9
Sony	34	57	33	3.9	4.1	3.6
Toshiba	25	29	46	2.9	2.1	5.0
European Companies	3	1	1	0.3	0	0.1
SGS-Thomson	1	1	1	0.1	0	0.1
TEMIC	2	0	0	0.2	0	0

Table 5-3 (Continued)
Each Company's Factory Revenue from Shipments of Static RAM to Asia/Pacific (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Asia/Pacific Companies	475	704	516	54.8	50.7	55.7
LG Semicon	45	47	49	5.2	3.4	5.3
Hualon Microelectronics Corp.	7	12	7	0.8	0.9	0.8
Hyundai	58	70	43	6.7	5.0	4.6
Mosel Vitelic	8	4	8	0.9	0.3	0.9
Samsung	141	157	162	16.3	11.3	17.5
United Microelectronics Corp.	98	163	126	11.3	11.7	13.6
Winbond Electronics	118	251	121	13.6	18.1	13.1

Source: Dataquest (May 1997)

Table 5-4
Each Company's Factory Revenue from Shipments of Nonvolatile Memory to Asia/ Pacific (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Total Market	1,022	992	1,177	100.0	100.0	100.0
Americas Companies	322	408	598	31.5	41.1	50.8
Advanced Micro Devices	49	79	70	4.8	8.0	5.9
Atmel	56	68	179	5.5	6.9	15.2
Catalyst	10	9	12	1.0	0.9	1.0
Cypress Semiconductor	3	3	2	0.3	0.3	0.2
Gould AMI	17	0	0	1.7	0	0
Integrated Silicon Solution Inc.	4	6	12	0.4	0.6	1.0
Intel	45	101	163	4.4	10.2	13.8
ITT	10	0	0	1.0	0	0
Microchip Technology	18	23	37	1.8	2.3	3.1
Motorola	8	0	1	0.8	0	0
National Semiconductor	39	32	39	3.8	3.2	3.3
Silicon Storage Technology	0	25	48	0	2.5	4.1
Texas Instruments	57	57	30	5.6	5.7	2.5
WaferScale Integration	2	2	1	0.2	0.2	0
Xicor	4	3	4	0.4	0.3	0.3
Japanese Companies	274	241	253	26.8	24.3	21.5
Fujitsu	33	22	99	3.2	2.2	8.4
Hitachi	32	22	20	3.1	2.2	1.7
Matsushita	9	0	1	0.9	0	0
Mitsubishi	3	2	13	0.3	0.2	1.1
NEC	26	13	14	2.5	1.3	1.2
Oki	3	0	0	0.3	0	0
Ricoh	2	0	0	0.2	0	0
Rohm	6	7	7	0.6	0.7	0.6
Sanyo	1	1	4	0	0.1	0.3
Sharp	123	131	82	12.0	13.2	7.0
Sony	13	17	0	1.3	1.7	0
Toshiba	23	26	13	2.3	2.6	1.1
European Companies	89	93	102	8.7	9.4	8.7
Philips	5	0	0	0.5	0	0
SGS-Thomson	84	93	102	8.2	9.4	8.7

Table 5-4 (Continued)
Each Company's Factory Revenue from Shipments of Nonvolatile Memory to Asia/Pacific (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Asia/Pacific Companies	337	250	224	33.0	25.2	19.0
LG Semicon	53	59	47	5.2	5.9	4.0
Hualon Microelectronics Corp.	39	42	14	3.8	4.2	1.2
Holtek	0	0	2	0	0	0.2
Macronix	80	62	76	7.8	6.3	6.5
Samsung	106	77	60	10.4	7.8	5.1
United Microelectronics Corp.	58	4	15	5.7	0.4	1.3
Winbond Electronics	1	6	10	0	0.6	0.8

Source: Dataquest (May 1997)

Table 5-5
Each Company's Factory Revenue from Shipments of EPROM to Asia/Pacific (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Total Market	288	246	231	100.0	100.0	100.0
Americas Companies	160	150	143	55.6	61.0	61.9
Advanced Micro Devices	24	23	20	8.3	9.3	8.7
Atmel	40	44	69	13.9	17.9	29.9
Cypress Semiconductor	3	3	2	1.0	1.2	0.9
Integrated Silicon Solution Inc.	4	3	6	1.4	1.2	2.6
Microchip Technology	6	2	2	2.1	0.8	0.9
National Semiconductor	26	23	19	9.0	9.3	8.2
Texas Instruments	55	50	24	19.1	20.3	10.4
WaferScale Integration	2	2	1	0.7	0.8	0.4
Japanese Companies	19	16	13	6.6	6.5	5.6
Fujitsu	2	1	0	0.7	0.4	0
Hitachi	11	10	8	3.8	4.1	3.5
Mitsubishi	1	1	1	0.3	0.4	0.4
NEC	4	4	4	1.4	1.6	1.7
Toshiba	1	0	0	0.3	0	0
European Companies	72	65	55	25.0	26.4	23.8
SGS-Thomson	72	65	55	25.0	26.4	23.8
Asia/Pacific Companies	37	15	20	12.8	6.1	8.7
Macronix	37	15	20	12.8	6.1	8.7

Source: Dataquest (May 1997)

Table 5-6
Each Company's Factory Revenue from Shipments of EEPROM to Asia/Pacific (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Total Market	91	86	170	100.0	100.0	100.0
Americas Companies	59	58	129	64.8	67.4	75.9
Atmel	13	14	56	14.3	16.3	32.9
Catalyst	9	8	10	9.9	9.3	5.9
Integrated Silicon Solution Inc.	0	3	3	0	3.5	1.8
Microchip Technology	12	21	35	13.2	24.4	20.6
Motorola	8	0	0	8.8	0	0
National Semiconductor	13	9	20	14.3	10.5	11.8
Texas Instruments	0	0	1	0	0	0.6
Xicor	4	3	4	4.4	3.5	2.4
Japanese Companies	14	13	12	15.4	15.1	7.1
Hitachi	2	2	2	2.2	2.3	1.2
NEC	3	4	3	3.3	4.7	1.8
Oki	3	0	0	3.3	0	0
Rohm	6	7	7	6.6	8.1	4.1
European Companies	15	13	29	16.5	15.1	17.1
Philips	5	0	0	5.5	0	0
SGS-Thomson	10	13	29	11.0	15.1	17.1
Asia/Pacific Companies	3	2	0	3.3	2.3	0
Samsung	3	2	0	3.3	2.3	0

Source: Dataquest (May 1997)

Table 5-7
Each Company's Factory Revenue from Shipments of Flash Memory to Asia/Pacific (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Total Market	84	246	489	100.0	100.0	100.0
Americas Companies	76	200	325	90.5	81.3	66.5
Advanced Micro Devices	25	56	50	29.8	22.8	10.2
Atmel	3	10	54	3.6	4.1	11.0
Catalyst	1	1	2	1.2	0.4	0.4
Integrated Silicon Solution Inc.	0	0	3	0	0	0.6
Intel	45	101	163	53.6	41.1	33.3
Motorola	0	0	1	0	0	0.2
Silicon Storage Technology	0	25	48	0	10.2	9.8
Texas Instruments	2	7	4	2.4	2.8	0.8
Japanese Companies	3	18	120	3.6	7.3	24.5
Fujitsu	1	15	99	1.2	6.1	20.2
Matsushita	0	0	1	0	0	0.2
Mitsubishi	1	1	12	1.2	0.4	2.5
NEC	0	0	1	0	0	0.2
Sanyo	0	0	3	0	0	0.6
Sharp	1	2	4	1.2	0.8	0.8
European Companies	2	15	18	2.4	6.1	3.7
SGS-Thomson	2	15	18	2.4	6.1	3.7
Asia/Pacific Companies	3	13	26	3.6	5.3	5.3
Macronix	3	13	19	3.6	5.3	3.9
Samsung	0	0	7	0	0	1.4

Source: Dataquest (May 1997)

Table 5-8
Each Company's Factory Revenue from Shipments of Mask ROM to Asia/Pacific (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Total Market	559	414	287	100.0	100.0	100.0
Americas Companies	27	0	1	4.8	0	0.3
Gould AMI	17	0	0	3.0	0	0
ITT	10	0	0	1.8	0	0
Texas Instruments	0	0	1	0	0	0.3
Japanese Companies	238	194	108	42.6	46.9	37.6
Fujitsu	30	6	0	5.4	1.4	0
Hitachi	19	10	10	3.4	2.4	3.5
Matsushita	9	0	0	1.6	0	0
Mitsubishi	1	0	0	0.2	0	0
NEC	19	5	6	3.4	1.2	2.1
Ricoh	2	0	0	0.4	0	0
Sanyo	1	1	1	0.2	0.2	0.3
Sharp	122	129	78	21.8	31.2	27.2
Sony	13	17	0	2.3	4.1	0
Toshiba	22	26	13	3.9	6.3	4.5
Asia/Pacific Companies	294	220	178	52.6	53.1	62.0
LG Semicon	53	59	47	9.5	14.3	16.4
Hualon Microelectronics Corp.	39	42	14	7.0	10.1	4.9
Holtek	0	0	2	0	0	0.7
Macronix	40	34	37	7.2	8.2	12.9
Samsung	103	75	53	18.4	18.1	18.5
United Microelectronics Corp.	58	4	15	10.4	1.0	5.2
Winbond Electronics	1	6	10	0.2	1.4	3.5

Source: Dataquest (May 1997)

Table 5-9
Each Company's Factory Revenue from Shipments of Other MOS Memory to Asia/Pacific (Millions of U.S. Dollars)

	Revenue			Market Share (%)		
	1994	1995	1996	1994	1995	1996
Total Market	30	51	36	100.0	100.0	100.0
Americas Companies	15	26	16	50.0	51.0	44.4
Advanced Micro Devices	0	1	0	0	2.0	0
Cypress Semiconductor	3	2	5	10.0	3.9	13.9
Integrated Device Technology	6	16	10	20.0	31.4	27.8
Motorola	0	1	1	0	2.0	2.8
Texas Instruments	6	6	0	20.0	11.8	0
Japanese Companies	10	11	16	33.3	21.6	44.4
Mitsubishi	0	1	1	0	2.0	2.8
NEC	0	0	3	0	0	8.3
Oki	0	1	1	0	2.0	2.8
Other Japanese	10	9	11	33.3	17.6	30.6
European Companies	3	3	4	10.0	5.9	11.1
SGS-Thomson	3	3	4	10.0	5.9	11.1
Asia/Pacific Companies	2	11	0	6.7	21.6	0
Hyundai	1	0	0	3.3	0	0
Mosel Vitelic	0	11	0	0	21.6	0
Samsung	1	0	0	3.3	0	0

Source: Dataquest (May 1997)

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